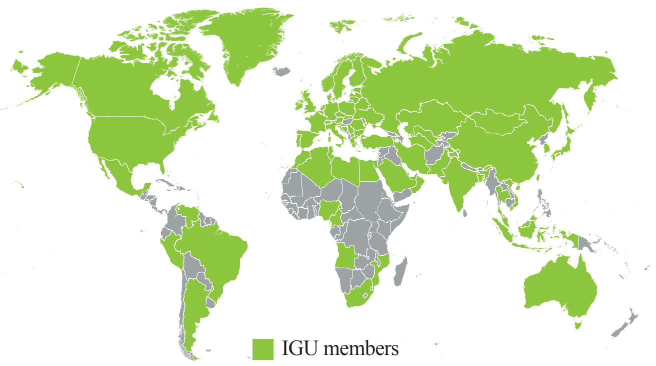
IGU

The International Gas Union (IGU), founded in 1931, is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate for gas as an integral part of a sustainable global energy system. IGU has more than 110 members worldwide and represents more than 95% of the world's gas market. The members are national associations and corporations of the gas industry. The working organization of IGU covers the complete value chain of the gas industry from upstream to downstream. For more information please visit www.igu.org.



International Gas Union (IGU)

News, views and knowledge on gas – worldwide

Global Vision for Gas

The Pathway towards a Sustainable Energy Future

IGU

INTERNATIONAL GAS UNION

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Global Vision for Gas

The Pathway towards a Sustainable Energy Future

Produced by:

International Gas Union

June 2012

Foreword

Over the past four decades, natural gas has enjoyed phenomenal growth and has emerged as the fuel of choice - all over the world - in many consuming countries and sectors. In recent years, however, public perception of natural gas was noted to be less relevant. Concern that natural gas was being overlooked in the wider energy and environmental policy debate was underscored at the 24th World Gas Conference in Buenos Aires, where a number of challenges confronting the gas industry were put forward. While many people acknowledge that natural gas - with its economic, efficiency and environmental advantages, relative abundance and expanding infrastructure - should be a natural choice in meeting the world's expanding energy needs, its future role and positioning cannot be taken for granted.

In line with the above, the 2009-12 Triennial Work Programme of the International Gas Union (IGU), prepared and executed by the Malaysian Presidency, states that the first Strategic Guideline is to enhance the role of gas for sustainable development and balance the needs of all stakeholders.

IGU initially prepared a working paper on "Improving IGU Advocacy on Natural Gas" and conducted a workshop on the subject with the Executive Committee members in Bali, on 7 April 2010. This led to a major initiative by IGU to rally efforts among members and like-minded organisations to advocate for the natural gas industry. Such effort resulted in a global movement towards raising awareness of the merits of natural gas among key stakeholders. This initiative coincided with a number of significant global developments that have raised the profile of gas among energy policy makers, such as the "shale gas revolution" in the United States, the Fukushima nuclear accident in Japan and the wave of political change in several Middle Eastern countries. IGU set about the task to develop a fact-based toolkit and - through its members - actively engaged with various stakeholders through alternative media and platforms. This effort has achieved a high degree of success, and there is now a greater awareness and recognition of the role of gas in achieving a low carbon energy future. We are pleased that the incoming IGU French Presidency (2012-15) will continue this work under a new Task Force set up for that purpose.

With the advocacy work very much established and ongoing through various regional groups, companies and gas associations, IGU then decided to put forward a global vision and pathway for natural gas development, with the objective of clearly defining the contribution that natural gas could make towards achieving a low carbon energy future for the planet. The goal is to reaffirm and consolidate the role of natural gas - at times mistakenly perceived as a "transitional fuel" - as an integral part of the global energy system for the long-term, and build wider confidence that gas is indeed a "no regrets" option across a variety of sectors. This will, in turn, help attract the necessary investments that are needed for the long-term sustainability of the gas industry.

Such "global vision and pathway" is condensed in the present report, which covers the merits of gas as a fuel, and provides a quantified pathway of global energy use through to 2050 that is sustainable. The pivotal role of natural gas, alongside other energy sources, is highlighted in terms of its affordability, reliability, and its role in economic development as well as its contribution to reducing greenhouse gas emissions. Key policy enablers to help realize the vision for gas are also enumerated across the different continents. This report constitutes one of the key deliverables at the 25th World Gas Conference (WGC), to be held in Kuala Lumpur (Malaysia), in June 2012.

The report was prepared under the coordination of a Steering Committee headed by Ho Sook Wah, Chair of IGU's Coordination Committee (2009-12), and comprising of Hans Riddervold (Director, IGU), Roberto Brandt (CC Chair 2006-09), Georges Liens (CC Chair 2012-15), Mel Ydreos (CC Chair-elect 2015-18), Lori Traweek (Senior Vice President, AGA) and Michel Romieu (Consultant).

The report's primary author was Michael Stoppard, Managing Director, IHS Cambridge Energy Research Associates (IHS CERA), who assisted IGU throughout the whole process. He was supported by the advice and contribution of Dr Daniel Yergin, Chairman of IHS CERA and a Wise Person of IGU, and several other colleagues, in particular James Taverner, Federico Ferrario, and Xavier Lambin. While IHS CERA helped in the development and analysis of this report, the final views and recommendations represent those of the IGU and not IHS CERA.

The high quality of the report would not have been possible without the advice and guidance of IGU President, Datuk (Dr) Abdul Rahim Hashim and IGU Secretary General, Torstein Indrebø and the support of the IGU Executive Committee members and the incoming IGU President, Jerome Ferrier.

We sincerely hope that this document will be a useful reference tool for the governmental, corporate and international organisation decision makers, researchers and consultants, journalists and students who are part of or actively follow the exciting developments and progress of the international gas industry.

International Gas Union (IGU)

June 2012

Executive Summary

Energy is critical to the daily livelihoods of each and every one of us. But how will we meet the needs of our children and our children's children? The 'Global Vision for Gas' lays out a clear pathway towards a sustainable energy future. That is, a future of improved air quality and public health, affordable energy, available resources, and sharply reduced greenhouse gas emissions.

The Vision Pathway argues strongly for the need for a portfolio approach in energy, calling upon enhanced energy efficiency, expanded use of zero carbon technologies, and it emphasises specifically the advantages of natural gas. It illustrates that the immediate wider deployment of natural gas based on proven technologies can have a significant near term impact on emissions and the quality of life. The Vision Pathway also shows how investments in the gas industry today set up a sustainable platform for future greenhouse gas (GHG) emissions mitigation without predetermining the choice of technologies.

Making the case for natural gas is urgent and timely. Urgent, because following the re-examination of nuclear power in the aftermath of the 2011 Fukushima accident in Japan, the world has an even greater need for finding alternative clean forms of energy supply. Timely, because the 'revolution' under way with unconventional and ultra-deepwater gas is leading to a radical upward assessment of the potential role that natural gas can play.

The Vision Pathway outlines how including a major role for natural gas will cost less than an all renewable supply in power generation. Hence, natural gas could help the affordability of the parallel adoption of new zero carbon (or near zero carbon) technologies. Finally, use of natural gas is a powerful spur to economic growth and creates a significant number of jobs.

The Vision

The world faces certain key challenges over the coming half-century to meet the aspirations of its citizens. These include:

- **Population & Resource Availability.** The world's population is expected to increase from 7 to 9.3 billion by 2050. It will be essential to have the necessary resources to deploy--whether natural, human, or capital.

- **Economic Development & Employment**. The aspiration for a better standard of living will continue, particularly as the developing economies seek to close the gap with the standards of the developed world. The provision of employment and education will be critical.

- **Energy Poverty & Public Health**. The provision of energy—a basic staple of a more advanced lifestyle—will continue to be rolled out to communities still without either commercial energy or power. Lack of modern energy remains a global challenge: indoor pollution is a major cause of illness for more than three billion people who continue to depend on wood, dung, and coal for their daily living.

- **Air Quality & Climate Change**. The focus to improve public health and address environmental issues such as air quality and clean water will be critical. Climate change will also remain one of the key global challenges of the twenty first century.

- **Mobility**. Mankind has an innate desire to connect and to travel. The means to provide ever greater travel, and methods to meet that demand in a sustainable manner are needed.

- **Affordability**. Today 71 percent of the world's population live in a country with a GDP per capita of less than US$4,000. Food, water, and energy will need to be affordable in these countries but governments will have limited scope for subsidies. In developed economies, rising bills--that are partly a result of more costly alternative energies--are a major concern for consumers and voters.

Natural gas is a fuel very well-suited to meet these challenges. (See Figure 1: Natural Gas: Addressing the World's Challenges). The growing availability of conventional and unconventional natural gas provides a natural resource stock to see the world well beyond 2050. Natural gas is an enabler of economic development. The clean properties of natural gas make it attractive for urban living. Gas in power generation is a low carbon option with excellent complementarity with intermittent renewable power. And its lower carbon content—relative to the other fossil fuels—makes it a useful tool to address climate change. Natural gas is a highly cost competitive form of low carbon energy and hence an affordable source of electricity, while as a form of heat it continues to be priced below the alternative of oil. As such it requires less or no subsidies to foster its commercial use. The technologies associated with natural gas are proven and therefore involve less risk than many alternatives.

Besides its innate characteristics, a key advantage of natural gas for policy makers is its adaptability. Notably for power generation natural gas uses an adaptable technology. Conventional gas-fired power generation leads to the immediate benefit of cleaner cities, clearer skies, and reduced greenhouse gas (GHG) emissions from the backing out of coal and oil. And in the longer term, gas-fired generation can evolve in a variety of directions: either to capture carbon through retrofit technology; or to a partnership role with intermittent sources of renewable power generation; or to a greater inclusion of carbon-neutral biogas. The choice of pathway between these options can be adjusted according to technological progress. Similarly, the gas pipeline and storage system is an option on either a future CO_2, biogas, or hydrogen network. Investment today in natural gas builds the platform for the future without predetermining the final structure. For this reason, natural gas is a 'zero regrets option'.

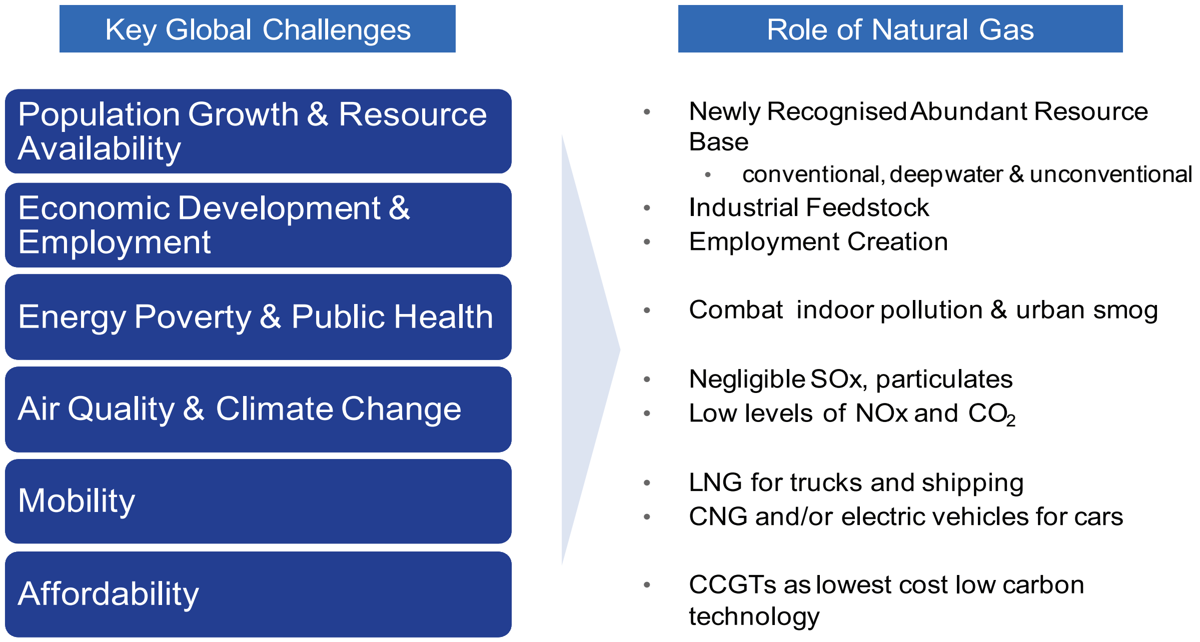

Figure 1: Natural Gas: Addressing the World's Challenges

Source: IGU

The Pathway

The Vision Pathway presents a fully quantified pattern of global energy use that is consistent with mitigating both local pollution and the challenge of climate change. Specifically, the Vision Pathway follows a trajectory of carbon dioxide (CO_2) emissions consistent with the threshold limit of a 2 degree Celsius increase in global temperatures recommended by the United Nations Environment Program. [Source: "Bridging the Emissions Gap", United Nations Environment Program, November 2011]. The Pathway is a complete picture covering all major consumption sectors and continents.

The task to meet future global energy needs whilst at the same time addressing air quality and climate change concerns is challenging. Global CO_2 emissions are expected rise under an unconstrained base case from 31 billion tons in 2010 to 53 billion tons in 2050. Emissions by 2050 need to come down to 12.6 billion tons to be consistent with the recommendations of the IPCC, equivalent to a 60 percent cut from 2010. Using a combination of abatement choices, the Vision Pathway shows a trajectory for global energy demand consistent with this emissions target.

In the short term, moving from coal and oil to gas provides significant emission reductions, especially in the fastest growing regions such as Asia Pacific which is currently heavily reliant on coal.

In the longer term, more zero carbon abatement options are needed to reach the reduction target. Development of carbon capture technologies and increased biogas production can provide major contributions toward the end of the period. There will also be a substantial and indispensable role for renewable energy supply supported by, if chosen by governments, nuclear power. Figure 2 shows the different impact of each major abatement method in reaching the emissions target.

