The Golden Age of Gas: Opportunities and Challenges for LNG as a Fuel for the 21st Century

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Introduction

The world is facing serious energy-related challenges that are further complicated by increasing concerns about global climate change. While energy is a key driver of economic progress throughout the world, the development, transport, and use of fossil fuels has contributed to an increase in greenhouse gas (GHG) emissions. These duel concerns have been brought to the top of the agenda in business, politics, and public debate and people around the world are searching for ways to meet rising energy demand in a cleaner and more sustainable manner.

Through the lens of the International Energy Agency's (IEA) Special Report issued in June 2011, *The Golden Age of Gas*, this paper addresses the role of LNG in the global energy supply mix in the context of climate change and environmental sustainability, public acceptance and government support for natural gas, and the potential opportunities and challenges arising from recent developments in the global shale gas industry.

Section 1 of this paper discusses the increasingly important role of natural gas in the global energy mix, including a discussion of the divergent views of natural gas as the world struggles to meet growing energy demand in the coming decades with cleaner burning fuels.

Section 2 of this paper looks the role of natural gas through the lens of the IEA's Special Report, *The Golden Age of Gas*. Will the 21st century be the Golden Age of Gas? What are the key drivers identified for the expected increase in natural gas in the global energy mix? Where are the opportunities and what are the challenges?

Section 3 addresses the role of LNG in the Golden Age of Gas and highlights the importance of LNG as the "glue" linking global gas markets.

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Section 3 also discusses the global environmental challenges of reducing long-term growth in greenhouse gas emissions while still providing the energy required to meet the demands of growing populations and economies. This section of the paper analyzes the environmental impact of LNG and discusses the safety and environmental issues pertaining to the liquefaction, shipping, and regasification of LNG in the context of increased public opinion and environmental challeng*es* to LNG facilities and projects. Section 3 also analyzes the role that natural gas and LNG can play in a carbon-constrained world.

Section 4 of the paper provides a discussion of global shale gas development and the potential impact on LNG markets. Will the success of shale gas development in the United State's be replicated elsewhere? Where are the global shale gas resources located and what are the challenges to development? This section also highlights the controversy over the environmental impacts of hydraulic fracturing which is necessary to unlock the vast tracks of shale gas round throughout the world.

Section 5 of the paper analyzes the potential impacts global shale gas development will have on global gas markets and in particular, on LNG markets. How will significant development of the world's shale resources impact LNG? Will US shale gas production ultimately lead to the US becoming an exporter of LNG? What are the legal, policy, and environmental challenges for US LNG exports?

Keywords: Natural gas, LNG, Golden Age of Gas, energy security, climate change, greenhouse gas emissions, sustainability, environment.

1. The Role of Natural Gas in the 21st Century

As the world entered the 21st century, policy makers around the world were grappling with issues related to energy security, energy poverty, and an expected increase in future demand for all energy sources. At the same time, concerns about global climate change and reducing greenhouse gas emissions also emerged as primary issues to be addressed as the world searched for a sustainable energy future.

As a clean-burning fuel, many business and policy leaders began to look to natural gas and liquefied natural gas, LNG, to meet growing energy demand using more environmentally sustainable fuels. During the first decade of the 21st century, natural gas demand increased significantly as did LNG's share in worldwide natural gas trade.

In the global market place, however, natural gas received mixed reviews, especially as concerns about global climate change grew in the mid-2000s. Some environmental groups view natural gas as yet another fossil fuel with its own set of environmental and emissions considerations. Other groups and policy makers took the view that at the least, natural gas could be a "bridge fuel" to a renewable energy future. Not surprisingly, the energy industry has embraced natural gas not just as a "bridge" or transition fuel, but also as a primary fuel for the 21st century.

During the first decade of the 21st century, these divergent views tended to influence whether or not natural gas and LNG were perceived as a fuels for the future. As new technologies are developed and new opportunities for natural gas and LNG sought by governments and industry, these debates are likely to continue throughout the 21st century. Despite the often divergent views about natural gas and LNG, however, as the world enters the second decade of the 21st century, natural gas and LNG seem poised to assume a far greater role in the energy supply mix for many reasons that will be discussed throughout this paper.

1.1. The Divergent Views About Natural Gas

As the world entered the 21st century, the role of natural gas in the energy supply mix was anything but clear. As concerns about climate change grew in the early to mid-2000s, there were a number of competing views regarding the role of natural gas coming from the industry, environmentalists, and a large group in the middle.

1.1.1. The Industry View – The Many Benefits of Natural Gas

Not surprisingly, the worldwide energy industry has embraced natural gas as an important fuel for the 21st century. In support of their view, the natural gas industry has focused on the many benefits of natural gas and has set forth a coordinated view that highlights natural gas as a clean, affordable, reliable, efficient and abundant source of energy.[2]

Natural Gas is Clean: Natural gas produces less emissions than any other fossil fuel and the most advanced combined cycle gas turbine (CCGT) power plants emit almost 50% less CO2 than coal-fired power plants.

Natural Gas is Affordable: Natural gas power plants have a capital cost of less than half of the cost of coal, 1/3 the cots of nuclear, and 1/5th the cost of onshore wind. Natural gas does not require subsidies unlike most renewable technologies.

Natural Gas is Reliable: In contrast to renewable technologies that in some cases may take decades of research, natural gas is readily available now from a variety of sources. Natural gas is also a reliable back-up power source for intermittent energy sources such as wind and solar which facilitates the phase-in of renewables.

Natural Gas is Efficient: Modern gas-fired power plants are 40% more efficient than coal fired power plants and require less construction time than coal or nuclear power plants.

Natural Gas is Abundant: Global production of natural gas is expected to increase in the coming decade with growing supplies coming from both conventional and unconventional resources. As will be discussed in Section 4, the significant increase in reserves and production of shale gas in recent years has led many to call shale gas an "energy game changer."

[2] International Gas Union (IGU), *Advocacy Messages for the Natural Gas Sector*, Nov. 2010,http://www.igu.org/gas-advocacy/Gas%20Advocacy%20IGU%20Presentation.pptx/view.

1.1.2. From Big Oil to Big Gas?

In addition to more focused efforts to highlight the benefits of natural gas to the public, many of the world's largest international energy companies (IOC's) are increasingly focusing their core businesses on natural gas.[3] For example, with its $40B acquisition of XTO Energy, Inc., ExxonMobil became the world's largest natural gas company in terms of reserves. While Exxon has defended its move into natural gas, some industry experts have opined that the rush to natural gas is driven largely by declining oil reserves and a shrinking access to oil fields around the world due to geopolitical reasons.[4]

Royal Dutch Shell PLC (Shell) is also betting big on natural gas with plans to make gas roughly half of its total production by 2012.[5] Shell also believes that natural gas, and LNG especially, will play critical roles in meeting global energy demand to 2050 during which time the world must reduce greenhouse-gas emissions by half.[6]

In February 2009, Woodside Petroleum, a leading Australian oil and gas company, unveiled a new corporate logo designed to place a greater emphasis on the future of its liquefied natural gas business. It was just the fourth version of Woodside's logo in the 55-year history of the company, and the first substantial change in 32 years.

According to the company, the changed logo comprised of three ellipses coming together to form a "W" and symbolize a flame, better acknowledges Woodside's emergence as a global leader in LNG and the expectation that natural gas will dominate Woodside's production portfolio going forward.[7]

The role of natural gas as an accessible, relatively inexpensive, environmentally friendly and widespread natural source of energy was outlined in a report issued in December 2010 by the European Gas Advocacy Forum. The Gas Advocacy Forum is an informal group of players from the European gas industry and includes Centrica, Eni, E. ON Ruhrgas, Gazprom Export, GDF SUEZ, Qatar Petroleum, Shell and Statoil.

According to the report, Europe can reach its climate targets of reducing CO2 emissions by 80% (compared to 1990 levels) by 2050, in a faster and more cost-efficient way if natural gas plays a

[3] *Beyond the black stuff, Big Oil is being forced to rethink its future*, The Economist, Feb. 4, 2010, http://www.economist.com/node/15473681
[4] Russell Gold and Angel Gonzalez, *Exxon Struggles To Find New Oil*, Wall St. J., Feb. 6, 2011.
[5] Nick Snow, *Half of Shell's production will be gas by 2012, CEO says*, Oil&Gas Journal (OGJ), Oct. 9, 2009, http://www.pennenergy.com/index/petroleum/display/0480477872/articles/oil-gas-journal/drilling-production-2/2009/10/half-of_shell_s_production.html
[6] Warren R. True, *Gastech: Shell sees critical roles for gas, LNG*, OGJ, Apr. 11, 2011, http://www.ogj.com/index/article-display/7479183575/articles/oil-gas-journal/volume-109/issue-15/general-interest/gastech-shell-sees-critical-roles-for-gas.html.
[7] Woodside Media Release, *New Look for Woodside*, Feb. 4, 2009, http://www.woodside.com.au/Investors-Media/Announcements/Documents/04.02.2009%20Media%20Release%20-%20New%20look%20for%20Woodside.pdf

significant part in the energy mix going forward. If Europe were to switch from coal to gas now, the reduction target can be met at a savings of 400-450 billion Euros if one compares it to the European Climate Foundation roadmap launched earlier this year. Additional cost savings for the period 2030-2050 would most likely also be achieved because natural gas in power generation requires lower investments.[8]

The universal support for natural gas by major energy companies is significant since any transformation in the energy sector is almost impossible without such support. This is primarily because most energy companies, whether multinational or national (e.g. controlled by the State) are vertically integrated. This means they actively participate along the entire supply chain from locating the natural reserves, drilling and extracting the reserves, transporting the products around the world, and then refining and distributing the final products to end users.[9] So, for example, it would be extremely difficult, absent perhaps significant government intervention, to significantly expand the use of natural gas vehicles without the support of major energy companies to help provide the huge infrastructure investments that are needed in terms of re-fueling stations.

1.1.3. Natural Gas is Still a Fossil Fuel

In a world concerned about climate change and greenhouse gas emissions, some critics of natural gas have taken the view that natural gas is yet another fossil fuel that should *not* play a major role in the world's future energy mix.

Critics of natural gas argue that increasing dependence on yet another fossil fuel doesn't really move the world towards a real renewable energy future. These critics point out that natural gas is still a fossil fuel that has some of the same negatives as coal and oil. For example, unlike renewables, natural gas is a fossil fuel resource that we may eventually exhaust. These same critics point out that the recent increase in unconventional shale gas drilling wouldn't be occurring but for the fact that the US has already exhausted its conventional gas resources. Shale gas drilling comes at its own environmental risks including potential water contamination and increased greenhouse gas emissions. In addition, while burning natural gas releases less CO_2 than coal, there are still methane emissions to consider.[10] The main fear of natural gas critics seems to be that the potential dependence on another fossil fuel, even though cleaner burning, could "doom" the world to "another few decades of fossil fuel reliance" at the sake of "making serious inroads in clean energy deployment."[11]

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[8] Jorn Madslien and Damian Kahya, *Coal-to-gas power shift 'to cut energy costs*', BBC News, Dec. 10, 2010, http://www.bbc.co.uk/news/business-11961564, *Gas Paves the Way for European Energy Savings*, Natural Gas for Europe, http://naturalgasforeurope.com/gas-paves-the-way-for-european-energy-savings.htm, *The Future Role of Natural Gas, A Position Paper by the European Gas Advocacy Forum*, http://www.gazpromexport.com/content/file/egaf/Making_the_green_journey_work_-_web_version.pdf.
[9] ExxonMobil is one of the best-known vertically integrated energy companies. See, ExxonMobil, 2010 Financial and Operating Review, http://www.exxonmobil.com/Corporate/Files/news_pubs_fo_2010.pdf.
[10] Phi Radford, *"Natural" Gas Fails the Sniff Test*, Greenpeace, June 27, 2011, http://www.greenpeace.org/usa/en/news-and-blogs/campaign-blog/natural-gas-fails-the-sniff-test/blog/35470
[11] Brian Merchant, "Incoming: A Glut of "Natural Gas is Green" Nonsense, Treehugger.com, June 9, 2011, http://www.treehugger.com/files/2011/06/incoming-glut-natural-gas-green-nonsense.php

1.1.4. Natural Gas is a "Bridge" Fuel

Some prominent groups have taken the view that at the very least, natural gas could be a "bridge fuel" to a renewable energy future. This view acknowledges that the abundance of natural gas, particularly US shale gas, creates an opportunity to utilize more natural gas to displace coal or oil thereby significantly reducing CO2 emissions.[12] Thus, so long as appropriate low-carbon policies are in place, such as a cap-and-trade system or a carbon tax, natural gas can play an important role as a bridge fuel to a renewable energy future.

In the absence of low-carbon policies, however, there is a risk that reliance on natural gas will increase overall energy consumption and displace nuclear or other renewable energy sources for power generation, which ultimately would increase CO2 emissions.[13]

Other prominent groups have focused their attention on the potential of natural gas to displace coal for power generation citing significant power plant emissions that would result. In 2010, researchers at the Massachusetts Institutes of Technology (MIT) released the results of a two-year study that analyzed the increased use of natural gas in the US as a short-term substitute for replacing aging coal-fired power plants. The report, titled "The Future of Natural Gas," acknowledged, however, that US energy and climate policy was in a state of flux and cautioned that while natural gas is often touted as a "bridge" to the future, continuing effort is needed to ensure that the bridge has a landing point – such as the expansion of nuclear power or coal power generation using carbon capture technology (CCS) to reduce emissions in the long-term. Thus, while the report found that natural gas is less carbon intensive than coal or oil, at the reduction levels required by 2050, the emissions from natural gas start to represent an emissions problem.[14]

1.2. The Global Economic Crisis and Projections for Natural Gas Leading into COP 15

In the midst of the debate over the role of natural gas in the future energy supply mix, the global economic crisis hit and between 2008 and 2009, demand for all forms of energy dropped. Demand for natural gas in particular plummeted. At the same time, however, an enormous expansion of gas supply was underway in terms of unconventional or shale gas and LNG. Also in flux was the outcome of climate change negotiations and commitments and their potential

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[12] The US based Center for American Progress offers this summary of natural gas a bridge fuel: "Natural gas is the cleanest fossil fuel – it produces less than half as much carbon pollution as coal. Recent technology advancements make affordable the development of unconventional natural gas resources. This creates an unprecedented opportunity to use gas a bridge fuel to a 21st-century energy economy that relies on efficiency, renewable sources, and low-carbon fossil fuels such as natural gas." John D. Podesta and Timothy E. Wirth, *Natural Gas, A Bridge Fuel for the 21st Century*," Center for American Progress, Aug. 10, 2009, http://www.americanprogress.org/issues/2009/08/bridge_fuel.html.

[13] Stephen P.A. Brown, Alan J. Krupnick, and Margaret A. Wallls, *Natural Gas: A Bridge to a Low-Carbon Future?* Resources for the Future/NEPI, Dec. 2009, Issue Brief 09-11, http://www.rff.org/RFF/Documents/RFF-IB-09-11.pdf.

[14] *The Future of Natural Gas*, MIT Energy Initiative (MITE), http://web.mit.edu/mitei/research/studies/report-natural-gas.pdf

impact on world energy markets. All of these issues created unprecedented uncertainty in world energy markets in the late 2000s.[15]

In the World Energy Outlook 2009, the IEA noted that the challenges were “urgent and daunting” and that how governments rise to the challenge will have “far-reaching consequences for energy markets.”[16] In particular, the IEA noted the upcoming climate change talks to be held in Copenhagen, Denmark, December 7-18, 2009 (COP15) and whether leaders would agree to a successor treaty to the Kyoto Protocol that would put the world on a sustainable energy path.[17]

In terms of demand for natural gas, the IEA noted that under any scenario, worldwide demand for natural gas was projected to grow in light of constraints at which low-carbon technologies can be deployed. The pace of that demand growth, however, “hinges critically on the strength of climate policy action.” Over the long term, the IEA projected that more stringent policy actions might favor efficiency and low-carbon technologies thereby reducing natural gas demand.[18]

As the world became mired in economic problems towards the end of 2009, it became increasingly unlikely that world leaders would reach agreement on a successor treaty to Kyoto at COP15. Ultimately, and just prior to the COP15 conference in Denmark, it was announced that "President Obama and other world leaders have decided to put off the difficult task of reaching a climate change agreement . . . agreeing instead to make it the mission of the Copenhagen conference to reach a less specific “politically binding” agreement that would punt the most difficult issues into the future."[19]

The result of COP15 was a 'political accord' known as the “Copenhagen Accord”[20] which was negotiated by only a subset of the parties, including US and China. Since this was not negotiated within the United Nations Framework Convention on Climate Change (UNFCCC)[21] process, it was only 'noted' by the COP, which left unclear which governments supported the Accord and the legal and operational significance of the Accord.[22]

Needless to say, leading into 2010, global energy markets were in a state of flux with energy and climate change policy in most countries uncertain.

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[15] IEA WEO-2009 at p. 41.
[16] IEA WEO-2009 at p. 41.
[17] IEA WEO-2009 at p. 41.
[18] IEA WEO-2009 at p. 48.
[19] Helen Cooper, *Leaders Will Delay Deal on Climate Change*, NY Times, Nov. 14, 2009, http://www.nytimes.com/2009/11/15/world/asia/15prexy.html?_r=1.
[20] The Copenhagen Accord is available on the UNFCCC website at http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=4.
[21] There is a wealth of information and publications about climate change and the climate change conferences and a detailed discussion is beyond the scope of this book. Information on the UNFCCC and the status of climate change discussions can be found at http://unfccc.int/2860.php.
[22] Jacob Werksmen, “*Associating with the Copenhagen Accord: What Does It Mean*?”, World Resources Institute, March 25, 2010, http://www.wri.org/stories/2010/03/associating-copenhagen-accord-what-does-it-mean.