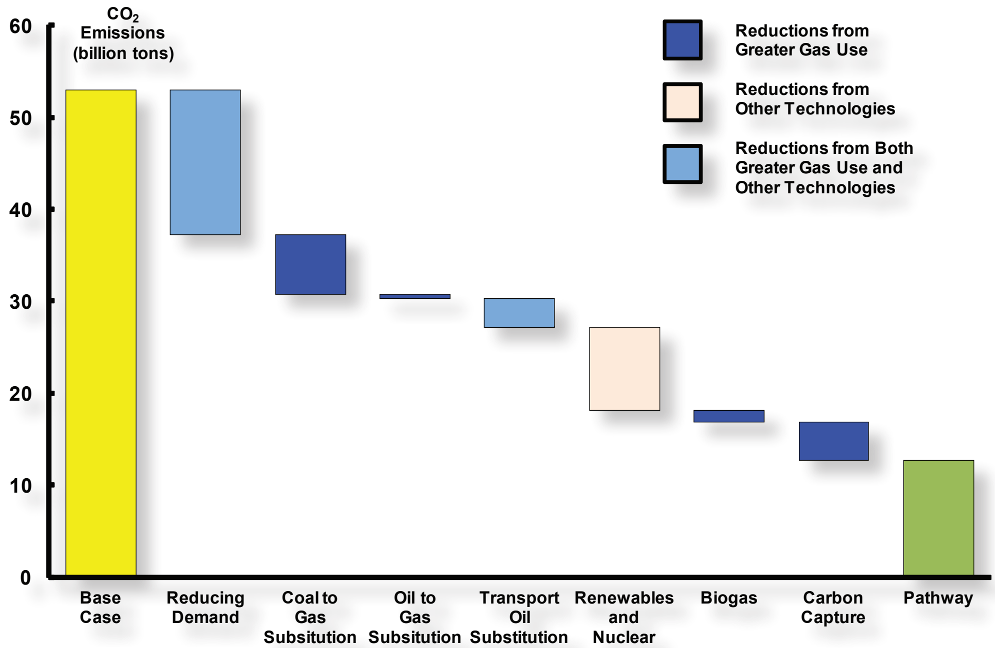

Figure 2: Global Emissions Reductions by Abatement Method

The demand for gas grows in the Vision Pathway. In 2035 gas demand reaches 6.6 TCM and rises to 7.1 TCM by 2050. The Vision Pathway demonstrates --

- first, that *extended* use of natural gas is a powerful enabler toward economic development and affordable energy, and at the same time is an early step to moving in the direction of sustainability and climate change goals

- second, that *continued* growth of natural gas use into the longer-term is also consistent with development goals and a strict global emissions target. In fact natural gas increases its share of primary energy from around one fifth today to around one third by 2050 in the Vision Pathway. (See Figure 3: Gas Market Share of Primary Energy)

The natural gas option offers advantages in terms of cost and employment. Take power generation: gas-fired CGGTs (with and without carbon capture and storage) are generally the lowest cost form of power consistent with meeting global climate change targets. The growing abundance of natural gas should ensure its continued cost competitiveness. The choice exists and to opt for reliance on renewable power. But this would involve substantial extra cost. Most renewable technologies are shown to have a higher levelised cost of electricity (LCOE) than natural gas use. These costs become still greater when the need for back-up to intermittent renewable generation and the extra cost for system integration and transmission infrastructure are added. (See Chapter V).

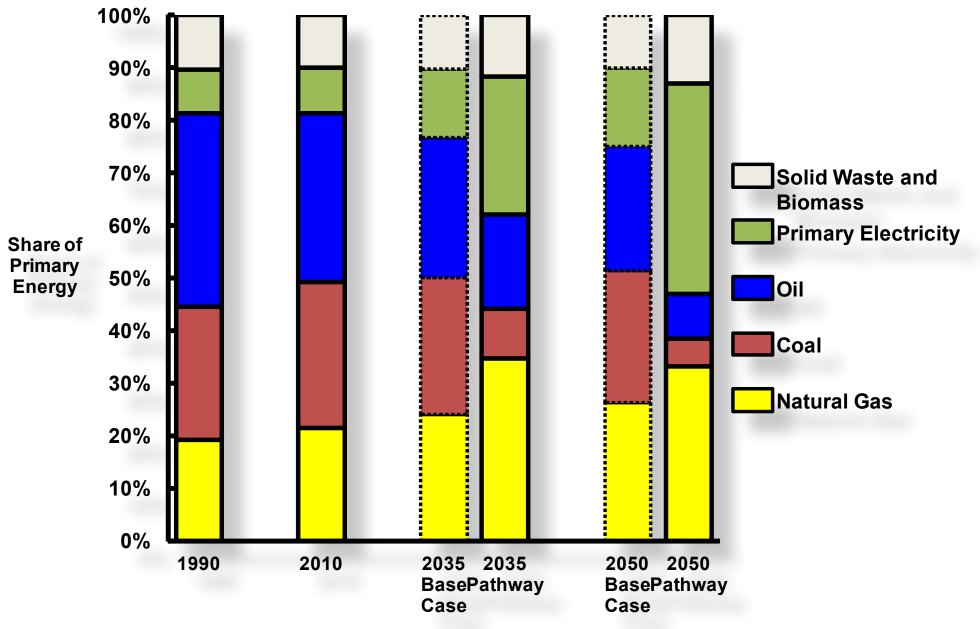

Figure 3: Gas Market Share of Primary Energy

The gas industry is also a major generator of employment across the globe. Direct employment in the global gas industry is estimated around 2.5 million today and will rise to around 6 million people worldwide by 2050 under the Vision Pathway.[1] The full number of jobs related to the gas industry—so-called 'indirect' and 'induced' jobs-will be several times greater than the direct jobs, perhaps a multiplier of four times.

The potential economic impact of the wider adoption of natural gas can be seen in the United States. The rapid growth of shale gas in the United States supported 600,000 jobs in 2010. Of these jobs, almost 150,000 were direct jobs, and the remaining 450,000 indirect or induced jobs.

Policy Enablers—Realizing the Vision

A conducive policy framework will be essential to bring about changes outlined by the Vision Pathway. Policy will be particularly important in the area where the greatest reductions in emissions are projected: namely demand reduction/energy efficiency, coal to gas substitution, and carbon capture. Research and development will also be critical.

1 *Precise employment figures related to natural gas do not exist for most developing economies. These figures apply a metric for North American employment globally. See Chapter V*

On the supply-side, measures are needed to allow the responsible development of unconventional gas internationally, so that it can supplement conventional gas supply. In parts of the developing world, the removal of subsidies, where possible, that set gas prices below the cost of production could provide a powerful investment impetus to help develop more gas to the overall benefit of the economy and inhabitants. Biogas needs to be facilitated to create a third pillar of global gas supply whose importance will need to grow substantially post 2030.

In many developing markets, infrastructure is needed if natural gas is to become a core part of the energy balance. Appropriate financing and regulatory incentives for infrastructure will be essential.

If the objective to reduce GHG emissions is to be achieved, it will be essential that the cost of carbon is included in the provision of energy. Adoption of carbon pricing would allow industry to decide the optimal or lowest cost means of abatement, without requiring policymakers to pick favoured technologies or fuels. Natural gas—based on its costs and low carbon content—would fare well under a neutral carbon scheme.

Conclusion

The ‘Global Vision for Gas’ lays out a clear pathway towards a sustainable energy future. The Vision Pathway shows in quantified form that natural gas needs to be a core pillar of this energy future. It illustrates that wider deployment of natural gas can have a significant near term impact and also sets up a sustainable platform for future without predetermining the choice of technologies. Furthermore a future that includes a major role for natural gas will likely cost less than opting for an all renewable supply pathway. Finally, the significant number of jobs associated with natural gas is highlighted and its contribution to economic growth.

Policy makers need to recognize the critical role that natural gas has to play alongside other low carbon options, and facilitate the appropriate policy enablers as befits each region based on its particular circumstances.

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BCM	Billion Cubic Meters
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CIS	Commonwealth of Independent States
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
GHG	Greenhouse Gas
GTL `	Gas to Liquids
IPCC	Intergovernmental Panel on Climate Change
LCOE	Levelised Cost of Electricity
LDV	Light Duty Vehicle
LNG	Liquefied Natural Gas
NOx	Nitrogen Oxides
OECD	Organisation for Economic Cooperation and Development
PTG	Power to Gas
PV	Photovoltaic
SOx	Sulfur Oxides
TCM	Trillion Cubic Meters
TWh	TeraWatt hours

I Introduction - A Key Building Block Towards a Sustainable Energy Future

Energy is critical to the daily livelihoods of each and every one of us. But how will we meet the needs of our children and our children's children? This report argues that natural gas can be, and needs to be, a key building block of the future architecture of global energy provision. This energy architecture meets the three principal tests of any viable energy system: sustainability, security of supply, and affordability.

Energy is a long-term business, one of the longest. And policy makers are already engaged in planning out the long-term energy future across geographies, technologies, and business areas. This report adds to the discussion of our long-term energy future. We present a conceptual vision of our energy future for the twenty first century and a quantified Vision Pathway to 2050. Of critical importance, the Vision Pathway presents a pattern of energy use that is consistent with mitigating both local pollution and the challenge of climate change. Specifically, it is a binding condition of the Pathway that the trajectory of carbon dioxide (CO2) emissions is consistent with the threshold limit of a 2 degree Celsius increase in global temperatures recommended by the United Nations Environment Program. [Source: "Bridging the Emissions Gap", United Nations Environment Program, November 2011].

The Vision Pathway is not meant to be the 'correct' or only pathway; there are many. Nor is it a forecast. Rather it is an illustration of one pathway with clear merits and trade-offs. It is a plausible vision of the future but one that will require major policy initiatives, of which the key ones are highlighted. But it is a quantified pathway that demonstrates in particular --

- first, that *extended* use of natural gas is a powerful enabler toward economic development and affordable energy, and at the same time is an early step to moving in the direction of sustainability and climate change goals
- second, that *continued* growth of natural gas use into the longer-term is also consistent with development goals and the global emissions target. In fact natural gas increases its share of primary energy from around one fifth today to around one third by 2050 in the Vision Pathway.

This is very much a 'symphony of energies', not a 'gas concerto'. That is to say, this is not a gas Pathway as such, but rather an energy Pathway that highlights the significant contribution that natural gas can make alongside other low and zero carbon technologies which will also be needed. Energy efficiency will also be essential. It is a complete picture covering all major sectors. And given the global nature of climate change, it necessarily covers the whole world. It also recognizes the limitations and challenges of achieving such an ambitious goal and lays out key 'policy enablers'.

Making the case for natural gas is urgent and timely. Urgent, because following the re-examination of nuclear power in the aftermath of the 2011 Fukushima accident in Japan, the world has an even greater need for finding alternative clean forms of energy supply. Timely, because the 'revolution' under way with unconventional gas is leading to a radical upward assessment of the potential role that natural gas can play.

But the single biggest advantage of natural gas may be its adaptability. We cannot predict with any precision the technologies of the future—what they will be, how they will be sourced, what they will cost, and how quickly they can scale up. And developments and needs will vary across different continents. Given these huge uncertainties, we need a Pathway that is flexible and can adapt to changes; not one that locks us into a single route to the future. Notably in the area of power generation natural gas uses an adaptable technology and flexible fuel choice option. The wider adoption of natural gas pays an immediate dividend in the form of cleaner cities, clearer skies, and reduced greenhouse gas (GHG) emissions from the backing out of coal and oil. And this is based on existing proven generation technology. In the longer term, gas-fired generation can transition in a variety of directions: either to capture carbon through retrofit technology; or to a partnership role with intermittent sources of renewable power generation; or to a greater inclusion of carbon-neutral biogas. The choice of pathway or the balance between these options remains open and can be adjusted according to the technological progress of each alternative. For this reason, natural gas is sometimes called a 'zero regrets option'.

This adaptability is true not just for power generation but for much of the gas value-chain. For example, adoption of natural gas use into the residential and commercial sector has immediate benefits. And in the longer term, greater roll-out of photovoltaics on site could work well alongside natural gas to achieve still further benefits. Similarly the gas pipeline grid is an open option on either a future CO_2, biogas, or hydrogen network subject to appropriate technical adjustments.

Hence investment today in natural gas builds the platform for the future without predetermining the final structure.

As such policy makers need to recognize the positive role that natural gas---whose use depends on tried and tested technology-- can play both for the immediate benefits of those living today and as an adaptable fuel option for future generations.

Section II provides a qualitative description of a long-term 'vision' for natural gas. We highlight its attributes and the role it can play alongside other energy forms. We trace how that role will change over time as different regions move down the carbon intensity 'ladder'. And we consider the role of technologies discernible today.

Section III describes our methodology and key assumptions used to develop a base case outlook for energy use and the sustainable pathway. Section IV presents the quantified Vision Pathway towards a sustainable energy future. We highlight the various CO_2 abatement options and technology choices, and illustrate the change in energy use. The shift in energy use and the implications for CO_2 emissions are described by sector, by region, and by technology abatement option.

Section V addresses affordability and explores, at a high level, the costs of the Vision Pathway. Comparisons are made between the Vision Pathway and a scenario with more emphasis on zero carbon technologies. The implications for employment are highlighted.

Section VI explores the challenges of implementation, and the limitations. We identify specific policy enablers that would be needed to help move energy use in the indicated direction and, in particular, to help ensure natural gas can meet its appropriate role.

Section VII provides details on the regional pathways, emphasising the special characteristics and opportunities for each region.

Section VIII provides concluding remarks.

II A Global Vision for Natural Gas

The IGU's Pathway presents a vision of the world's evolving energy use. This vision meets the three key tests of energy policy: sustainability, security of supply, and affordability.

We cannot know today what technologies will emerge in the future, how economic growth will pan out, nor what geopolitical factors will predominate. We do know however some of the key drivers that need to channel our thinking and orient our planning.

- **Population & Resource Availability.** In 2011 the world's population surpassed 7 billion. By 2050 the world's population is expected to be around 9.3 billion. Life expectancy is increasing leading to more older and retired people. It will be essential to have the necessary resources to deploy--whether natural, human, or capital-- throughout the value chain.
- **Economic Development & Employment**. The human aspiration for a better standard of living will continue, particularly as the developing economies seek to close the gap with the standards of the developed world. The provision of employment and education will be critical to meeting these aspirations given the numbers of young people in many of the expanding economies.
- **Urbanisation.** We are becoming a planet of city-dwellers. In 2008 the number of people living in cities surpassed the 50 percent level of the global population. The trend of urbanisation is expected to continue with the creation of new 'mega-cities' with all the implied challenges of planning, congestion, smog, and utility provision.
- **Energy Poverty & Public Health**. The provision of energy—a basic staple of a more advanced lifestyle—will continue to be rolled out to remaining communities still without either commercial energy or power. Lack of efficient and clean energy—natural gas and electricity-- remains a global challenge. More than three billion people continue to depend on wood, dung, and coal for their daily living. Yet indoor pollution from the use of such solid fuels is a major cause of a wide range of illnesses.
- **Air Quality & Climate Change**. The focus to improve public health and address environmental issues such as air quality and clean water will be critical. Climate change also looks set to remain one of the key global challenges of the twenty first century.
- **Mobility**. Mankind has an innate desire to connect and to travel. The means to provide ever greater travel, and methods to meet that demand in a sustainable manner are needed.
- **Affordability**. Today 71 percent of the world's population live in a country with a GDP per capita of less than US$4,000. Food, water, and energy will need to be affordable in these countries but governments will have limited scope to sustain subsidies. In developed economies, rising bills--that are in part a result of more costly alternative energies entering the mix--are weighing on consumers and increasing the number of people living in 'energy poverty', that is spending a large component of low incomes on energy provision.