1.3. Natural Gas Grows in Importance - IEA WEO 2010 New Policies Scenario

By early 2010, the world appeared to be emerging from the worst of the economic crisis and demand for energy resumed its pre-recession upward trajectory.[23] Also starting in 2010 was the growing recognition that regardless of the divergent views about natural gas, natural gas would play a greater role in the world's future energy mix for a variety of reasons including demand growth, environmental benefits over other fossil fuels, and energy security. Another reason for the growing importance of natural gas was that in the face of continuing global economic challenges, with most governments facing huge budget deficits, it seemed unlikely that governments, industry and the private sector would make the trillions of dollars in investment needed for renewables. According to the IEA, approximately $18 trillion (in year 2009 dollars) of additional spending is needed on low-carbon energy technologies.[24]

In November 2010, the IEA issued its annual World Energy Outlook (IEA WEO-2010) that explicitly highlighted the increased role that natural gas would play in the 21st century. In the WEO-2010, the IEA raised the question of "are we entering the golden age of gas?" and noted that while this may be an exaggeration, natural gas was "certainly set to play a central role in meeting the world's energy needs for at least the next two-and-a-half decades."[25]

In the WEO-2010, the IEA acknowledged at the outset that while the pace of the global economic recovery was key to energy prospects in the near term, it is how governments respond to the "twin challenges of climate change and energy security" that will shape the future of energy in the longer term.[26] The IEA went on to present several policy scenarios that differed according to the level of commitment to these challenges.[27]

The *Current Policy Scenario* assumes that no policy commitments to meet climate change goals are acted upon. The *New Policies Scenario* takes account of the broad policy commitments and plans that have been announced by countries around the world, including national pledges to reduce greenhouse gas emissions and phase out fossil-energy subsidies, and assumes that governments will actually implement the policies and measures to meet the set goals. The *450 Scenario*, which was first presented in IEA WEO-2008, sets out an energy pathway consistent with the goal of reducing greenhouse gas emissions to around 450 parts per million of CO2 equivalent (ppm CO2-eq) in order to limit global temperature increase to 2˚C.[28] For purposes of this discussion, the focus will be on the *New Policies Scenario*.

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[23] As of the date this paper was submitted to the WGC, the economic outlook for the coming years remains uncertain, amid fears of a double-dip recession and burgeoning government deficits. Despite this uncertainty, history has shown that while economic forces may lead to ups and downs in terms of energy demand, over the long-term, future energy demand is projected to grow and along with it, the role of natural gas and LNG in the global energy mix. This paper takes this long-term view.
[24] IEA WEO-2010 at pp. 379- 416.
[25] IEA WEO-2010 at p. 179-80.
[26] IEA WEO-2010 at p. 45, 78-79.
[27] IEA WEO-2010 at p. 79.
[28]IEA, Latest Information, "Prospects of limiting the global increase in temperature to 2˚ is getting bleaker," May 30, 2011, http://www.iea.org/index_info.asp?id=1959. For this reason, much of the IEAWEO-2010 is devoted to the "450 Scenario," a detailed discussion of which is beyond the scope of this book.

The IEA WEO-2010 *New Policies Scenario* was centered around several themes, each of which are discussed in detail below: world energy demand increases significantly in the coming decades under any scenario; natural gas will play a central role in meeting energy demand; and climate change emissions targets and the impact on the energy sector.[29]

1.4. World Energy Demand Grows Under Any Scenario

In the *New Policies Scenario*, the IEA assumed that world economic growth averages 3.2% per year between 2008 and 2035 with non-OECD countries showing the highest growth.[30] World primary energy demand increases by 36% between 2008-2035, or 1½% per year on average with non-OECD countries accounting for 93% or the projected increase in world primary energy demand, reflecting growth of economic activity, industrial production, population[31] and urbanization.[32]

In particular, the IEA noted that, "it is hard to overstate the growing importance of China in global energy markets."[33] In 2009, China overtook the United States to become the world's largest energy user. Between 2000-2008, China's energy consumption was more than four times greater than the prior decade and contributed to 36% of the growth in global energy use. Even greater growth is projected in the coming decades given that China's per-capita energy consumption level remains low compared to the OECD average and that China, with 1.3 billion people, is the world's most populous nation. By 2035, China accounts for 22% of world energy demand, up from 17% today.[34]

As a result of China's importance, global energy projections remain highly sensitive to the key variables that drive energy demand in China, including prospects for economic growth and developments in energy policy. This is a critical factor that will come up again in the IEA's Golden Age of Gas Report (See discussion below).

India is the second largest contributor to the increase in global energy demand to 20235, accounting for 18% of the rise. Outside of Asia, the Middle East experiences the fastest rate of increase at 2% per year. In terms of OECD countries, energy demand growth rises slowly to 2035 with the US projected to be the second-largest energy consumer with China the first and India a distant third.[35]

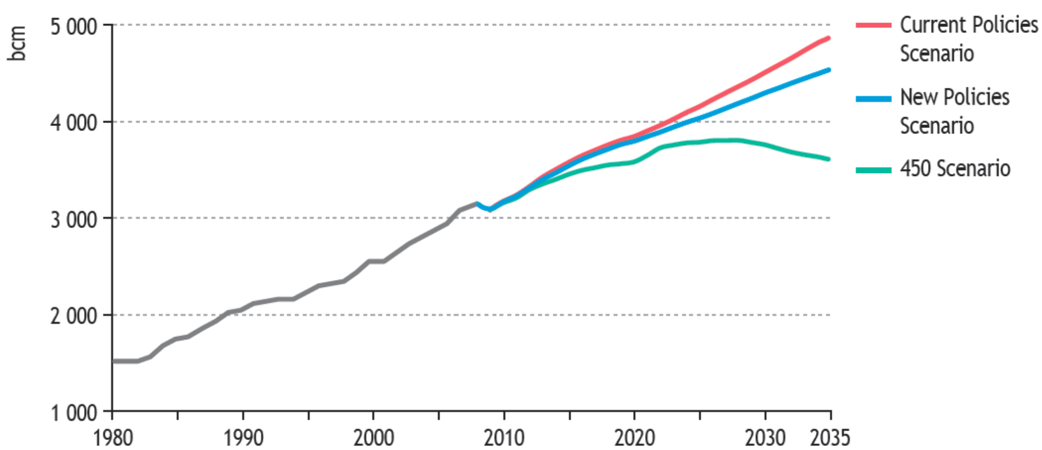
[29] IEA WEO 2010 at p. 60-62.
[30] IEA WEO 2010 at p. 68.
[31] The IEA notes that population growth is an important driver of energy use. World population is projected to grow by .9% per year on average, from an estimated 6.8 billion in 2008 to 8.5 billion in 2035. IEA WEO-2010 at p. 64.
[32] IEA WEO-2010 at p. 81-84.
[33] IEA WEO-2010 at p. 47.
[34] IEA WEO-2010 at p. 87.
[35] IEA WEO-2010 at p. 84-88.

1.5. Natural Gas Will Play A Central Role In Meeting Energy Demand to 2035

In terms of gas demand and trends, the IEA WEO-2010 *New Policies Scenario* highlighted the fact that natural gas is set to play a key role in meeting the world's growing energy needs over the 25 years.[36]

Under each of the three policy scenarios, natural gas is the only fossil fuel for which demand is higher in 2035 than in 2008, although it grows at different rates depending on the scenario. In the *New Policies Scenario*, demand reaches 4.5 trillion cubic metres (tcm) in 2035 – an increase of 1.4 tcm, or 44% over 2008 and an average rate of increase of 1.4% per year.[37]

Figure 1.1. World primary natural gas demand by scenario



Source: IEA WEO-2010, Figure 5.1, p. 180.

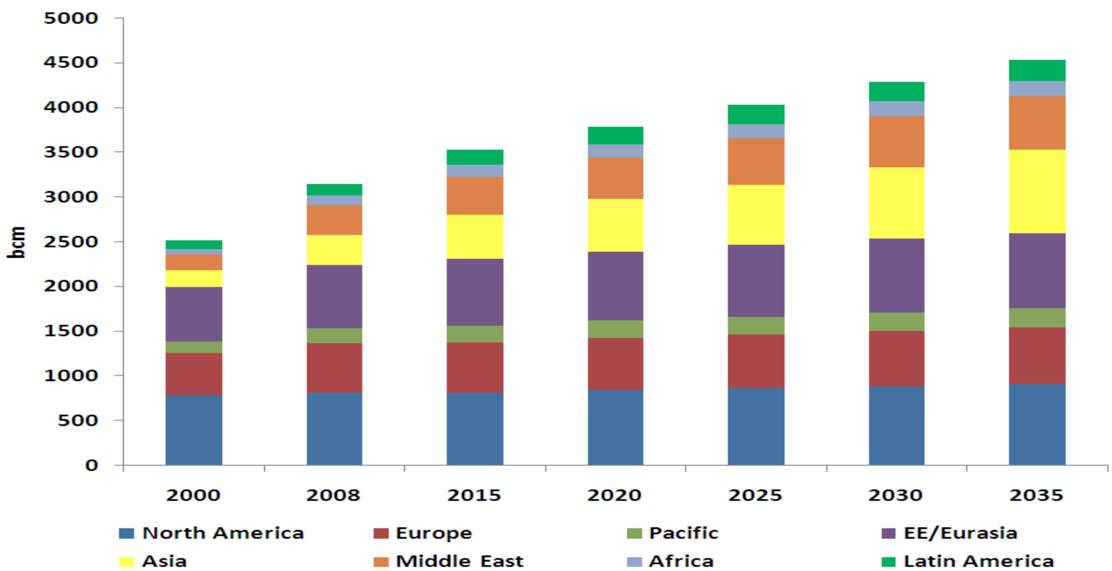
Non-OECD countries are the key drivers of demand growth and account for almost 80% of the growth in gas demand to 2035, primarily because non-OECD economies and population grow much faster and therefore require more energy use. China's demand grows the fastest at an average rate of almost 6% per year and accounts for more than 1/5th of the increase in global demand to 2035.[38] The potential for Chinese gas demand to grow even faster depending on whether coal use is retrained for environmental reasons led the IEA to note that "China could lead us into a golden age for gas."[39]

Although growth in gas demand is the highest in China, somewhat surprisingly, demand growth for natural gas in the Middle East increases almost as much as projected in China, primarily

[36] IEA WEO-2010 at p. 180.
[37] IEA WEO-2010 at p. 180.
[38] IEA WEO-2010 at p. 180-181.
[39] IEA WEO-2010 at p. 49.

driven by the power sector.[40] India is also a key source of demand growth for natural gas.[41] Growth in gas demand in OECD countries is considerably slower than in the non-OECD countries, although the US and Europe remain two of the largest users of natural gas through 2035.[42]

Figure 1.2. Gas demand grows mostly in non-OECD, mostly Asia.



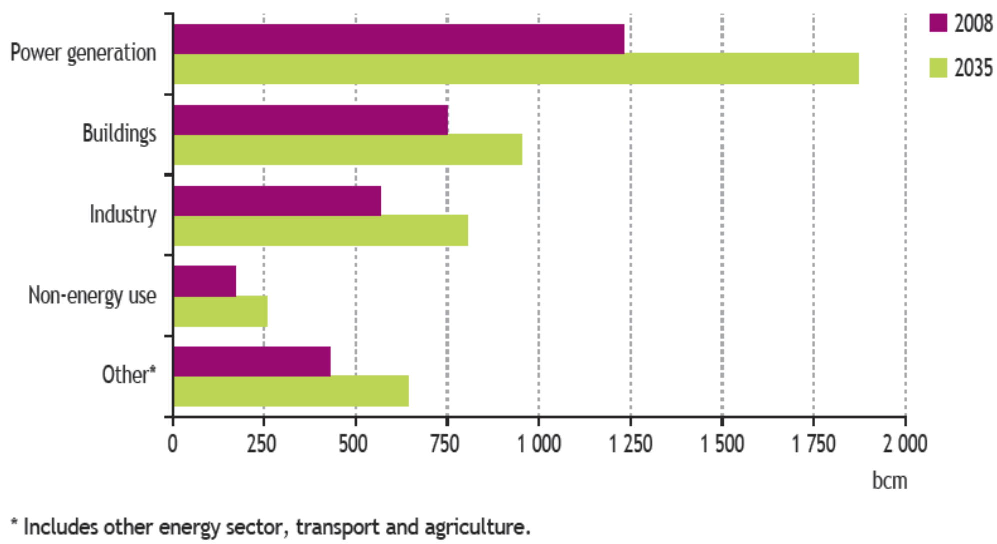
Source: IEA MTOGM 2010

1.5.1. Power Generation Drives Demand Growth

In the *New Policies Scenario*, power generation is the main driver of natural gas demand growth in most regions to 2035 and accounts for almost half of the incremental growth in demand (Figure 1.3) The IEA noted that would demand for electricity is expected to grow more strongly than any other final form of energy, growing from 2.2% per year between 2008-2035 with more than 80% of the demand occurring in non-OECD countries. In China along, electricity demand triples between 2008-2035 and over the next 15 years, China is projected to add generating capacity equivalent to the current total installed capacity of the United States.[43]

[40] IEA WEO-2010 at p. 182.
[41] IEA WEO-2010 at p. 182.
[42] IEA WEO-2010 at p. 183.
[43] IEA WEO-2010 at p. 183-84

Figure 1.3. World primary natural gas demand by sector



Source: IEA WEO-2010, Figure 5.2, p. 184.

The world is undergoing a period of profound change in the way electricity is generated as governments shift to low-carbon technologies and fuels to enhance energy security and curb emissions of CO2. Even assuming slowly rising gas prices, combined-cycle gas turbines (CCGTs) are expected to be the main choice for new power plants in many regions for several reasons. In non-OECD countries, electricity demand is rising rapidly and natural gas fired power plants are easier, less costly and quicker to build than other forms of power generation plants. In OECD countries, natural gas fired power is competitive with coal due to proposed CO2 prices and policies, which are assumed to be implemented.

Natural gas demand for power generation is lower for those countries with more support for renewables. The use of renewables, including hydro, wind, solar, geothermal, modern biomass and marine energy, triples over the period to 2035 and its share in total primary energy demand increases from 7% to 14%. Nuclear power increases from 6% in 2008 to 8% in 2035. The IEA cautioned, however, that the future of renewables hinges critically on strong government support and that the need for such support would increase if natural gas prices are lower than assumed since low natural gas prices would displace more expensive renewables.

The IEA noted that government support for renewables could be justified by the long-term economic, energy-security and environmental benefits renewable can bring but cautioned that attention needs to be given to the cost-effectiveness of support mechanisms.

1.5.2. Energy Poverty

The IEA-WEO 2010 also recognized the concept of “energy poverty” which is an emerging issue making its way through policy circles that recognizes that despite the projected increase in energy use around the world, many households in the developing world still lack access to modern energy services. The numbers are quite striking – the IEA estimates that 1.4 billion people – over 20% of the global population – still lack access to electricity and some 2.7 billion people still rely on traditional uses of biomass for cooking. The IEA notes in the New Policies Scenario that energy poverty continues to 2030 and that substantial progress is needed on improving access to energy in the coming decades.

1.5.3. Natural Gas for Transportation

In the New Policies Scenario, natural gas used in the transportation sector accounts for just 4% of additional demand during 2008-2035. Nearly all new gas consumption from natural gas used in vehicles is from compressed natural gas (CNG). Non-OECD Asia, Latin America and North America are responsible for the majority of the increase in demand. The greatest potential may be in North America due to low natural gas prices driven by increased production of shale gas. The scope of demand for natural gas in the transportation sector depends on the future market penetration of natural gas vehicles (NGVs) that today comprise a very small share of the world car fleet (less than 1%) and face significant infrastructure hurdles. The greatest potential seems to be with heavy-duty vehicles that are primarily used in fleets and thus face less infrastructure costs.[44]

1.5.4. Climate change emissions targets and the impact on the energy sector

Under the Copenhagen Accord, countries made commitments to reduce their greenhouse-gas emissions with the ultimate goal of limiting the global temperature increase to 2˚C.
In the WEO-2010, the IEA noted at the outset of its discussion of climate change and the energy sector that the commitments announced under the Copenhagen Accord collectively fall short of what would be required to put the world on a path to achieving the 2˚C goal.

Under the *New Policies Scenario*,[45] the IEA assumes that countries act upon the commitments in a cautious manner, which has some impact, but that rising demand for fossil fuels continues to drive up energy-related CO2 emissions through 2035. “Such a trend makes it all but impossible to achieve the 2˚C goal, as the required reductions in emissions after 2020 would be too steep.” Nonetheless, the emissions under the New Policies Scenario are a notable improvement from the Current Policies (e.g. no action) Scenario where emissions grow at 1.4% per year versus .7% per year under the New Policies Scenario.

Under the *New Policies Scenario* emission trends are in line with stabilizing the concentration of greenhouse gases at over 650 parts per million (ppm) or CO2-eq, resulting in a likely temperature rise of more the 3.5˚C in the long term. In order to have a reasonable chance of achieving the 2˚C goal, much more vigorous action is needed.

[44] IEA WEO-2010 at p. 186.
[45] IEA WEO-2010 at p. 95-97.

According to climate change experts, in order to achieve this goal, the concentration of greenhouse gases would need to be stabilized at a level no higher than 450 ppm CO2-eq. The IEA's *450 Scenario* describes how the energy sector could evolve to meet this target. Under this Scenario, much more ambitious targets than those announced under the Copenhagen Accord are assumed as are more rapid implementation of the removal of fossil-fuel subsidies as agreed by the G-20. These actions bring about a faster transformation of the global energy sector and a correspondingly faster slowdown in global CO2 emissions. Under the 450 Scenario, oil demand peaks before 2020 at 88 mb/d, coal demand peaks before 2020, and natural gas demand peaks before the end of the 2020s. Renewables and nuclear double their current combined share to 38% in 2035. Under the 450 Scenario, additional spending on low-carbon energy technologies (business investment and consumer spending) amounts to $18 trillion (in year 2009 dollars).[46]

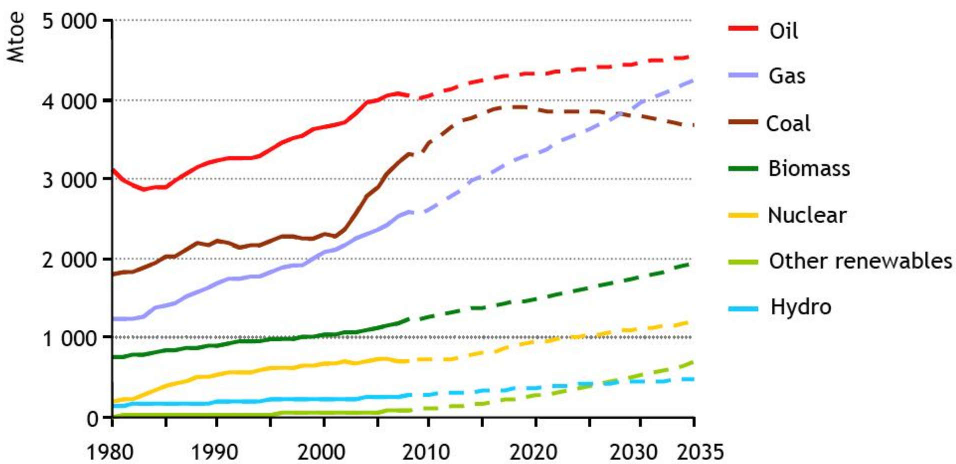
2. The Golden Age of Natural Gas

In early 2011, several significant events transpired which called into question some of the key assumptions in WEO-2010. As a result of the potential cumulative impact of these events, on June 6, 2011, the IEA released a Special Report titled "Are We Entering a Golden Age of Gas?" (IEA Golden Age Gas Report) which presents a new natural gas focused scenario (IEA GAS Scenario).[47]