And above all, given the huge uncertainties about the future, we need a Pathway that is flexible and can adapt to changes; not that one locks us into a single route to the future.

Natural gas is a fuel very well-suited to meet these challenges. The growing availability of conventional and unconventional natural gas provides a natural resource stock to see the world well beyond 2050. Renewable gas (biogas) and super-abundant gas hydrates can potentially extend the resource time horizon through the rest of the century and beyond. Natural gas is an enabler of economic development. The clean properties of natural gas make it attractive for urban living. Gas in power generation is a proven, low carbon option with excellent complementarity with intermittent renewable power. Natural gas is an efficient form of energy where the energy used is a relatively high percentage of the energy produced. And its lower carbon content—relative to the other fossil fuels—makes it a useful tool to address climate change. Natural gas is a highly cost competitive relative to other forms of low carbon energy and hence an affordable source of electricity, while as a form of heat it continues to be priced below the alternative of oil. As such it requires less or no subsidies to foster its commercial use.

Finally the technologies associated with natural gas are proven. Hence the adoption of natural gas by policy makers involves less risk than many alternatives.

Population & Resource Availability

Population expansion and growing wealth are putting pressure on global natural resources. Fortunately natural gas is an increasingly abundant resource. Global proven gas reserves are estimated to be 187 TCM (Source: BP Statistics, Cedigaz, IHS, Oil & Gas Journal). Based on current levels of global production or consumption this implies 59 years-worth of reserves.

In reality these oft-quoted figures represent the tip of an iceberg. The global stock of proven conventional gas reserves rises each year as new discoveries and upward revisions to existing fields surpass the levels of extraction. For the past 40 years, remaining reserves of gas have increased each year by 1% on average despite growing consumption. (Source: IHS) This should not come as a surprise since exploration of natural gas—compared to oil—is much less advanced on a global level.

New frontiers are opening up. For example 2011 saw major discoveries in the Eastern Mediterranean and East Africa. Not only were these discoveries significant in scale, but they opened up whole new theatres for potential gas production. In each case, they were only possible because advances in technology allow drilling in ultradeep water (greater than 1,500 meters depth) not previously viable. The Arctic may be another important province in the future.

But if technology continues to sustain growth in *conventional* gas reserves, technology has also opened up a whole new resource, *unconventionals*. Developments in hydro-fraccing and horizontal drilling have now enabled us to access so called unconventional gas—tight gas, shale, and coal-bed methane (and additional technologies under study could also offer high potential). The impact has become clear in the US where shale gas alone accounted for 30 percent of total production in 2011, having been negligible ten years ago. And in Australia development of coal-bed methane is set to launch a new LNG province in Queensland.

The global resource base for unconventional gas is little understood in detail, but its size is not in doubt. Figure II.1 scopes the size of the global gas resource base. It is believed—conservatively—that unconventional gas doubles the recoverable resource base relative to simply conventional gas.

- Almost 100 TCM of natural gas has been consumed over the last 120 years plus, up to today.
- Remaining proven reserves are just shy of 200 TCM
- Conventional potential is estimated to add approximately a further 200 TCM
- Unconventional recoverable potential adds a further 400 TCM

Regional specific research, for example by IHS for Europe, China, and the Ukraine, suggests the recoverable resources of shale may be significantly higher, and extractable at or below today's cost structure. [See: IHS Unconventional Frontier Suite 2011/2012]

While growing concerns related to the environmental impacts of extraction of unconventional gas has been growing, the development of regulations, best practices, and more transparency will lead to the development of this tremendous resource.

Figure II.1 also demonstrates how even assuming a sustained and substantial rise in gas consumption with a CAGR of 3.5 percent to 2050 (far higher than historical growth), this would deplete around one third of today's remaining recoverable resources.

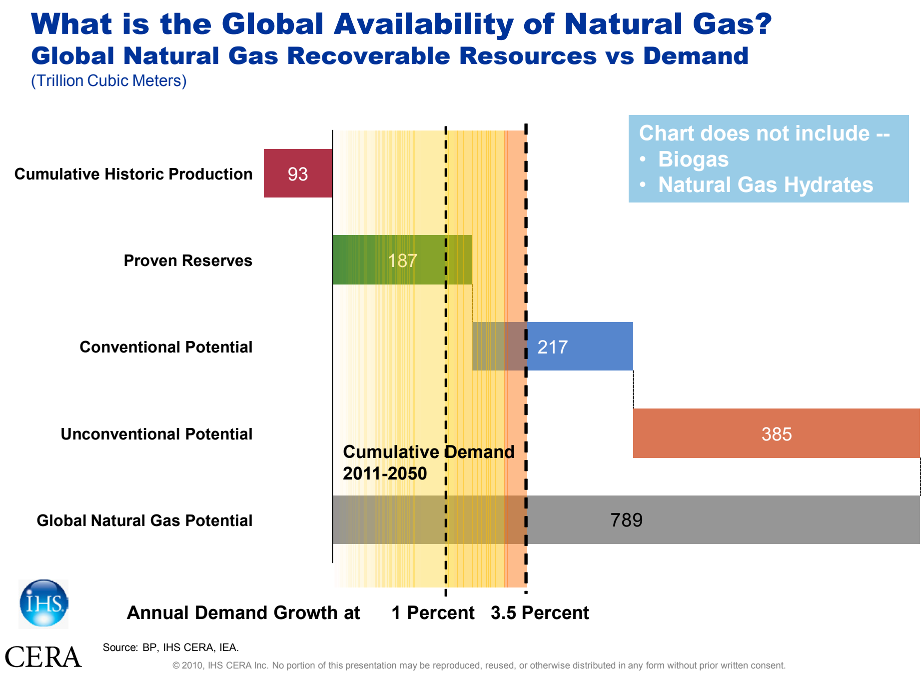

Figure II.1: Global Natural Gas Recoverable Resources vs Demand

Two additional forms of gas extend the time horizon for the resource. Firstly, natural gas hydrates but these are not currently technically recoverable. Secondly, biogas is a renewable form of energy. As the world looks to zero-carbon renewable sources of energy, biogas will take on a greater role. Especially as we seek efficient ways to harness energy from our growing load of waste and landfill. Some European studies suggest that for every 1 million people, biogas has the potential to supply about 1 TWh per year (0.09 BCM). ["A Biogas Roadmap for Europe", European Biogas Association, October 2009]

Not only is gas abundant, it is also distributed widely geographically. It is true that some 50 percent of proven gas reserves are located in three key countries—Russia, Iran, and Qatar. But the global spread of conventional gas—based on discoveries—is widening the distribution. Unconventional gas completely changes our understanding of the global distribution of the resource base with very substantial resources in North America, Australia, Europe, Latin America, South Africa and China among other places.

Natural gas has proven itself to be a reliable and secure form of energy provision. However, two drivers will reinforce this and help mitigate security of supply concerns. First, there is a growing network of international trade providing sellers and buyers with greater diversity of supply. International pipeline networks continue to expand, and a global LNG market is developing with greater variety of countries on both the supply and demand side. Witness the ability of LNG markets to respond to consumer needs for example following the nuclear closures in Japan in 2011, or pipeline disruptions to Europe. Secondly, unconventional gas is so widely distributed it is likely to see an increased scope for indigenous sourcing of gas—supplemented indeed by locally–produced biogas.

In conclusion, natural gas appears to offer a resource rich endowment for generations to come with an improving picture in terms of diversity of supply.

Air Quality and Climate Change

Natural gas is a clean-burning and low carbon fuel. Figures II.2 & II.3 show the level of emissions for a variety of pollutants. The emissions of NOx from natural gas are typically 63 percent less than from oil and at least 60 percent less than for coal. The emissions of SOx from natural gas are almost negligible, and so are particulates. These local pollutants are particularly important with growing urbanisation and the need to control smog levels in cities. The improvement in health, and associated cost savings in health care, are significant.

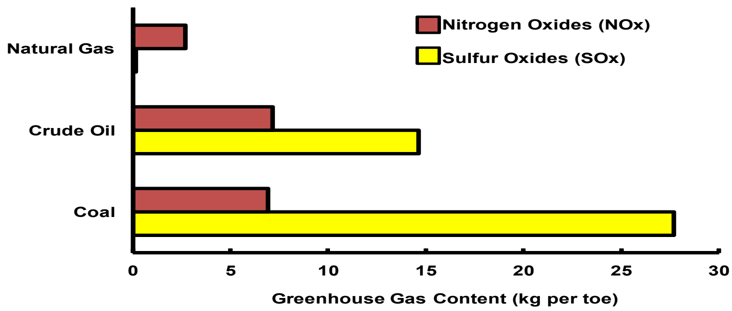

Figure II.2: NOx and SOx Content by Fuel
Source: Intergovernmental Panel on Climate Change (IPCC)

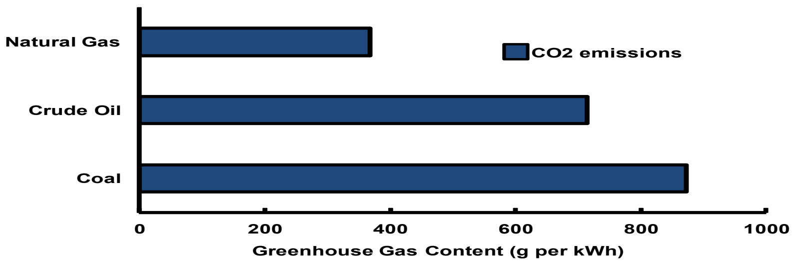

Figure II.3: Carbon Dioxide Emitted During Electricity Generation by Fuel[2]
Source: IHS CERA, IPCC.

Natural gas can be the tool toward cleaner air and less noise in cities through two distinct paths, either the direct use of natural gas in vehicles or reducing tailpipe emissions. Compressed natural gas (CNG) would be the technology of choice for light-duty vehicles (LDV). It is also an attractive choice for middle duty vehicles such as buses, garbage trucks, and short haul depots. For heavy duty needs, long-haul liquefied natural gas (LNG) with its greater fuel density and longer driving range is the preferred option. Alternatively electrification of the LDV fleet would move all emissions from the vehicle and transfer them to the power station. The benefits of gas-fired power come to play.

In terms of carbon dioxide, natural gas typically has 40 percent less carbon content than coal, and 25 percent less carbon content than oil. But the gains from switching are often more substantial because of the high efficiency of natural gas notably for power generation purposes. To generate a fixed amount of power a best-in-class combined-cycle gas turbines (CCGT) will emit 60 percent less CO_2 than a coal-fired plant.

Another environmental advantage of gas is the relatively low geographical footprint of underground pipelines once they are in place. Underground pipelines are often easier to permit than overhead power cables for example. As the issue of siting becomes more difficult and protracted in developed economies, this advantage will likely grow.

Pipeline & Storage—Out of Sight

The natural gas industry is more than simply a stock of fuel. There are many thousands of miles of gas transmission pipelines built across the world, and many times more low pressure distribution pipeline networks. The pipeline networks are connected to storage facilities. These assets—largely out of sight and minimal in intrusion—are a valuable asset and can play an important role.

Pipelines have very long-life spans. They tend to have financial depreciation profiles of between 40 to 60 years. With proper pipeline integrity programs, they can continue to operate beyond their financial accounting lives. Over time the natural gas industry will reduce its environment footprint further, for example through more efficient compressors and lower levels of loss. The carbon content of this gas can also be reduced as natural gas is blended with biomethane. Carbon content can also be reduced by the partial blending of hydrogen, although within reasonably narrow tolerance levels.

2 *Power Generation Efficiencies Assumed: Natural gas 55%, Crude oil 37%, Coal 39%.*

If desired this network can transition to a new role—depending on the direction of technological and policy advance in the longer term.

- In a scenario of extended renewable energy supply, gas pipelines can be used to store surplus power generation, known as 'power-to-gas'. Wind or solar power generated at times of surplus power supply can, through a process of methanation and electrolysis, be stored within the transmission pipeline and wider gas storage system, and then used to help meet peak demand. This might make economic sense at times when renewable power would otherwise need to be curtailed because of surplus supply on the grid or lack of sufficient power network connections. A trial for the storage of renewable power within the gas system has been proposed in Germany ("E.ON examines options for storing wind power in the gas grid", E.ON Press Release, 11th November 2011). This scheme has two potential benefits. First, it helps to solve the problem of intermittent renewable generation by providing back-up or storage within the pipeline network. Indeed back-up is provided by renewable gas itself. Second, it increases the productive utilisation rates of renewable power and might thereby reduce unit costs.

- If carbon capture and sequestration (CCS) is to play a major role in future energy provision, gas pipelines could transition to carriers of CO_2 with suitable technical adjustments. The pipelines lead directly back to depleted reservoirs that can be used to store the very carbon they originally housed—a grand form of 'recycling'.

- Finally if hopes of a hydrogen economy materialize, then the gas pipeline system would become the natural delivery system for hydrogen.

Gas storage assets are another key enabler toward a sustainable energy future. Gas storage can either be natural underground formations, notably aquifers, salt caverns and depleted oil and gas fields, or LNG tankage. LNG storage provides particularly high response flexible supply. Gas storage is critical, not least given that electric power cannot be stored, and provides two fundamental services. First it helps meet demand fluctuations for natural gas both seasonal and daily. Secondly, storage helps provide the back-up fuel for intermittent power generation.

Carbon Capture

Even without carbon capture, the substitution of inefficient and old generating plant (whether coal-fired, oil-fired or gas-fired) with best-in-class new plant fuelled with natural gas offers a quick, cheap, and practical means to lower emissions.

However, this approach has its limits: thermal generation without carbon capture reaches a specific minimum level of emissions. To achieve further reductions in emissions, it will be necessary either to rely exclusively on non-fossil fuel options, or to deploy carbon capture technologies widely in addition to the non-fossil fuel options. Carbon capture therefore offers policy makers a critical extra option.