The GAS Scenario takes the IEA's WEO 2010 New Policies Scenario as the starting point but incorporates recent assumptions about "policy, prices and other drivers that affect gas demand and supply prospects" over the coming decades.[48] Under the new GAS Scenario, global use of natural gas rises by more than 50% from 2010 levels with global gas demand increasing nearly 2% per year.[49] Natural gas sees the strongest demand growth of all energy sources in the GAS Scenario and overtakes coal before 2030 (see Figure 2.1) and by 2035, natural gas comprises 25% of the world's fuel mix.[50]

[46] IEA WEO-2010 at pp. 379- 416. In Chapters 13-15 of the WEO-2010, the IEA sets out in detail the climate change goals under the Copenhagen Accord as well as the IEA's 450 Scenario on what is required to achieve those goals and the implications for the energy sector. A detailed discussion of those chapters is beyond the scope of this book which focuses on the role of natural gas/LNG but the readers interested in climate change and energy are urged to review those chapters for more detail.
[47] IEA World Energy Outlook 2011, Special Report, "Are We Entering a Golden Age of Gas?" (IEA Golden Age Report), June 6, 2011, http://www.iea.org/weo/docs/weo2011/WEO2011_GoldenAgeofGasReport.pdf. (IEA Golden Age Gas Report).
[48] IEA Golden Age Gas Report at p. 14.
[49] IEA Golden Age Gas Report at p. 19.
[50] IEA Golden Age Gas Report at p. 19.

Figure 2.1. World primary energy demand by fuel in the GAS Scenario



Source: IEA Golden Age Report, ©OECD/IEA 2011, Fig. 1.1, p. 19.

As in the IEA WO-2010, the GAS Scenario highlights that the largest sector for gas demand continues to be power generation, which along with the industry sector, it experiences the largest increase compared to the New Policies Scenario.[51]

At the outset, the IEA noted that since the IEA WEO 2010 was issued, more recent developments created considerable opportunities for greater future use of natural gas globally, depending on the interaction between economic and environmental factors and various policy interventions in the market. The report analyzes the key factors that could result in a more prominent role for natural gas in the global energy mix as well as the implications for other fuels, energy security and climate change.

In the Report, the IEA indicated that several factors arose in early 2011 that point to a future in which natural gas plays a greater role in the global energy mix. These factors, which will be addressed in detail below include: (1) increased demand from China as set forth in China's 12th 5 year plan; (2) lower growth of nuclear power as a result of the March 2011 nuclear crisis at Japan's Fukushima Daiichi power plant; (3) more planned use of natural gas in transportation; and (4) continued increase of availability of gas, mainly through increased shale gas production, which lowers average gas prices.

[51] IEA Golden Age Gas Report at p. 23.

The Report strikes a cautious note about the role of natural gas to meet climate change targets and notes that although natural gas is the cleanest burning fossil fuel, an expansion of natural gas is not enough on its own to put the world on the agreed path of limited carbon emissions consistent with a temperature rise of no more than 2˚C.

2.1. Increased Demand from China – China's 12th Five-Year Plan

One of the key policy drivers noted in the GAS Scenario was China's recently announced (March 2011) 12th Five-Year Plan (FYP) for 2011-2015 which outlines a path for a more sustainable energy future, focused on energy efficiency and the use of cleaner energy sources to mitigate environmental impacts.[52] Given its enormous demand for energy, China is the most important country in shaping future energy markets and thus energy policy in China matters and can affect the trajectory of global gas demand.[53]

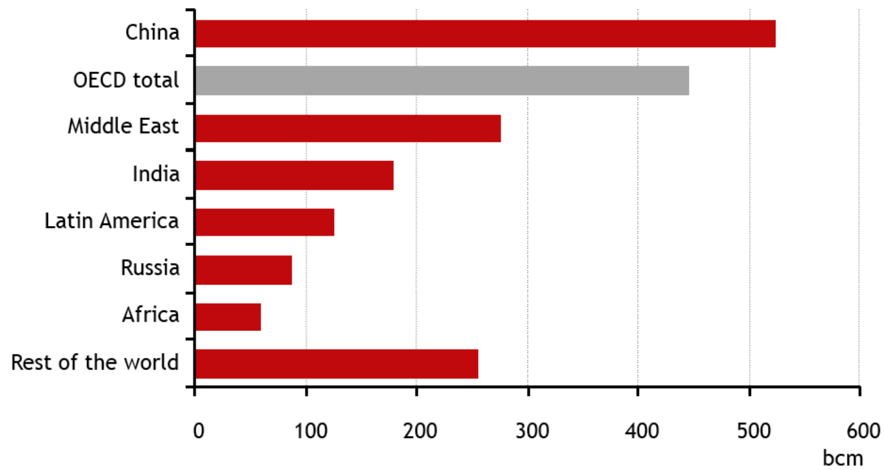
China's 12th FYP sets out targets for China's primary energy mix and has a strong focus on natural gas which is targeted to comprise an 8.3% share in primary energy mix in 2015 (260 bcm annually) – up from 85 bcm consumed in 2008 (3.8% of energy use). This is a significant upward revision from the IEA WEO-2010 New Policies Scenario in which China's demand was projected to reach 170 bcm in 2015. China is encouraging natural gas in all sectors but the near term priority is in power generation.

Other key growth regions noted in the IEA's Golden Age Scenario include the Middle East North Africa (MENA) Region which sees increase in gas demand from 300 bcm to 630 bcm by 2035. Demand for natural gas in India and Latin America also sees significant growth.

As shown in Figure 2.2, non-OECD countries account for 80% of demand growth to 2035 with China along making up nearly 30% of global growth in demand for natural gas.[54] By 2034, China will use as much natural gas as the EU.

[52] IEA Golden Age Report at p. 15.
[53] Golden Age Report, at p. 14.
[54] N. Tanaka & J. Corben, IEA Presentation to the Center for Strategic and International Studies (CSIS), June 8, 2011, available at http://csis.org/files/attachments/110608_EnergyIEAGas.pdf. (IEA CSIS, ©OECD/IEA 2011)

Figure 2.2. Increase in natural gas consumption in the GAS scenario, 2010-2035



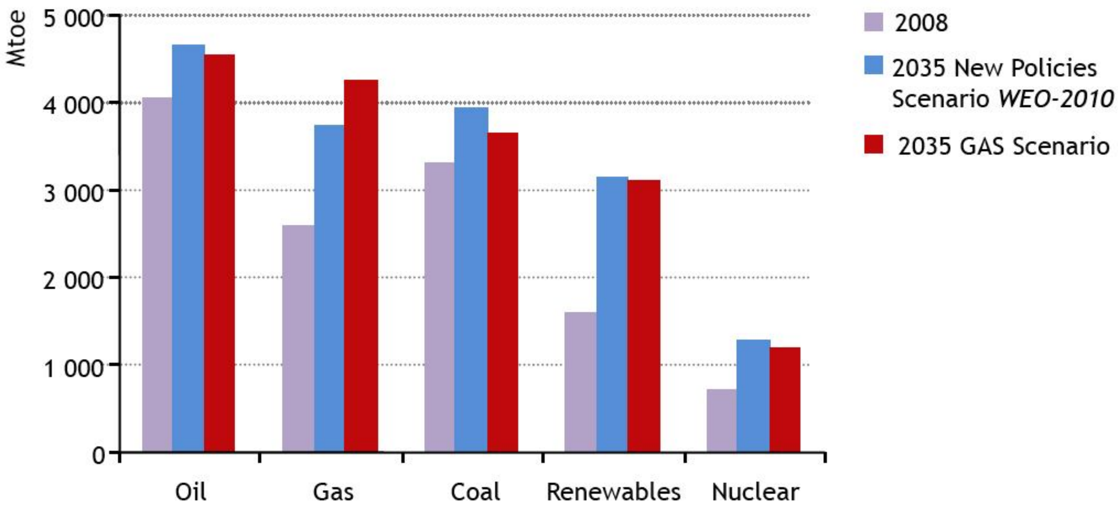
2.2. Lower Growth of Nuclear Power – Japan's Fukushima Daiichi Crisis

Another key event relevant to the IEA's GAS Scenario was the March 2011 disaster at the Fukushima Daiichi nuclear power plant in Japan.[55] As a result of that incident, many countries around the world are re-thinking, and in some cases, suspending, their nuclear programs.[56] Thus, IEA's GAS Scenario assumes that there will be lower global nuclear power generation capacity than in the WEO 2010 New Policies Scenario (see Figure 2.3).

[55] On March 11, 2011, Japanese authorities informed the International Atomic Energy Agency (IAEA) that an earthquake and tsunami had struck Japan, resulting in damage to Japan's Fukushima Daiichi nuclear power plant. Flooding caused by the tsunami disabled diesel generators intended to provide back-up electricity to the plants cooling system and Japanese officials declared a nuclear emergency situation. IAEA, "Fukushima Nuclear Accident Update Log," March 11, 2011. http://www.iaea.org/newscenter/news/2011/fukushima110311.html. As the tragedy in Japan unfolded, many countries began reviewing the safety of their own existing nuclear facilities and started to re-think previous plans for new nuclear installations.

[56] For example, on May 30, 2011, Germany announced that it would phase out all of its nuclear power plants by 2022. The announcement followed mass anti-nuclear protests in Germany in response to Japan's nuclear crisis. BBC News Europe, *Germany: Nuclear power plants to close by 2022*, May 30, 2011, http://www.bbc.co.uk/news/world-europe-13592208.

Figure 2.3. World primary energy demand by fuel and scenario



Source: IEA Golden Age Report, ©OECD/IEA 2011, Fig. 1.2, p. 20.

This lost nuclear power generation will most likely be replaced by gas-fired power generation leading to an increase in natural gas demand.[57] Japan's nuclear crisis has reverberated through the LNG market as Japan has had to import record amounts of LNG to make up for the nuclear power lost in the wake of the crisis. Japan's imports of LNG for April 2011 were 23% higher than April 2010 and many analysts assume this elevated demand will continue through 2011-2012. Analysts also assume that Japan's increased use will absorb any excess supply of LNG and may possibly even lead to a global LNG shortage which will drive up LNG prices in other markets, most notably Europe.[58]

[57] IEA Gas Scenario. The IEA has cautioned that Germany's moratorium on nuclear-power generation add around 25 million metric tons a year to the country's carbon-dioxide emissions, which will have to be offset elsewhere by replacing coal-fired power with cleaner gas-burning plants. James Herron, *IEA Warns on Impact of German Nuclear Halt*, Wall. St. J., May 27, 2011, http://online.wsj.com/article/SB10001424052702304520804576348943486991956.html

[58] James Herron, *Japan LNG imports surge, supporting global prices,* MarketWatch, May 17, 2011, http://www.marketwatch.com/story/japan-lng-imports-surge-supporting-global-prices-2011-05-17. See also, *Japan LNG Imports to Increase After Quake Hits Energy Infrastructure*, LNG World News, March 12, 2011, http://www.lngworldnews.com/japan-lng-imports-to-increase-after-quake-hits-energy-infrastructure/, *Japanese Utilities Prepare to Step Up LNG Imports to Meet Summer Electricity Demand,* IHS Global Insight, June 10, 2011,http://www.ihs.com/products/global-insight/industry-economic-report.aspx?ID=1065929775.

2.3. Natural Gas in Transportation

While no new events or policies are introduced in the GAS Scenario, the IEA nonetheless assumes that governments in some countries will encourage the greater use of natural gas vehicles than in the New Policies Scenario. The New Policies Scenario projected around 30 million NGVs by 2035, and the GAS Scenario projects around 70 million.[59]

2.4. Price and Supply of Natural Gas

In the GAS Scenario, the IEA noted that price is a key determinant of the level of future global gas demand.[60] The price assumptions for natural gas in the GAS Scenario as compared to the New Policies Scenario are markedly different (see Figure 2.4). In the GAS Scenario, the rate of increase slows around the middle of the Outlook period before accelerating again as it approaches 2035. The price path set out by the IEA reflects expectations of demand and supply but primarily represents a more optimistic assumption relating to increases in future gas supply, largely driven by availability of unconventional shale gas at relatively low cost.

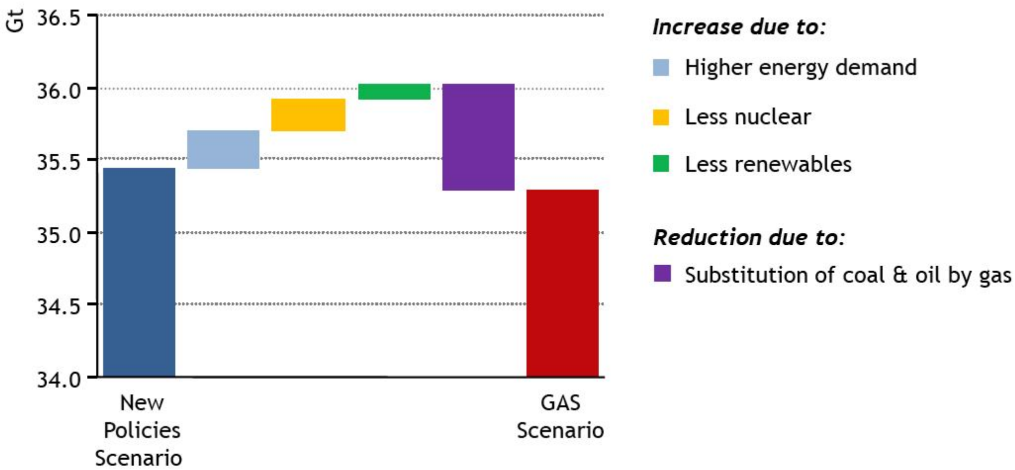
2.5. Climate Change and the Role of Natural Gas in the GAS Scenario

At the UN climate change talks in Cancun 2010, global leaders agreed to a target of limiting temperature increase to 2˚C. For this goal to be achieved, the long-term concentration of greenhouse gases in the atmosphere must be limited to around 450 parts per million of CO2-equivalent which is only a 5% increase compared to an estimated 430 parts per million in 2000.[61]

In the GAS Scenario, the IEA notes that natural gas is the cleanest burning fossil fuel and thus has emissions and environmental benefits when compared to other fossil fuels, and in particular, coal.[62] In the GAS Scenario, energy related CO2 emissions follow a similar path to that in the WEO-2010 and reach 35.3 gigatonnes (Gt) in 2035, which is just 160 million tones (Mt) lower than emissions in the New Policies Scenario in that year (see Figure 2.4).[63]

Figure 2.4. CO2 emissions in the GAS Scenario relative to New Policies Scenario 2035

[59] GAS Scenario at p. 16.
[60] IEA Golden Age Report at p. 17.
[61] IEA, Latest Information, "Prospects of limiting the global increase in temperature to 2˚ is getting bleaker," May 30, 2011, http://www.iea.org/index_info.asp?id=1959.
[62] IEA Golden Age Report at p. 9.
[63] IEA Golden Age Report at p. 37.



Source: IEA Golden Age Report, ©OECD/IEA 2011, Fig. 1.16, p. 38.

In the Golden Age Report, the IEA notes the competing interactions between natural gas emissions benefits, prices and renewables. While low natural gas prices encourage displacement of more carbon intensive fuels such as coal and oil, in the absence of a global cap on CO2 emissions, low natural gas prices may also displace more expensive low-carbon fuels such as nuclear and renewables. As a result, the IEA specifically notes that an increased share of natural gas in the global energy mix is not enough on it's own to put us on a carbon emissions path consistent with an average global temperature rise of no more than 2' C. To meet this target, we need a greater shift in low carbon energy sources, increased efficiency, and new technologies such as CCS.

The GAS Scenario assumes that governments will continue to provide regulatory and financial support for renewables (WEO-2010 estimated $57 billion of support for renewables and biofuels) but notes that "lower gas prices may put pressure on some governments to review their policies and level of support."[64] Thus, it remains to be seen whether there will be any net benefit from an increase in natural gas use over other more carbon intensive fuels such as coal and oil.

2.6. Are We Entering a Golden Age of Natural Gas?

The above sections highlight the competing interactions at work as natural gas struggles to find its role in the future energy supply mix. On the one hand, natural gas is a clean burning, flexible fuel that can be used extensively in power generation and other sectors to help reduce emissions by displacing other fuels, such as coal and oil. Natural gas resources are abundant and with the prospects of global shale gas development imply that the world will be well supplied with natural gas in the 21st century. On the other hand, the emissions benefits of natural gas, on their own, will not be enough to meet global climate change goals, especially if

[64] IEA Golden Age at p. 18.

low natural gas prices lead to displacement other cleaner fuels such as nuclear and renewables. After weighing these factors and recognizing that there are many uncertainties that may tip the scales, the IEA noted in the GAS Scenario that with natural gas demand expected to "rise by more than 50% and account for over 25% of the world demand in 2035," the Golden Age of Natural Gas is upon us.[65]

3. The Role of LNG in the Golden Age of Gas: LNG is the "Glue" Linking Global Gas Markets

The Golden Age of Gas would not be possible were it not for liquefied natural gas – LNG. Most natural gas is consumed in the same region in which it is produced due to the costs and impracticalities of transporting natural gas via pipeline over long distances. LNG is natural gas that has been cooled to approximately -161°C at which point it condenses to a liquid that occupies approximately 1/600th of the volume of natural gas thereby allowing it to be shipped via LNG tanker or stored.[66] Of primary significance is the fact that LNG provides a sea-borne solution to the impracticality of serving distant natural gas markets via pipeline or for exploiting otherwise "stranded" gas reserves.[67] Since the majority of natural gas reserves are located away from key markets, LNG offers an important solution for the global gas markets in terms of moving natural gas to markets where it is most needed.