Discussion around carbon capture has traditionally been associated with coal-fired plant given that coal plants have the highest levels of carbon emissions. But the technology can also be applied to gas-fired or even biomass plants. Indeed part of the critical experience or knowhow for CCS resides within oil and gas companies who have pioneered CCS technology in some of their upstream production operations.

Given that very few commercial scale carbon capture power plants are in operation, the costs are necessarily tentative. The comparative costs of coal versus natural gas carbon capture will depend in part on the coal-gas price differential. However, natural gas CCS is likely to have two significant cost advantages over coal CCS

- The capex cost for gas will be lower. The capex cost of a gas power station with carbon capture is estimated at between $2,500-$3,000 per kW compared to $5,000-$6,000 per kW for a similar coal plant, about double.

- The cost of CO_2 transportation and storage (T&S) will be lower. For each unit of power generated, natural gas produces a little less than half as much CO_2 as a coal plant. Therefore the costs of CO_2 T&S per MWh generated by a gas plant are also expected to be approximately half or less.

Therefore gas CCS should usually be favored over coal CCS on economic grounds for new build power generation.

Lack of availability of storage could be a constraint on CCS as a long-term solution. Depleted oil and gas fields are unlikely to offer sufficient pore space if CCS is expanded at a large scale. Aquifers potentially offer a much greater level of storage.

Should there be a constraint on storage capacity, natural gas presents an advantage over coal requiring only half as much pore space for the same amount of power produced. Changing the fuel mix from coal to gas could therefore extend the scope for CCS.

The case for carbon capture would be strengthened if carbon could be ‘put to work’ rather than be treated as a waste product. This would ease concerns on storage and potentially improve the economics of carbon capture. The most obvious application is use of CO_2 for enhanced oil and gas recovery. CO_2 flooding is well established in the US with great scope for wider global application.

Besides enhanced oil and gas recovery, there is a wide array of technologies at the R&D or trial stage which seek to utilize carbon rather than simply to store it. These include the production of building materials, CO_2 as a chemical feedstock, bichar, algae and third generation biofuels, and synergies between enhanced coal-bed methane and CO_2. This is an area where further research is required. [“Putting CO_2 to Use: What Prospects for Carbon Capture and Utilization?”, IHS CERA, February 2012]

III Methodology & Approach

The analysis in this report was built up in three stages:

(i) Development of a base case outlook for global energy demand to 2050. This base case is based on a continuation of existing energy trends, and without any binding environmental constraints

(ii) Development of the IGU Vision Pathway towards a sustainable energy future. This Vision Pathway was designed to be consistent with the stabilization of global temperature rises to below 2 degrees Celsius through reduction of CO_2 emissions. The primary focus was on decarbonisation options that use natural gas where they make most practical and economic sense, supplemented with other low-carbon and efficiency approaches

(iii) Comparison of the Vision Pathway with an alternative renewable energy supply case for power generation. The costs of using a portolio of natural gas and renewable energy sources from the Vision Pathway was compared to the costs of a pure renewable supply case without use of natural gas.

Base Case Outlook

The base case outlook was developed using an integrated energy model, assessing demand using a 'bottom-up' approach. The model builds up energy demand both 'bottom-up' by key industrial sector, and on a regional basis.

The key underlying drivers of economic growth, population, and primary energy intensity (the linkage between economic size and overall energy use) are shown in Figures III.1, III.2, and III.3). This outlook assumes multispeed global economic growth, with gross domestic product (GDP) projected to grow fastest in the Asia Pacific and Latin America regions, and most slowly in Europe (see figure III.1)

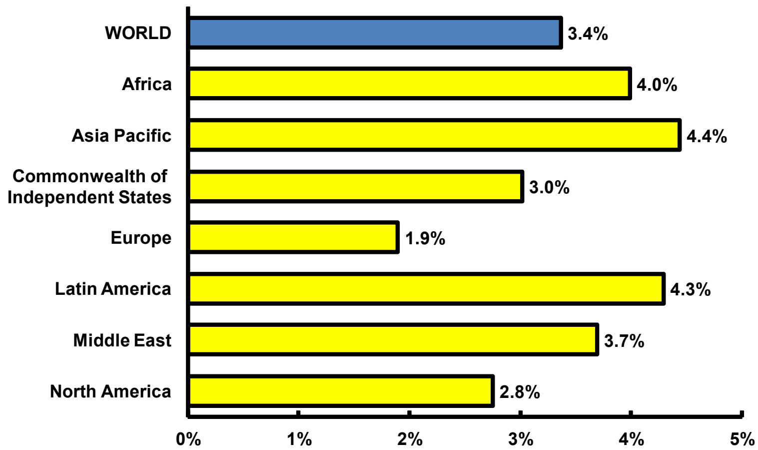

Figure III.1 Outlook for Real GDP Growth by Region, 2010–50
Source: IGU, adapted from IHS Global Insight.
GDP growth calculated using real local currency growth rates (compound annual growth rate from 2010–50), aggregated using real exchange rate-based weights.

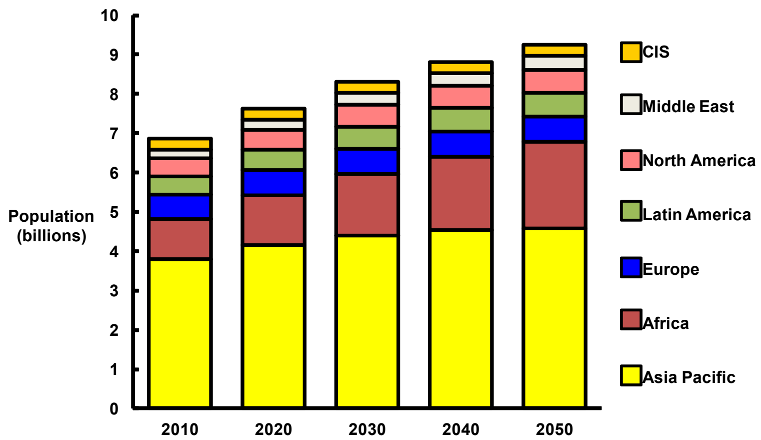

Figure III.2 Outlook for Population by Region
Source: United Nations

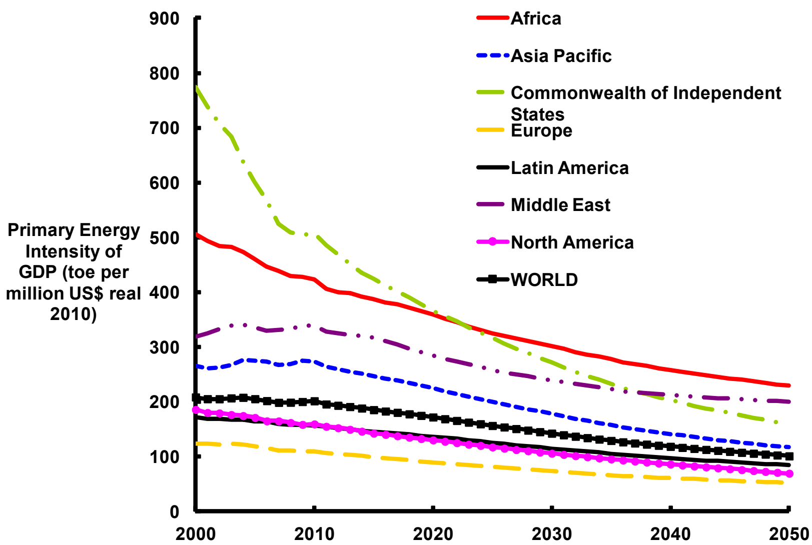

Figure III.3 Primary Energy Intensity of GDP by Region
Source: IGU, IHS CERA

The historical elasticity of demand to macroeconomic factors—including GDP, industrial production, population growth, household numbers, and urbanization—was used to project demand forward with adjustments reflecting the continuation of existing efficiency trends. A total energy demand outlook was developed for by region and for each of the following sectors:

- Residential and commercial
- Industrial (energy, feedstock, and agricultural use)
- Transportation (road, marine, and aviation)
- Power generation (including heat generation)
- Other (transmission and distribution losses, energy used in upstream production and refineries, statistical difference).

Once the total demand for each region and sector is determined, it is then split into specific fuels. Some substitution effects (largely away from coal and oil) have been assumed, applying continuations of existing policies and trends. No significant step changes toward renewables have been assumed in the base case. Other factors such as grid expansion and pricing effects also influence the fuel mix. The sum of the shares of sector electricity demand determines the demand for power generation. The resulting energy balance projections by fuel, sector, and technology are then used to calculate CO_2 emissions.

Vision Pathway

Using the base case analysis as a starting point, an alternative pathway was constructed to produce an emissions trajectory consistent with a likely change of stabilizing global temperature rises to below 2 degrees Celsius. The Vision Pathway analysed the impact of a range of carbon abatement methods using gas to reduce emissions:

- **Coal-to-Gas Substitution.** Replacement of coal with gas-fired capacity in power and heat generation, assumed to take place when the coal-fired station reaches 25 years of operations. Gas substituting for coal in end-use sectors, particularly residential use but also industrial applications. Some residual coal use is assumed to remain where gas infrastructure cannot easily reach.
- **Oil-to-Gas Substitution.** Replacement of oil with gas-fired capacity in power and heat generation at the end of the oil-fired station's useful life. Liquefied Natural Gas substituting for oil as a fuel in shipping and heavy goods vehicles. Natural Gas Vehicles replacing Internal Combustion Engine light duty vehicles. Gas substituting for oil in end-use sectors, particularly residential use but also industrial applications. Some residual oil use is assumed to remain, particularly as a feedstock.
- **Biogas.** Widespread development and production of biogas, and use as a zero-carbon fuel.
- **Carbon Capture and Use**. Using carbon capture to further reduce emissions from natural gas combustion.

Other low and zero-carbon abatement methods not specifically related to natural gas were also applied to reach the trajectory:

- **Reducing Demand.** Accelerating efficiency improvements in end-user segments, including building insulation, boiler efficiencies, industrial applications, replacing older inefficient gas-fired power generation with modern CCGT, improving internal combustion engine vehicle efficiency, reducing transmission and distribution losses, and behavioural change including reduction in passenger miles travelled.
- **Oil Substitution in Transport.** Replacement of combustion engine light duty vehicles with electric vehicles, both plug-in-hybrid and battery.
- **Renewables and Nuclear.** Step change in the use of renewables in power generation, supplemented with increased nuclear capacity.

See section IV for further details

Vision Pathway Portfolio versus All Renewables Costing

A comparison was then made of the costs of power generation for the Vision Pathway compared with an alternative case where all natural gas use in power generation is switched to a portfolio of renewable technologies. Focus was put on power generation because it becomes by far the largest sector over time (given regular power growth plus the electrification of large parts of transportation) and because it is a clear area for policy choice between technologies. Using typical levelised costs for each form of technology and each region, the cost of electricity was calculated for each of the three cases—the base case, the vision pathway, and the renewables pathway. (See Section V).

IV The Pathway Towards a Sustainable Future

Energy Baseline & GHG Abatement Options

The task to meet future global energy needs whilst at the same time addressing air quality and climate change concerns is challenging. Figure IV.1 summarizes the growth of carbon emissions under a base case, and maps against that the trajectory needed to contain climate change.

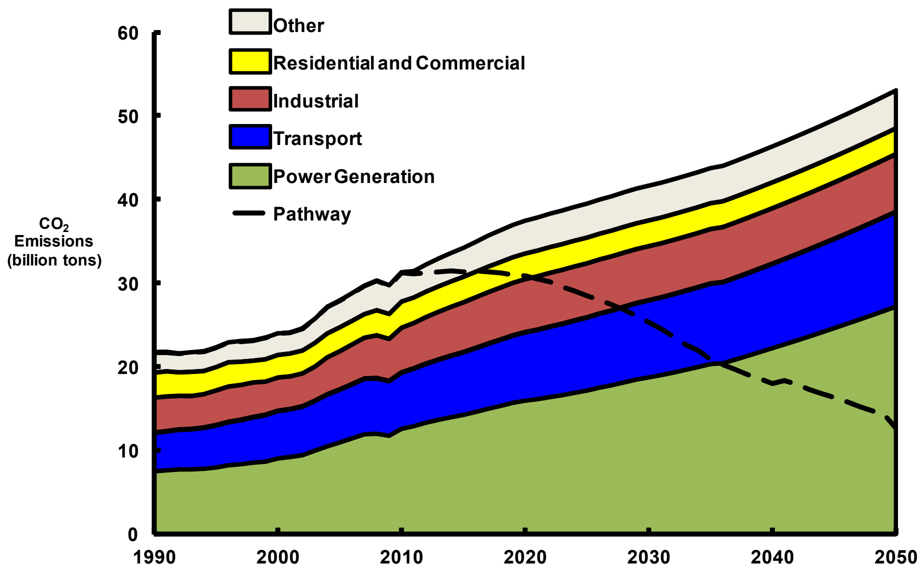

Figure IV.1: Global Emissions Trajectory Base Case
Source: IGU

- Global CO_2 emissions rise under the base case from 31 billion tons in 2010 to 53 billion tons in 2050.
- Emissions by 2050 need to come down to 12.6 billion tons to be consistent with the recommendations of the IPCC. This is equivalent to a 60 percent cut from 2010, and a giant 76 percent reduction from the 2050 base case.
- Power generation is the largest sector for emissions in 2010, and is also the sector expected to grow the most rapidly in the future. Power generation is slated to account for 49 percent of emissions in 2050 in the base case. Most of the emissions in this sector come from coal-fired power generation, with a small amount from old inefficient oil use and a growing contribution from natural gas as it increases its penetration of the market. [A decarbonisation scenario involving the partial or full electrification of transportation would, ceteris paribus, further increase the emissions from this sector, but reduce overall emissions].
- Transport—primarily road transport—is the second largest source of emissions. Transport is slated to account for 21 percent of emissions by 2050. These emissions are primarily from oil use: diesel or gasoline vehicles in road transport; fuel oil in the shipping sector; and jet fuel in aviation.
- A large component of the emissions in residential, commercial and industry is from heating, using a mixture of fossil fuels.

- 'Others' includes substantial emissions associated with the production of oil and gas, or the mining of coal. It also includes system losses.[3]

Abatement Choices

Three ways exist to bring down emissions from the base case. First, reduce overall primary energy demand either through lower final consumption or through more efficient production and conversion of energy. Second, replace higher carbon emitting fuels with lower, or near, zero carbon forms of energy. In other words, back out coal and oil with a combination of natural gas, nuclear, and renewable energy supply. Third, install carbon capture technologies where fossil fuels are burned. Below we examine the supply-side abatement options looking at the maximum potential for each case. These cases are 'pure' stylised cases in order to convey the approximate relative impact of each. They have not been modelled in detail at a regional or country level.

Power Generation

The following main options exist for power generation

- **Natural Gas**. Replace all oil and coal-fired plant (after 25 year lifespan) with best-in-class unabated gas-fired combined cycle gas turbines (CCGT). This reduces power sector emissions by 41 percent. Blending of biomethane into the gas network and/or direct power generation from biogas would further reduce the fossil-based carbon emissions.
- **Gas Combined Heat and Power (CHP)**. CHP units have the potential to increase energy conversion facilities from 60 percent for stand-alone power plants to over 80 percent, backing out energy use and emissions from the residential or industrial sector. At a maximum, this combined with the case above could reduce emissions by 1 billion tons. Integrated energy systems an another significant approach. A move away from large central plants to integrate energy within a micro grid, combining small scale renewables with biogas, with natural gas, capture and redistribute waste heat thus improving the overall efficiency of the energy system.
- **Full Carbon Capture.** If all fossil fuel plants were to install carbon capture, it would reduce power sector emissions by 88 percent, assuming a permanent 90 percent carbon capture rate.
- **Nuclear Baseload/Gas Support**. Nuclear plants could be built to service baseload needs, and CCGTs would be used for mid-merit and peak-shaving. The cut in emissions will depend on the regional demand profile, and the choice between simple-cycle or combined cycle back-up.
- **Intermittent Renewables/Gas Support**. Coal and oil plant is replaced with renewable energy supplies. Natural gas is used to support intermittency (wind and solar PV).
- **Zero Carbon**. Theoretically enough renewable and nuclear power could be built to replace all fossil fuel use. In order to reconcile erratic and intermittent renewable production with consumer demand, surplus renewable could be turned into synthetic gas and stored within the existing legacy gas network and redeployed in gas-fired plants at times of peak demand. Combustion emissions by definition tend to zero.

3 *The IGU Pathway quantifies the output for CO2 at the point of combustion. It does not quantify total GHG emissions.*

It should be noted that the simple and practical natural gas case brings significant and early benefits—a 41 percent reduction in power emissions -- without ruling out continuation to the more extreme decarbonisation options. The natural gas case is based on proven available technology and is low cost.

In addition to the supply-side options, it will be essential to reduce the level of power consumption. A panoply of demand-side measures will be needed. The introduction of smart meters and smart energy infrastructure may help optimise consumption. Efforts should also be made to minimize transmission and distribution losses.

Transportation

The following supply-side options exist for transportation

- **LNG**. All heavy goods vehicles and all shipping are switched over to LNG in line with the natural turnover of the capital stock. This reduces transportation emissions from these vehicles by at least 20 percent, and reduces overall transportation emissions by 6 percent.
- **CNG**. If the entire light-duty vehicle fleet were to switch from gasoline/diesel to compressed natural gas (CNG), it would reduce total transportation emissions by 23 percent.
- **Electric Vehicles**. The full lifecycle carbon footprint of electric vehicles depends on the choice of power generation. However, assuming that all power were generated from gas-fired plant, the net reductions in emissions would be approximately 2 billion tons, the equivalent of 36 percent of transport emissions. It should be noted that electric vehicles fueled from gas-fired power will generally have a lower carbon footprint than natural gas-fueled vehicles because of the more efficient electric motor, even after taking into account the higher losses from electric transmission and distribution.

Two further options exist that have certain benefits. They may not yield sufficient reductions in carbon emissions but they significantly improve local pollution.

- **GTL**. GTL is a clean burning and high performance diesel-type fuel, and it has the major advantage that it can be introduced with the existing incumbent retail network and incumbent car engine technologies. However, the Fischer Tropsch process entails significant losses of around 35 percent. Aviation is a sector which may lend itself well to adoption of GTL.
- **Fuel Cells**. Hydrogen fuel cell vehicles might become an attractive technology in the future, providing only water vapour tailpipe emissions. Natural gas is the primary option to produce hydrogen. However, use of natural gas to produce hydrogen would not significantly reduce carbon emissions.

Residential/Commercial

Three areas stand out as means to reduce emissions within this sector

- Fuel switching away from coal and oil either to natural gas, biomass or to electricity, will reduce emissions
- Efficient condensing boilers offer significant improvements over the current installed capacity, notably in Europe

- Microturbines offer the prospect of increasing efficiencies in heating. Best-in-class microturbines can achieve an efficiency of over 80 percent.

Industry & Agriculture

The main supply-side option in industry is fuel switching away from use of coal and oil to natural gas, biomass/biogas or power. Other areas of focus include

- New technologies. The focus is currently on real time process controls of burners (linkage-less controls, better control of gas valves). Burner efficiency improvements with lots of emphasis on low NOx burners which can reduce efficiency but also reduce emissions

- General maintenance, such as steam system repairs (leaky lines and traps) and ovens/furnace leaks and infiltration

Upstream Use

There is substantial scope for reduction of emissions from the production of fossil fuels.

- The oil industry has made progress to reduce upstream flaring of gas, but there remains significant potential to reduce further. Flaring occurs when the infrastructure to harness the value of natural gas is not in place. Therefore flaring means there is an opportunity to make better use of natural gas while at the same time reducing waste and emissions. It is estimated that 134 BCM was flared in 2010, equivalent to about 4.3 percent of total gas production [Source: US National Oceanic and Atmospheric Administration]. The majority of flaring takes place in Russia, Nigeria and Iran. Where gas can be collected and monetised through conventional channels, it should be. Where it cannot, mini-GTL could provide one possible innovative solution.
- Power efficiencies need to be increased closer to the levels achieved in the regular power generation fleet. Greater interconnection of offshore oil and gas production with onshore power grids would support this
- There are significant synergies to be developed between offshore oil and gas production and the development of offshore wind
- There may be synergies to develop between oil and gas production in hot desert areas, and the use of concentrated solar power in conjunction with gas generation
- The decline of coal use will result in lower energy use for mining

It should be remembered that methane—the principal component of natural gas—is a potent greenhouse gas emission. It is absolutely critical therefore that direct releases of methane into the atmosphere must be minimised. In upstream production, operators already work hard to minimize venting of methane for safety and operational reasons—not to mention the financial driver to maximize saleable volumes. Regulation of venting will need to ensure volumes are reduced to a minimum. In the midstream/downstream, improvements in pipeline materials is already leading to significant reductions in losses that are expected to continue. While growing concerns related to the environmental impacts of extraction of unconventional gas has been growing, the development of regulations, best practices, and more transparency will lead to the development of this tremendous resource.

The Vision Pathway Trajectory

Using combinations of these abatement choices, we have developed a gas Pathway trajectory for global energy demand consistent with a likely chance of stabilizing global temperature rises to below 2 degrees C. Scientific modelling of the environmental impact of emissions pathways has suggested the importance of quickly reversing carbon emission growth in order to sustain atmospheric concentration at a lower level.

In this Pathway, the early use of natural gas to substitute for higher-emitting fossil fuels slows down and reverses CO_2 emissions growth within a short period of time. From the 2010 level of 31.3 billion tons today, pathway emissions peak at 31.4 billion tons within the next decade. They then fall to 12.6 billion tons per year in 2050, one quarter of the projected level in the base case.

In the short term, moving from coal and oil to gas—particularly in power generation, but also in end-user sectors—provides significant savings toward achieving this pathway. This can be particularly effective in the regions with the fastest growing sectors, such as Asia Pacific which is currently heavily reliant on coal in the energy mix.

The abatement methods that provide the greatest medium-term role are measures to reduce energy demand, through both the replacement of older less efficient equipment and infrastructure, as well as changes in consumer behavior.

In the longer term, more zero carbon abatement options are needed to reach the reduction target. Development of carbon capture technologies and increased biogas production can provide major contributions toward the end of the period. Further zero-carbon generation will also be needed to reduce the carbon-intensity of electricity after coal and oil is largely substituted out of the mix post-2040. There will be a substantial and indispensable role for renewable energy supply supported by, if chosen by governments, nuclear power. Figure IV.2 shows the different impact of each major abatement method in reaching the emissions target.

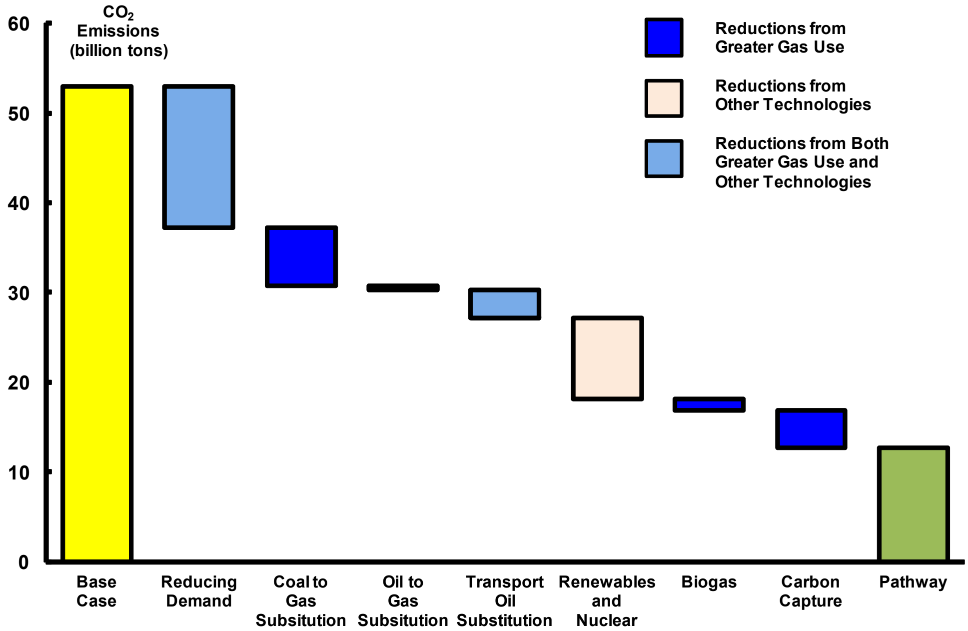

Figure IV.2: Global Emissions Reductions by Abatement Method

Figure IV.3 shows the contribution of each sector towards meeting the target. The sector where the greatest savings can be made is in power generation. This sector provides 23 billion tons of carbon emission reductions, or over half of total savings between the base case and gas Pathway trajectory in 2050. Electricity generation is lower than in the base case through more efficient use in final sectors and in transmission, but the carbon-intensity of this generation also falls from 6.3 tons per ton of oil equivalent (toe) electricity produced today to 1.0 tons per toe in 2050.

Significant reductions are also made in the transportation sector, through the use of gas and electricity to substitute for oil products, improved efficiency of vehicles, and changes in consumer behaviour reducing the number of passenger miles travelled each year (such as car pooling, remote working, and greater use of mass transit). These abatement measures save over 8 billion tons of carbon emissions in the gas Pathway.

In the industrial sector, the greatest contribution is the substitution of gas for coal and oil in energy use. Some industrial applications, particularly where oil is used as feedstock, cannot be replaced by natural gas. Other abatement methods such as improving the efficiency of manufacturing equipment and using carbon capture (and potential recycling of the carbon) in large-scale industrial processes are also needed to reduce the footprint of this sector.

The 'other' sector includes emissions losses from transportation and distribution, and own use of energy in fossil fuel extraction, refineries, and coal- and gas-to-liquid technology. As oil and coal use declines rapidly in the gas Pathway, energy use and emissions in this sector also falls. Scope to reduce transmission losses also plays a role.

Smaller, but important, contributions also come from the residential and commercial sectors. The main improvements here come from efficiency improvements, such as boiler and insulation technologies, as well as greater use of renewables sources including biomass and heat pumps.

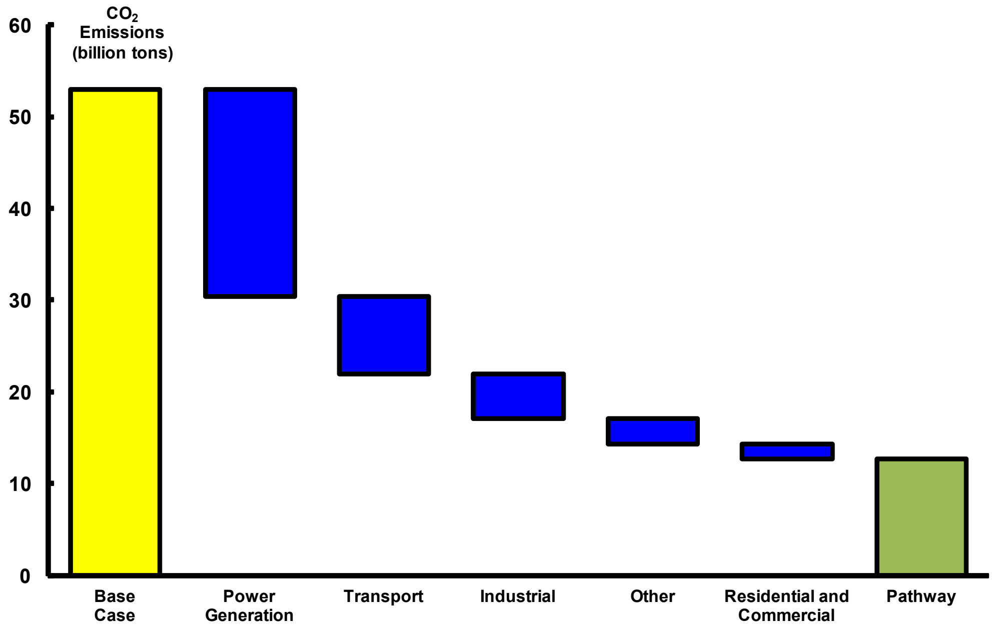

Figure IV.3: Global Emissions Reductions by Sector

The Pathway was developed at a regional level, with analyses carried out for Africa, Asia Pacific, Commonwealth of Independent States (CIS), Europe, Latin America, Middle East, and North America. The differing energy characteristics of each region suggest different combinations of these abatement methods. The large Asia Pacific region dominates (see Figure IV.4), providing 58% of the emissions reductions savings. Key dynamics of each region are summarised in the Appendix.