Between 2002-2007, global LNG trade expanded by around 50%, followed by almost no growth in 2008-2009 due to upstream issues in producing countries and the fall in demand due to the global economic recession.[68] Trade in LNG resumed its upward trajectory in 2010 as the global economy showed signs it was coming out of the recession. According to recent IEA projections, international trade in natural gas is set to grow significantly in the coming decades with more than half of that growth in the form of LNG.[69] The significant increase in LNG trade, particularly between the historically distinct regions, has led many to question in recent years whether the gas markets were "globalizing?"[70] The general consensus that seems to have emerged is that while the gas markets are "globalizing," they are not yet globalized since approximately two-thirds of global gas is still consumed in the country where it is produced and because there is not a single pricing structure for LNG.[71] Nonetheless, there is widespread recognition that LNG is the "glue" linking global gas markets![72]

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[65] IEA Golden Age at p. 9. The IEA noted that the rise in natural gas demand of more than 50%, accounting for 25% of world energy demand by 2035 was "surely a prospect to designate the Golden Age of Gas." Id.
[66] The LNG value chain is a complicated series of interactions that will be discussed in detail in Chapter 3.
[67] Foss, Michelle Michot, (2007), *Introduction to LNG*, Centre for Energy Economics, University of Texas at Austin, p. 7-8, available at, www.beg.utexas.edu/energyecon/lng.
[68] IEA Medium-Term Oil and Gas Markets 2010 (MTOGM 2010), at p. 158, 168.
[69] IEA WEO-2010 at p. 192.
[70] IEA Medium-Term Oil and Gas Markets 2010 (MTOGM 2010), at p. 158, 168.
[71] IEA MTOGM 2010 at p. 158-160.
[72] IEA MTOGM 2010 at p. 158.

3.1. Safety and Environmental Sustainability of LNG

As a clean-burning fuel, many policy leaders have suggested that liquefied natural gas, LNG, can play an important role as the world struggles to meet growing energy demand using more environmentally sustainable fuels. However, others have claimed that safety issues and the environmental impact of LNG projects, including the life-cycle emissions of producing and shipping LNG, may nullify any clean-burning benefit LNG might otherwise provide.

This chapter analyzes whether LNG is a fuel for a sustainable energy future in the context of the above-mentioned issues. Over the same time period that the trade of LNG has grown, it has become increasingly clear that energy production and use will play key roles in moving toward an environmentally sustainable future.

Going forward, new projects in Australia and elsewhere will inform the debate over the environmental sustainability of LNG and there is much room for research and debate on this topic. Some of the key issues that need to be analyzed include will require a balancing of a number of factors including:

1) The environmental impact of LNG facilities;
2) Safety issues pertaining to LNG;
3) The economic benefits associated with large energy projects;
4) LNG methane and life-cycle emissions; and
5) Technological breakthroughs that are making the production and transportation LNG more efficient and sustainable.

3.1.1. Environmental Impact of LNG Facilities

The construction of LNG facilities, whether liquefaction or regasification/import terminals, gives rise to numerous potential environmental impacts. While the potential impacts and necessary regulations vary depending on the project and the country, the International Finance Corporation (IFC) has issued guidelines that are illustrative of the many issues faced by all countries when assessing the environmental impact of proposed LNG facilities. The IFC's *Environmental, Health, and Safety Guidelines for Liquefied Natural Gas (LNG) Facilities* are technical reference documents with general and industry specific examples of Good International Industry Practice (GIIP). When one or more members of the World Bank Group are involved in a project, the EHS Guidelines are applied as required by their respective policies and standards. (IFC EHS Guidelines)

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables are taken into account. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. (IFC EHS Guidelines)

The EHS Guidelines provide that the following environmental issues associated with LNG facilities should be considered as part of a comprehensive assessment and management program:

- **Threats to aquatic and shoreline environments:** Construction and maintenance dredging, disposal of dredge spoil, construction of piers, wharves, breakwaters, other structures, and erosion may lead to short and long-term impacts on aquatic and shoreline habitats. Additionally, the discharge of ballast water and sediment from ships during LNG terminal loading operations may result in the introduction of invasive aquatic species.

- **Hazardous material management:** Storage, transfer, and transport of LNG may result in leaks or accidental releases. LNG tanks and components should meet international standards for structural design integrity and operational performance avoid failures and to prevent fires.

- **Wastewater:** The guidelines provide information on wastewater management, water conservation and reuse, along with wastewater and water quality monitoring programs.

- **Air emissions:** Air emissions from LNG facilities include combustion sources for power and heat generation in addition to the use of compressors, pumps, and reciprocating engines. Emissions resulting from flaring and venting may result from activities at both LNG liquefaction and regasification terminals. Principle gases from these sources include nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2), and in cases of sour gases, sulfur dioxide (SO2).

- **Waste management:** Waste materials should be segregated into non-hazardous and hazardous wastes and a waste management plan should be developed that contains a waste tracking mechanism from the originating location to the final waste reception location.

- **Noise:** The main noise emission sources in LNG facilities include pumps, compressors, generators and drivers, compressor suction/discharge, recycle piping, air dryers, heaters, air coolers at liquefaction facilities, vaporizers used during regasification and general loading/unloading operations of LNG carriers/vessels.
- **LNG transport:** Common environmental issues related to vessels and shipping (e.g. hazardous materials management, wastewater, etc.) are covered in the EHS Guidelines for Shipping. Emissions from tugs and LNG vessels, especially where the jetty is within close proximity to the coast may represent an important source affecting air quality.

3.1.2. Is LNG Safe?

While the LNG tanker industry can claim a record of relative safety since LNG shipping began in 1959, the safety record of onshore LNG terminals is more mixed. In 1944, an accident at one of the United State’s first LNG facilities in Ohio killed 128 people and led to public fears about the safety of LNG that still persist today. While technology has made LNG facilities much safer, a January 2004 accident at Algeria’s Skikda LNG terminal has added to the ongoing controversy over LNG facility safety.

Most of the debate and concerns pertaining to the safety of LNG originates from the United States where LNG is officially classified as a hazardous material. While various experts have identified several potentially catastrophic events that could arise from an LNG release, the likelihood and severity of these events remains the subject of debate. Nonetheless, there appears to be a consensus that the greatest LNG hazards are:[73]

Pool fires: If LNG spills near an ignition source, the evaporating gas in a combustible gas-air concentration will burn above the LNG pool and the resulting "pool fire" would spread as the LNG pool expanded away from its source and continued evaporating. Many experts believe that that pool fires, especially on water, pose the greatest LNG hazard.

Flammable vapor clouds: LNG that spills without immediately igniting could from a vapor cloud that may drift some distance from the spill site. If the cloud encounters an ignition source, those portions of the cloud with a combustible gas-air concentration will burn. An LNG vapor cloud fire would gradually burn its way back to the LNG spill and continue to burn as a pool fire.

Flameless explosion: If LNG spills on water, it could theoretically heat up and regasify almost instantly in a "flameless explosion" (also called a "rapid phase transition"). The effects of tanker-scale spills have not been studied extensively however there is general believe among experts that the hazards of a flameless explosion are not as great as a pool fire or vapor cloud.

Terrorist Threats: The September 11, 2001 terrorist attacks in the United States focused more attention on the vulnerability of LNG infrastructure. A number of technical studies have been commissioned since the attacks, which has caused some controversy due to differing conclusions about the potential public hazard of LNG terminal accidents, or terror attacks. One widely cited report from Sandia National Laboratories (and sponsored by the U.S. Department of Energy) noted that more studies are needed for analyzing tanker-scale spills on waters.

3.1.3. LNG Terminal Siting in the United States

In 2003, it was anticipated that much of the growth in demand for LNG would come from the United States where LNG was expected to fill the supply gap caused by rising demand for natural gas coupled with falling indigenous natural gas reserves in the United States and Canada. Energy experts also suggested that the United States would need to rapidly invest in additional regasification terminals to accommodate the expected increase in LNG imports.[74]

In the United States, LNG projects are subject to numerous laws and regulations that are administered by a number of government agencies. As provided under the Energy Policy Act of 2005, the Federal Energy Regulatory Commission (FERC) has authority to site LNG terminals but States still retain rights to prevent or modify proposed LNG projects through the denial of permits required under the Clean Water Act, Clean Air Act, or Coastal Zone Management Act.

Despite encouragement by many energy experts and politicians, the proposed construction of new LNG import terminals in the United States generated considerable public opposition in

[73] Parfomak, Paul W., (March 25, 2008), CRS Report for Congress, Order Code RL32073, *Liquefied Natural Gas (LNG) Infrastructure Security: Issues for* Congress
[74] Yergin and Stoppard (2003), *The Next Prize*, at pp. 109-111.

many of the communities where the terminals would be built. For example, in California several proposed LNG terminals have been blocked including a proposed terminal in Northern California's Humboldt Bay, Sound Energy Solution's proposed terminal in Long Beach, California, and BHP Billiton's proposed floating LNG facility off the coast of Malibu, California.

Proposed LNG terminals on the East Coast of the United States have not fared much better and in April 2008, the New York Secretary of State rejected a proposal by Broadwater Energy to construct a floating storage and regasification unit for imported LNG in Long Island Sound. The proposed facility had been approved by FERC subject to more than 80 mitigation measures to enhance safety and security and minimize environmental impacts. More recently, plans for the proposed Weaver Cove terminal have been abandoned after years of trying to get community approval.

In summary, no LNG project has been successfully executed in the United Sates in the face of strenuous state and local opposition. In Western democracies like the United States, Canada and Australia, political and regulatory risks occur primarily in the pre-sanction phase and managing such risks can be particularly challenging, especially as environmental groups have become more proactive in mobilizing community opposition.

3.2. The Role of LNG in a Carbon Constrained World

Is LNG a contributor to a sustainable energy future? Initial analysis indicates that it may be. As the world grapples with issues related to climate change and carbon emissions, it has been widely recognized that natural gas is one of the cleanest burning fuels and produces relatively low carbon dioxide emissions. (CLNG Media Advisory) Nonetheless, there are two primary environmental considerations related to LNG. The first is the methane emissions that exist from all natural gas. The second consideration is the criticism that the energy needed to liquefy, transport, and regasify LNG (life-cycle emissions) diminishes any clean-burning benefits LNG might otherwise provide.