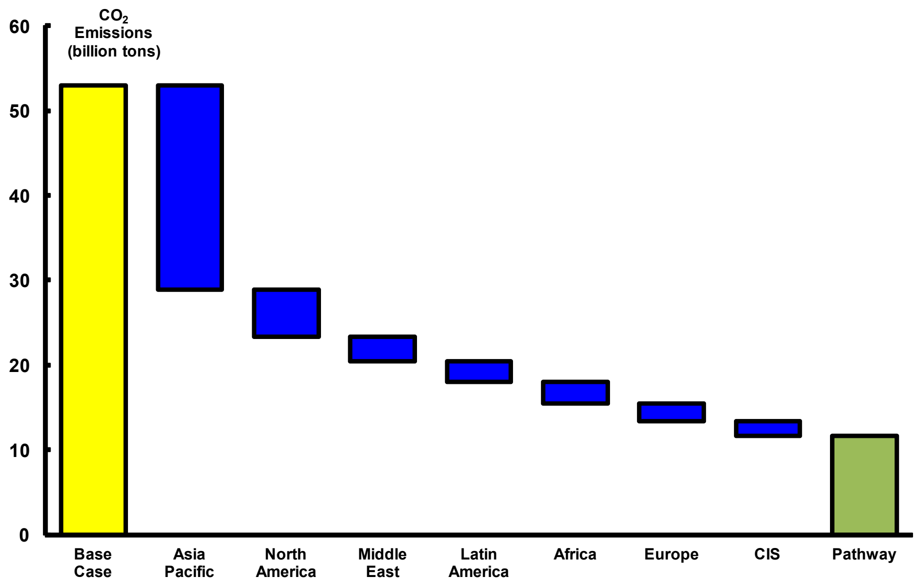

Figure IV.4: Global Emissions Reductions by Region

Implications for Gas Demand

The Pathway demonstrates that a low-carbon trajectory is consistent with a role for gas in the energy economy. Indeed, the ability of gas to quickly substitute for higher-emitting fossil fuels is critical to stabilize emissions over the next decade. Figure IV.5 shows the outlook for gas demand by sector in the Pathway. In 2035 gas demand reaches 6.6 TCM in the pathway, 23% higher than the base case, largely due to coal-gas switching in the power sector: . Demand is projected to rise to 7.1 TCM by 2050, just below the level expected in the base case. Of this 7.1 TCM, 6.4 TCM is natural gas, and 0.7 TCM is biogas.

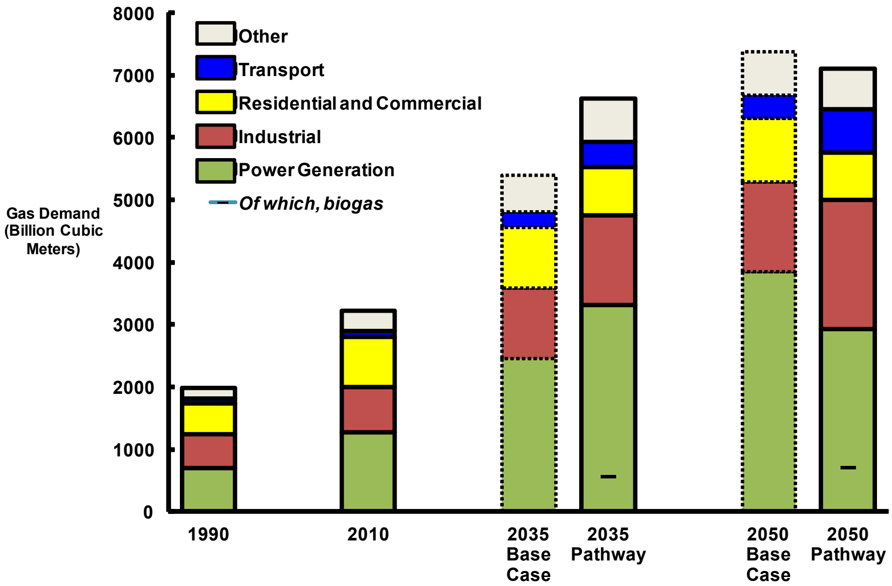

Figure IV.5: Gas Demand by Sector

As today, power generation will be the largest sector, with consumption in electricity and heat production alone reaching 2.9 TCM. By 2050, very little generation from coal and oil is left.. This generation is largely replaced by gas with carbon capture, complemented by expansion of nuclear and renewables.

In the industrial sector too (including consumption in agricultural and the use of hydrocarbons as a feedstock), the displacement of other fossil fuels coupled with some carbon capture leads to growth in gas demand, reaching 2.1 TCM in 2050. In the base case, coal and oil still provide over a third of energy use in this sector. In the Pathway, this is greatly reduced with remaining consumption largely applications where gas cannot substitute for oil as a feedstock—accordingly industrial consumption of gas in the Pathway is actually higher than in the base case. In the residential and commercial sectors, where the distributed nature of consumption means that carbon capture is not feasible, gas demand in the Pathway scenario is significantly lower.

Aggressive expansion of LNG in transportation, particularly in the marine and heavy goods vehicles segments, leads to gas demand in transport reaching 0.7 TCM annually by 2050, more than double the projected level in the base case.

Together, natural gas actually grows as a key pillar of the global energy mix, reaching one-third of primary energy demand in 2050, up from one-fifth today. (See Figure IV.6). In order to meet the low-carbon trajectory, the role of coal and oil is much diminished. Primary electricity (nuclear and renewable generation) grows considerably in the pathway, as well as an increased share for biomass.

In the Pathway, increased development of biogas plays an important role in reducing carbon emissions. By 2050, annual production and consumption is assumed to reach 710 billion cubic meters—10% of total gas demand—close to estimated sustainable global resources.

The overall growth in gas consumption depends critically on carbon capture and the use of biogas. Without these two technologies, growth in natural gas would not meet the GHG emissions target. In the Gas Pathway, 7.1 TCM of gas use contributes 8.4 billion tons of emissions in 2050. With no carbon capture or biogas, using this amount of gas would emit 13.3 billion tons of emissions. In effect, these technologies save nearly 5 billion tons of emissions—the equivalent of 2.2 TCM of gas consumption.

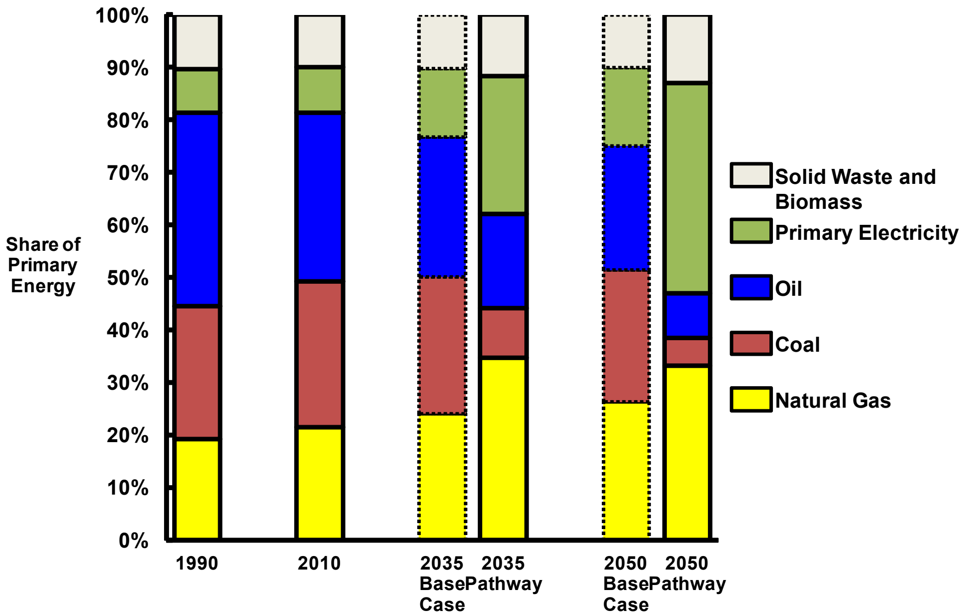

Figure IV.6: Gas Market Share of Primary Energy

The Power Sector

Power generation is the largest, fastest growing sector, and illustrates the costs of different pathways and technology choices. The lowest cost form of new baseload power generation today is generally gas-fired CCGTs in the OECD and coal-fired power in non-OECD markets. Table V.1 shows the typical range of levelised cost of electricity for the key technologies. They are divided into three types: gas-fired technologies, intermittent technologies that are assumed to use gas-fired power as back-up, and non-gas technologies.

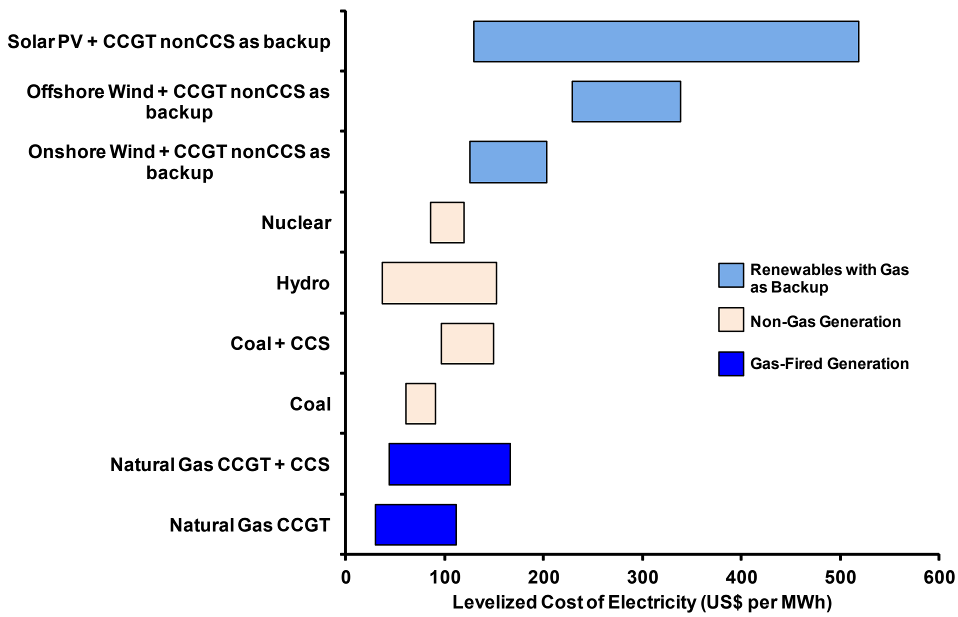

Table V.1: Indicative Levelised Costs of Electricity (LCOE) by Technology[4]

Source: IHS CERA, various.

4 *Ranges show indicative variation across regional averages. Individual plants may have costs that fall outside these ranges.*

		2010	2030	2050
Base Case	**TWh**	21,260	40,414	65,987
	$tn	2.0	4.3	7.2
	$/MWh	95	106	110
Vision Pathway	**TWh**	21,260	36,151	53,134
	$tn	2.0	4.0	6.9
	$/MWh	95	112	129
Renewables Pathway	**TWh**	21,260	36,151	53,134
	$tn	2.0	5.4	8.6
	$/MWh	95	148	161

Table V.2: Global Cost of Power Generation

Table V.2 shows the total global cost of power generation based on LCOE assumptions and the growth of power demand.

Several figures stand out-

- The average cost of power production globally in the base case is $95 per MWh , and the total global power bill $2.0 trillion in 2010.
- In the Base Case the cost of producing power rises to $7.2tn by 2050 reflecting market growth.
- The average cost of power in the Vision Pathway is $112 per MWh in 2030 and $129 per MWh in 2050. The replacement of cheap unabated coal in the developing world pushes up the global price of power to 2030. Thereafter the growth of renewable power and the use of CCS pushes up power costs further. [5]

As was argued in Chapter 1, the global resource base and the competitive costs of unconventional gas suggest that an assumption that gas prices remain broadly at today's levels is reasonable. Indeed, as the growth of natural gas demand flattens post-2040 (when excluding biogas), natural gas prices are likely to remain highly competitive. The higher costs for power in the Vision Pathway reflect primarily the cost of carbon capture and renewables as compared to the lower cost alternatives of coal and unabated gas. Carbon capture must inevitably involve a cost incremental to unabated gas (or coal) plant.

Policy makers have the option to minimize gas-fired power—at least in the longer term—and to opt for more renewable power. But at today's gas prices and today's capital costs for renewables, this would involve further extra cost.

These figures understate the cost advantage of natural gas-fired power relative to intermittent renewables. There is a growing recognition that the traditional LCOE approach to power economics does not capture fully the extra costs of incorporating intermittent power. The inclusion of intermittent renewables requires back up capacity (or power storage). In our calculations, this is assumed to be gas-fired currently, the lowest-cost and most practical option given the absence of commercially viable power storage options. Renewables also require significant investment in grid reinforcement and connection to the grid (although this is true of

5 *Power costs are for generation only, using the LCOE cost methodology. No attempt has been made to calculate transmission and distribution costs.*

other centralised power options). However even these calculations do not take into account that reliable dispatchable generation has a greater value per kWh than non-dispatchable generation. Unabated gas-fired generation is better suited to load following than both renewables and nuclear or coal—and this load following has a value.

Employment Impact

The gas industry is a major generator of employment across the globe. Table 3 shows data from the United States, Canada, and Australia regarding direct employment in recent years. This figure broadly includes those involved directly in exploring, developing, producing, transporting, and delivering natural gas, or providing onsite services. Both these countries can assume to operate broadly efficient levels of manpower. It suggests an approximate metric of 820 employees per BCM of annual consumption, split 60-40 between upstream and downstream operations. In practice each country will vary widely depending on its upstream industry, sectorial consumption, its cost of labor, and its overall productivity. However, this metric gives an indication of the employment impact of natural gas. It suggests direct employment of around 2.5 million today will rise to around 6 million people worldwide by 2050. The precise figure is likely much higher because developing countries will typically employ greater numbers.

	Direct Jobs Thousands	Indirect Jobs[4] Thousands	Volumes BCM	Multiplier Jobs per BCM[3]
Upstream (E&P)				
United States[1]	353	n/a	571	618
Canada[2]	63	n/a	160	394
Australia[2]	20	n/a	50	400
Downstream				
United States[1]	269	n/a	659	408
Canada[2]	17	n/a	94	181
World (inferred)				
--2009[4]	2,449	11,948	2,987	820
--Base Case 2050[4]	6,057	29,548	7,387	820
--Vision Pathway 2050[4]	5,811	28,344	7,086	820

[1] 2008 data
[2] 2010 data
[3] Direct Jobs
[4] Direct, Indirect & Induced Jobs assuming 4,000 Jobs per 1 BCM

Source: IHS Global Insight, US Bureau of Labor Statistics, APPEA, Canada Gas Association

Table V.3: Direct Employment related to the Gas Industry—
Regional Examples and Inferred Global Numbers

The full number of jobs related to the gas industry—so-called ‘indirect’ and ‘induced’ jobs--will be several times greater than the direct jobs. Studies in the US—where the data is most detailed and accessible—suggest a multiplier of at least four times.

The potential economic impact of the wider adoption of natural gas can be gleaned from evidence in the United States from the rapid growth of shale gas. By 2010 shale gas was producing around 170 BCM and had brought down gas prices sharply. Consumers are benefitting form lower bills and there is a revival of interest in gas-based feedstock industries with the knock-on positive effect on employment and economic development.

A recent study by IHS Global Insight found that shale gas in the United States supported 600,000 jobs in 2010. Of these jobs, almost 150,000 were direct jobs, and the remaining 450,000 indirect or induced jobs. This implies a factor of 4,000 jobs per 1 BCM of production. [Footnote: The Economic and Employment Contributions of Shale Gas in the United States, December 2011. Report prepared by IHS Global Insight for America’s Natural Gas Alliance].

The job impact will vary widely by country depending on many factors, not least the type of gas production and the location of the various supply chain support industries.

Conventional gas—which has generally higher up front capital costs and lower operating costs—will employ more people during field development, and less people during operations. Take for example the case of LNG. A typical two-train 10mt LNG train will take approximately four to five years to build and employs directly on site about 2,000-2,500 people at peak construction in addition to those working on upstream production. Many more are involved in the fabrication of equipment, design, research plus commercial support.

VI Policy Enablers

A conducive and supportive policy framework will be essential to bring about changes outlined by the IGU Pathway. Policy will be particularly important in the area where the greatest reductions in emissions are projected: namely demand reduction/energy efficiency, coal to gas substitution, and carbon capture. Research and development will also be critical.

On the supply-side, measures are needed to allow the responsible development of unconventional gas internationally, so that it can supplement conventional gas supply. In parts of the developing world, the removal of subsidies that set gas prices below the cost of production and supply, where possible, could provide a powerful investment impetus to help develop more gas to the overall benefit of the economy and inhabitants. Biogas needs to be facilitated to supply a third pillar of global gas supply whose importance will need to grow substantially post 2030.

Infrastructure is essential for the provision and delivery of natural gas to consumers. In many developing markets, infrastructure is needed if natural gas is to become a core part of the energy balance. It is the complexity of arranging an integrated approach between developing supply, building infrastructure and creating demand that often stymies natural gas developments and leads to use of more costly alternatives. Appropriate financing and regulatory incentives for infrastructure will be essential.

Additionally, if the objective to reduce GHG emissions is to be achieved, it will be essential that the cost of carbon is included in the provision of energy. This principle is key; the mechanism of whether to adopt a market-based cap-and trade approach or some form of taxation is a secondary issue where different regions may favour different solutions. Adoption of carbon pricing would allow industry or the market to decide the optimal or lowest cost means of abatement, without requiring policymakers to pick favored technologies or fuels. We believe natural gas—based on its costs and low carbon content—would fare well under a neutral carbon scheme; but ultimately the market will determine outcomes based on evolving competitive costs.

Demand Reduction/Energy efficiency

Of the seven abatement mechanisms identified in Section IV, demand reduction—both more efficient production of energy, and lower final use of energy-- is the largest single contributor to CO_2 reductions in the Pathway. Energy efficiency is driven by a combination of technological advance, regulation, pricing and taxation.

A wide range of well-studied policy opportunities are available to support energy efficiency goals. These include various forms of financial incentives and innovative financing schemes to address the up-front cost barrier to energy efficiency along with continued public awareness and training campaigns. Performance standards in buildings and appliances offer another important policy instrument that should be prioritised. Emphasis should in general be placed on new-build or end of life appliances, rather than retrofitting of old capital stock, much of which will be replaced by 2050. Wider use of road charging could optimize transportation while also managing congestion. Where it is possible and reasonable to cut energy subsidies, this will not only help reduce demand but also encourage supply-side investments.

For natural gas, greater efficiencies can be achieved by the encouragement of combined heat and power (CHP). This can take two forms. In a centralised energy system depending increasingly upon electrification or the creation of integrated energy systems, it will be essential to encourage large scale CHP plants with related district heating systems. CHP systems can reach efficiency levels above 85 percent compared to a theoretical maximum of around 62-65 percent for stand-alone thermal power production. Alternatively, in a more decentralized system, where there is direct provision of natural gas to the consumer, local microturbines should be encouraged to maximise efficiency of use. Microturbines can achieve overall efficiencies of over 80 percent.

It should be noted that—with the current state of technology—direct provision of natural gas to the consumer through pipelines involves lower losses than electricity via wires. Generally and depending upon the precise configuration, it is more efficient to provide water and space heating to a building with natural gas, than with electricity produced from natural gas. Hence policy needs to encourage direct use of natural gas, and to seek continued improvement in superconductivity and other means to reduce systems distribution losses from power. Developments in smart grid and smart meter technology are likely to play an important role in optimizing our use of energy, especially post-2030.

Coal to gas substitution

Substitution of coal with natural gas—notably in power generation—is one of the lowest cost and quickest means to reduce emissions. Modern CCGTs plants have lower capital cost of installation and shorter construction time than coal. Construction time is typically two years compared to four years for coal and much longer if nuclear were to be chosen.

Substitution takes the form either of closing down existing coal-fired generating plant, the conversion of existing coal fired plants to natural gas (which requires no new construction permits), or building gas-fired power plants where coal plant would normally be the default economic choice. Coal-fired power remains a highly cost competitive choice in much of the world. Conventional forecasts project big increases in coal-fired power in the developing world, and most especially in China and India.

Action is needed urgently. This simple substitution has a particular impact in the critical early period: **gas-coal substitution in power alone accounts for 21 percent of the emissions reductions from the base case by 2035**[6]. It is therefore recommended that investment in gas-fired power that substitutes for coal in developing countries should be included in some form of international credit certification system, such as the international Clean Development Mechanism (CDM). Specifically, investments in gas-fired power in developing countries that can demonstrate they result in additional abatement to business as usual—the so-called 'additionality' proviso—could so qualify. The gas industry could seek specific trade-offs for direct support of such new investments in developing countries, by negotiating pro-rata additional long term supply rights for gas-fired power in developed markets. These term commitments would in turn support the capital-intensive development of new natural gas production and long distance transportation infrastructure. Commitments to support major CCS demonstration projects could be structured in a similar fashion with additional long term supply rights.

Many of the fastest growing non-OECD economies have large volumes of unconventional gas, notably shale gas. This is especially true of China. Regulations to kick start shale gas development would support coal-to-gas substitution.

6 *Assuming coal plants retire after 25 years of service and are replaced by gas.*

Carbon Capture

In the longer-term post-2030, there will be a need for significant scale-up in all available zero carbon, or near zero carbon, technologies including nuclear and renewable. Carbon capture will be essential if widespread use of fossil fuels—including natural gas—are to remain a part of the energy mix at the same time as CO_2 emissions are to be cut. Although this is a longer term need, it is important that carbon capture technologies are shown to be potentially viable sooner rather than later. The risk is that a window of opportunity for carbon capture is missed as other technologies scale up. It is therefore highly desirable that industry and governments push forward together to build large scale power demonstration projects that provide reassurance on the technology, and initial evidence on costs.

Carbon storage remains the primary candidate for handling CO_2. Therefore industry and policy makers need to focus on the required regulatory framework that will support the conversion of depleted oil and gas fields from hydrocarbon production units, to CO_2 storage parks. The same applies for the conversion of oil and gas pipelines into potential CO_2 carriers. Besides the regulatory framework, policy makers and industry have an important role to play in winning public acceptance that has proved difficult in some developed markets to date.

However storage is not the unique option for CO_2. More research is also needed into examination of carbon usage options.

Carbon Markets vs Targeted Mandates and Incentives

Government policies will need to choose a combination of market mechanisms and more targeted policies to achieve environmental goals. No single 'all-fits' option will work. As a general rule, however, applying market mechanisms and applying a transparent value to carbon are recommended. This will

- Encourage the lowest cost abatement, which will often be replacement of coal with natural gas
- Reduce the need for policy makers to 'pick winners' by establishing a level playing field for competing technologies

It should be recognised, however, that carbon markets or carbon taxation provide the strongest incentives for established lower cost options—such as unabated CCGTs and onshore wind—while potentially not providing needed support for higher cost infant technologies that will also be needed to meet long term goals. These infant technologies may have better prospects of lowering costs substantially over time. These higher cost infant technologies will therefore need additional support mechanisms. For the gas industry, this means particularly carbon capture and biogas technology.

VII Regional Pathways

Asia Pacific

The Asia Pacific region is pivotal in determining the future trajectory of carbon emissions. The region is home to over half of the world's population, but only a quarter of global gross domestic product. Rapid economic growth—particularly in China and India—will lift this to a third of world GDP and significant falls in energy intensity will be needed to curb deterioration in local air quality and a large increase in emissions. In the base case, regional emissions are projected to reach nearly 30 billion tons of carbon—57% of the global total. In the Pathway, this is reduced to 6.5 billion tons, around half of current levels.

Nearly half of the Asia Pacific region's primary energy demand is met by coal, far above the global average of 27 percent. The rapidly-expanding power sector is particularly reliant on coal, with the fuel providing over two-thirds of electricity generation. Industry is also very coal-intensive—substituting these uses with gas would save 6 billion tons of emissions annually by 2050. In common with other regions, measures to reduce end-user demand provide the greatest impact—this is particularly important in the transport sector in Asia Pacific to mitigate the fast growth in road vehicle use.

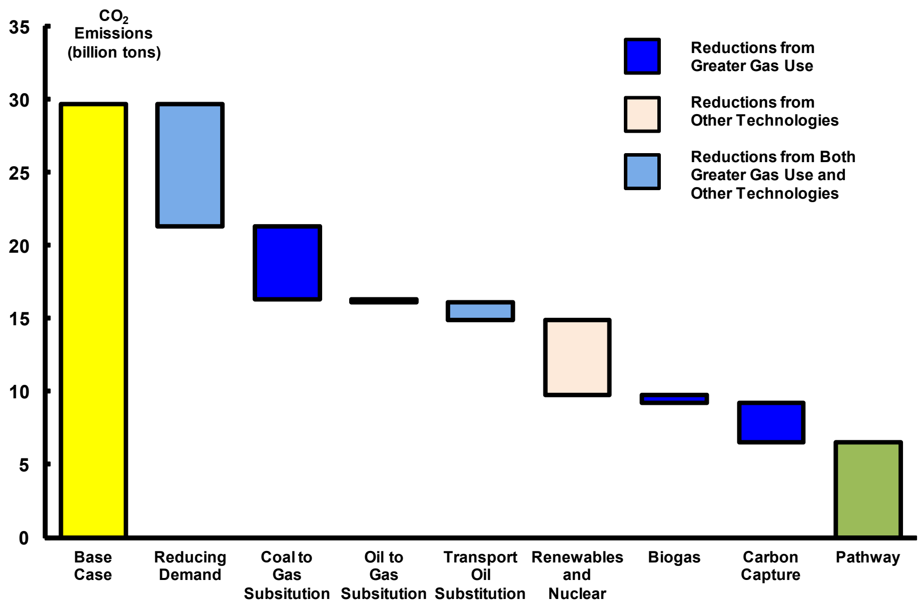

Figure VII.1: Emissions Reductions by Abatement Method—Asia Pacific

North America

North America is highly energy-intensive with by far the greatest consumption per person of any region. Energy intensity has been falling and continued gains in efficiency contribute to keeping emissions growth low in the base case. Carbon output is projected to increase only slowly from today's level of 6.7 billion tons to reach 7.3 billion tons per year in 2050.

The transportation sector is a major contributor to CO_2 output in North America, making up nearly a third of emissions now compared to the global average of 22%. Although coal is the fossil fuel that contributes most to global emissions, the large and relatively inefficient transportation sector means that oil is the biggest emitter in this region. High oil-gas price differentials and an abundant North American gas resource base provide a strong incentive for greater use of gas. Substitution for oil in transport, combined with measures to reduce end-user consumption, cuts emissions by 1.4 billion tons in the Pathway. Use of gas in the heavy goods vehicle and shipping sectors is supplemented by the replacement of the existing fuel-inefficient road fleet through the widespread deployment of electric vehicles in the passenger and light commercial vehicles.

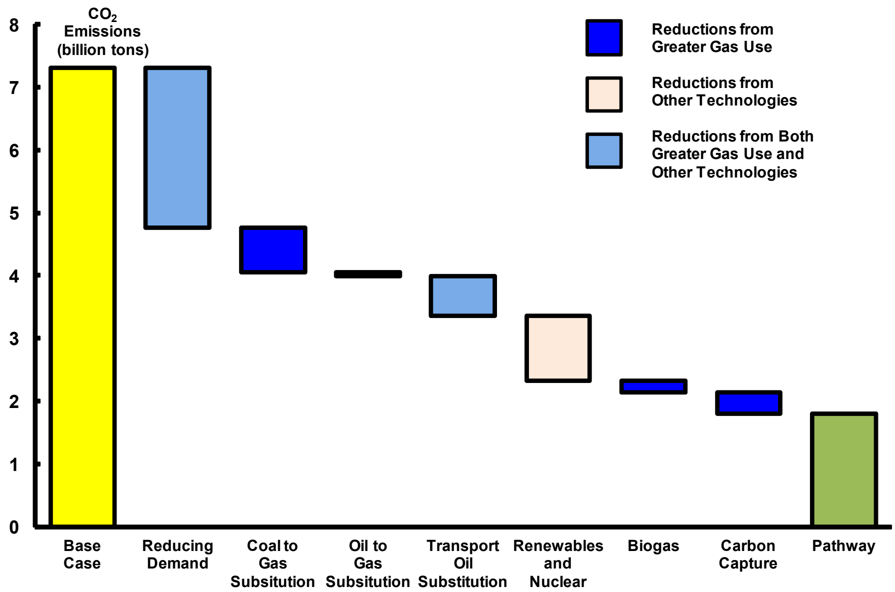

Figure VII.2: Emissions Reductions by Abatement Method—North America

Middle East

Although the Middle East accounts for only 5% of global energy consumption, demand per person is at similar levels to Europe and the CIS and is expected to keep growing. The population in the region is also one of the fastest growing, so meeting rapid increases in energy demand is a key priority for the region. In the base case, emissions are projected to rise from today's level of 1.6 billion tons up to 4.0 billion tons in 2050. Due to the available energy resources in the region, oil is by far the largest contributor to emissions, making up 59% of CO_2 output at present. Coal is much smaller, providing only 1% of primary energy in the Middle East compared to a global average of 28%. Gas abatement methods here focus on the substitution for oil, particularly in the industrial and transport sectors. These abatement methods combine to reduce carbon emissions in the pathway to 1.1 billion tons in 2050, a fall of one third from today's levels. The Middle East is rich in gas resources, but many countries are gas-constrained as a result of lack of investment and heavily subsidised gas pricing. Investment will need to be stepped up to follow this pathway.

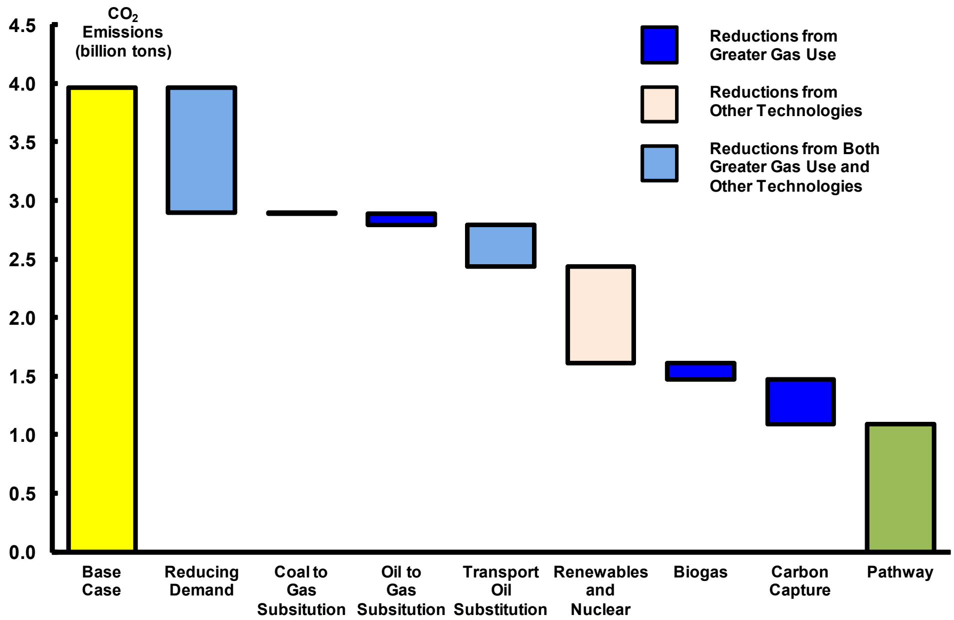

Figure VII.3: Emissions Reductions by Abatement Method—Middle East

Latin America

Carbon emissions are expected to grow significantly in the Latin America rising from current levels of 1.1 billion tons per year to 3.0 billion tons by 2050, just behind Africa in relative growth. In common with the Middle East region, oil dominates here, with coal accounting for only 4% of primary energy demand. The substitution of oil, largely in the transport sector, is a key part of bringing emissions down in this region. In the gas Pathway, emissions are projected to reach 0.6 billion tons by 2050, a fall of nearly half from today.

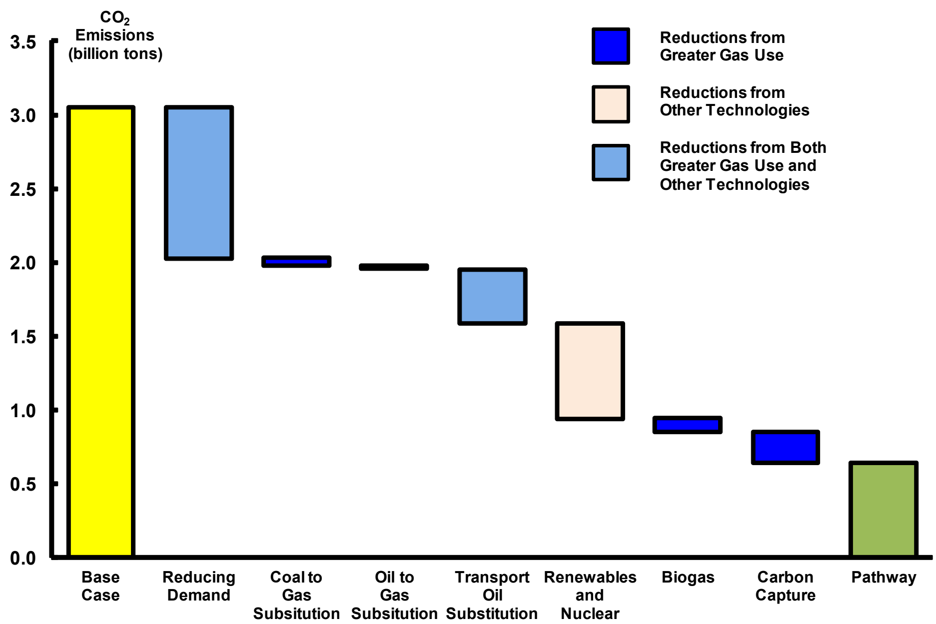

Figure VII.4: Emissions Reductions by Abatement Method—Latin America

Africa

Africa has the lowest energy consumption per person and is the smallest contributor to global emissions at present. Nearly half of primary energy is met through renewable sources—primarily the use of biomass in the residential sector. The use of biomass comes at a huge cost in terms of health and mortality rates. Africa will have the fastest growing population over the next forty years and the vision pathway allows the region to develop the energy infrastructure to support this growth in an affordable way. Natural gas will be a powerful generator of economic growth. Rapid development in both energy infrastructure and the wider economy are projected to lead to a higher contribution of fossil fuels in the energy mix, and carbon emissions trebling from 1.0 billion tons per year at present to 3.0 billion tons by 2050, the highest relative growth of any region.

The major source of carbon savings in the Vision Pathway is the mitigation of demand growth through initiatives to reduce end-user demand and energy intensity.

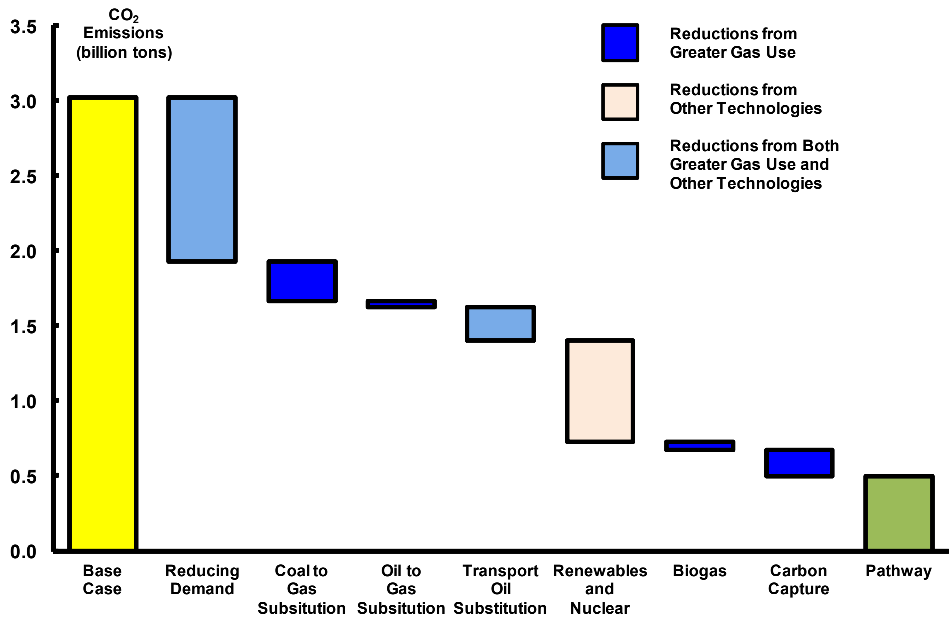

Figure VII.5: Emissions Reductions by Abatement Method—Africa

Europe

Although Europe is a significant energy consumer, its contribution to the Vision Pathway savings is disproportionately low. Europe is already among the most energy-efficient of regions, largely driven by policy. The decarbonisation agenda is assumed to make progress in the base case (even if falling short of targets) with large scale deployment of renewables and improvements in energy efficiency. This leads to a base case expectation of carbon emissions actually falling from 4.4 billion tons per year today to 3.6 billion tons in 2050—the only region with a projected decline.

Accordingly, there is less scope for further reductions from the base case than in some other regions. The use of biogas and carbon capture can make a particular contribution in Europe, given current development as well as some of the infrastructure already being in place from depleting gas production. In the gas Pathway, carbon emissions fall to a third of today's levels, reaching an annual 1.5 billion tons.

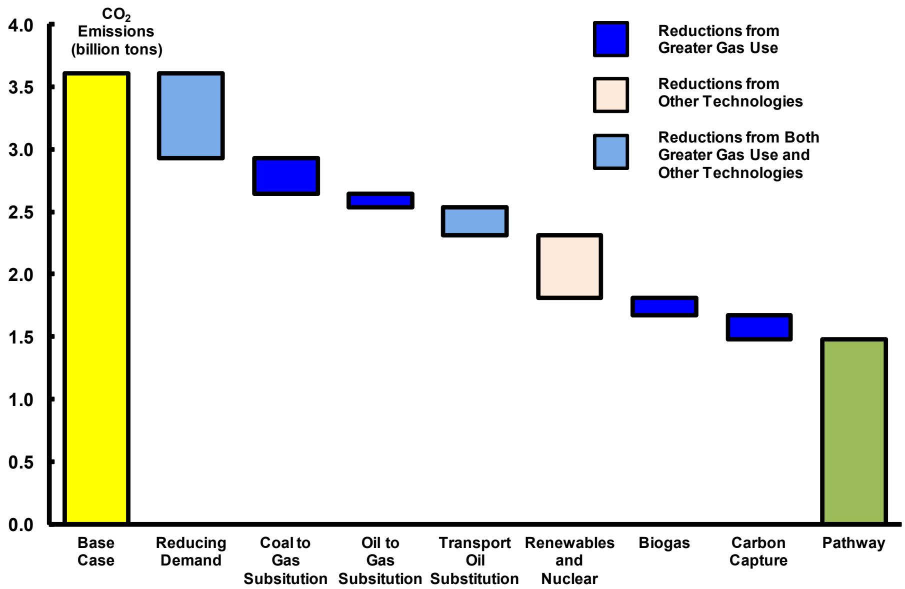

Figure VII.6: Emissions Reductions by Abatement Method—Europe

Commonwealth of Independent States (CIS)

As a key global hydrocarbon producer, the CIS has a long and well-developed fossil fuel energy industry. As such, existing infrastructure is older and less efficient than typical for other regions. This is particularly evident in the power sector. Less than 5 percent of the gas-fired fleet is efficient combined-cycle gas turbine, so replacing older power stations with modern plant would provide significant efficiency improvements and carbon savings. Similar investment in modernising older industrial facilities would make an important contribution. Measures like these to reduce demand account for half of the emissions savings by 2050.

In the base case, emissions are projected to stabilize from current levels of 2.4 billion tons, remaining at this level by 2050. The Pathway projection is for carbon emissions to fall to 0.6 billion tons by the end of the scenario period, only one quarter of today's figure.

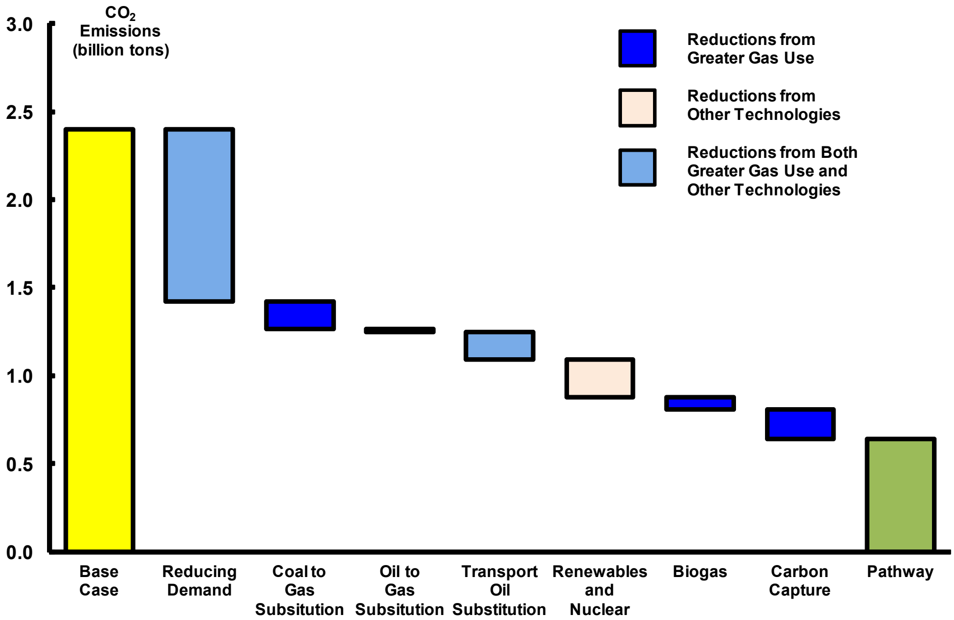

Figure VII.7: Emissions Reductions by Abatement Method—CIS

VIII Concluding Remarks

The 'Global Vision for Gas' lays out a clear pathway towards a sustainable energy future. That is, a future of improved air quality and public health, affordable energy, available resources, and sharply reduced greenhouse gas emissions. The Vision Pathway argues strongly for the need for a portfolio approach in energy, calling upon reductions in energy use, enhanced energy efficiency, expanded use of zero carbon technologies, and greater resort to clean-burning natural gas. It illustrates that the immediate wider deployment of natural gas would be based on proven technologies available today that can have a significant near term impact. The pathway also shows how investments in the gas industry today set up a sustainable platform for future mitigation without predetermining the choice of technologies. The report further argues that this portfolio approach that includes a major role for natural gas will likely cost less than opting for an all renewable supply route in power generation. Hence, inclusion of natural gas could help the affordability of the parallel adoption of new zero carbon (or near zero carbon) technologies. Finally, the significant number of jobs associated with natural gas—both directly and indirectly—is highlighted and its contribution to economic growth.

We conclude that policy makers need to recognize the critical role that natural gas has to play alongside other low carbon options, and facilitate the appropriate policy enablers as befits each region based on its particular circumstances.