3.2.1. Natural Gas Methane Emissions

Although natural gas is a relatively low-carbon, clean-burning fuel, the principal component of natural gas is methane (CH_4). Methane is a potent greenhouse gas (GHG) and has 23 times the radiative forcing impact of CO_2 on a weight basis over a 100-year period. Methane, or CH_4, is the largest contributor to anthropogenic GHG emissions after carbon dioxide and accounts for about 16 per cent of the total on a CO_2 equivalent basis. This factor makes the control of CH_4 emissions an important component of any GHG emissions mitigation strategy.[75]

Methane emissions occur in all sectors of the natural gas industry, from drilling and production, through processing and transmission, to distribution. Emissions primarily result from normal operations, routine maintenance, fugitive leaks and system upsets. As gas moves through the system, emissions occur through intentional venting and unintentional leaks. Venting can occur through equipment design or operational practices, such as the continuous bleed of gas from

[75] IPIECA Workshop Report (2006) *Natural Gas as a Climate Change Solution: Breaking Down the Barriers to Methane's Expanding Role*.

pneumatic devices (that control gas flows, levels, temperatures, and pressures in the equipment), or venting from well completions during production.

In addition to vented emissions, methane losses can occur from leaks (also referred to as fugitive emissions) in all parts of the infrastructure, from connections between pipes and vessels, to valves and equipment.[76]

3.2.2. Life-Cycle Emissions of LNG

Although LNG burns cleanly, concerns have been raised that the environmental impact and emissions associated with LNG production may nullify the clean-burning benefits of LNG. To date, there is limited independent research that analyzes the environmental impact of the entire life-cycle emissions of LNG and most environmental impact statements (EIS) tend to focus on just one aspect of the LNG supply chain, e.g. the emissions associated with the liquefaction process or import regasification terminal.

One recent study has suggested that the entire supply chain emissions from production through end-use of the delivered natural gas might be quite significant and should be considered in any environmental impact report.[77]

In the Heede study, an analysis was conducted of the life-cycle emissions resulting from BHP Billiton's proposed Cabrillo LNG terminal off the coast of southern California. In it's permit application to the U.S. Coast Guard and the State of California, BHP estimated greenhouse gas emissions only from the operation of its proposed Cabrillo Deepwater Port. The Heede study was commissioned to estimate the entire life-cycle emissions of the project from the production platform offshore Western Australia and across the Pacific Ocean to Southern California, including combustion by end-users in Southern California. (Heede, 2006).

The purpose of the Heede study was not to attribute the entire supply chain emissions to BHP but rather, to fully account for all the emissions attributable to the proposed project from start to finish – production to combustion. The study ultimately found that the "supply chain emissions from production through end-use of the delivered natural gas was equal 4.3 to 4.9 percent of California's total GHG emissions, and 5.3 to 5.9 percent of CO2 emissions using EIA emissions data." (Heede, 2006).

The largest component of the supply chain emissions was the combustion of the natural gas delivered to the Southern Californian utility and it's end users. The emissions estimates for this segment ranged from 15.82 to 15.89 MtCO2-eq plus 0.58 to 0.72 MtCO2-eq of methane for an average total estimate of 16.50 MtCO2-eq per year, or 72% of the total emissions.

The most relevant findings for this paper are the emissions estimate for the processing segment and the transportation segment. The emissions estimates for the processing segment range from

[76] Natural Gas STAR Program, available at http://www.epa.gov/gasstar/.
[77] Heede, Richard (2006) *LNG Supply Chain Greenhouse Gas Emissions for the Cabrillo Deepwater Port: Natural Gas from Australia to California*, available at http://www.edcnet.org/pdf/Heede_06_LNG_GHG_Anlys.pdf.

1.97 to 3.17 MtCO2-eq for an average total of 2.69 MtCO2-eq per year, or 11.8% of the total. The emissions estimates for the transportation segment range from a low of 1.80 MtCO2-eq to a high of 2.37 MtCO2-eq for an average of 2.09 MtCO2-eq, or 9.2% of the total (Heede, 2006).

A major limitation of the Heede Study is that it is based on estimates assuming industry best practices or in some cases, improvements over standard practice or industry benchmarks. The estimates were used since the facilities had not been designed or built and Heede did not have access to BHP engineering data other than limited information in the permit application. Nonetheless, the Heede study is instructive since the life-cycle analysis was used to support strong environmental opposition to BHP's proposed LNG facility – which was ultimately denied by the State of California.[78]

3.2.3. LNG versus Coal-Fired Power Plants

In much of the world, coal is a plentiful resource and therefore is the dominant fuel source for electrical power productions. Natural gas, and LNG as a supplement to domestic natural gas supplies, is increasingly playing a larger role in electrical power generation due to the perceived emissions benefits. At least two studies have accessed the GHG emissions from LNG versus coal-fired power plants and have reached different conclusions.

A study by researchers at Carnegie Mellon found that LNG imported from foreign countries to be used for electricity generation could have 35 percent higher lifecycle greenhouse gas emissions than coal used in advanced power plant technologies.[79]

The Carnegie Mellon Study "analyzed the effects of the additional air emissions from the LNG/SNG life-cycle on the overall emissions from electricity generation in the United States." The study found that with current electricity generation technologies, natural gas life-cycle GHG emissions are generally lower than coal life-cycle emissions, even when increased LNG imports are included. However, "the range of life-cycle GHG emissions of electricity generated with LNG is significantly closer to the range of emissions from coal than the life-cycle emissions of natural gas produced in North America." The study also found that upstream GHG emissions of NG/LNG/SNG have a higher impact in the total life-cycle emissions than upstream coal emissions. (Jaramillo, 2007)

The Carnegie Mellon Study also analyzed advanced technologies and suggested that as newer generation technologies and carbon capture and sequestration (CCS) are installed, the overall life-cycle GHG emissions from electricity generated with coal, domestic natural gas, LNG or SNG could be similar. For SOx, the study found that coal and SNG would have the largest life-cycle emissions. For NOx, LNG would have the highest life-cycle emissions and would be the only

[78] Sierra Club, *Huge Victory Against Offshore LNG Terminal,* available at http://www.sierraclub.org/ca/coasts/victories/victory2007-04-19.asp. See also, Sierra Club, *Liquefied Natural Gas Threatens California's Coastal Communities*, available at http://www.sierraclub.org/ca/coasts/lng.

[79] Jaramillo, P., Griffin, W.M., Matthews, H.S. (2007) *Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation,* Environ. Sci. Technol., 41 (17), 6290-6296, available at http://pubs.acs.org/cgi-bin/abstract.cgi/esthag/2007/41/i17/abs/es063031o.html

fuel that could have higher emissions than the current average emission factor from electricity generation, even with advanced power design. (Jaramillo, 2007)

In contrast to the Carnegie Mellon Study, a study commissioned by the Center for Liquefied Natural Gas (CLNG), found that existing US domestic coal power plants produce two and a half times more emissions on a life cycle basis than that of LNG. (CLNG) LNG emissions were even lower when compared to advanced ultra supercritical coal (SCPC) power plants and integrated gasification combined cycle (IGCC) coal fired power plants (neither of which are commercially viable in the U.S.) The production and combustion emissions were greater in all of the coal cases but the processing and transportation segment emissions were greater in the LNG cases. (See Table 3.1.).

Table 3.1. Summary of CLNG Results

	Production lbs CO2e/MWh	Processing lbs CO2e/MWh	Transportation lbs CO2e/MWh	Combustion lbs CO2e/MWh	TOTAL lbsCO2e/MWh
LNG	15	134	99	797	1,045
Coal IGCC	61	24	9	1,714	1,808
Advanced Ultra SCPC	61	24	9	1,773	1,868
Existing Coal Technology	76	30	12	2,614	2,731

Source: Pace, CLNG Report, all values in lbs CO2e/MWh

3.2.4. Greenhouse Gas Emissions and New Projects in Australia

Until recently, there has been very limited public data on emissions from LNG projects. New projects in Australia should provide some of the missing information. For example, Australia is planning a massive expansion in LNG liquefaction with several major projects underway including the massive Gorgon and Wheatstone projects. These new projects are just starting to shed some light on the potential emissions from LNG projects around the world and going forward, assessing the environmental sustainability of LNG will mainly be driven by analysis of the data coming from the planned Australian LNG projects.

For example, the Wheatstone Draft EIS, which was released in July 2010, offered the following glimpse of what the emissions might be in that project as well as other LNG projects around the globe. For the Wheatstone project, it is estimated that the annual greenhouse gas emissions from the Project may increase Australia's and Western Australia's greenhouse gas emissions by 1.7% and 13.5% respectively.

The DRAFT EIS argued that this increase should be considered in the context of the impact on global emissions and referenced a WorleyParsons study commissioned by Woodside Energy to compare exports of Australian LNG versus exports of Australian black coal in terms of lifecycle emissions where the end use was for electric power generation in China. According to the WorleyParsons Study, for each megawatt hour of electricity generated in China using LNG as a fuel (imported from Australia), between 440 and 600 kg of greenhouse gases were released to the atmosphere. For each megawatt hour of electricity generated using imports of Australian black coal, the range was between 720 kg and 1010 kg, or approximately 40% higher. Thus, the Wheatstone Draft EIA suggested that exporting LNG to China was a better alternative in terms of emissions than exporting coal to China.

The Wheatstone Draft EIS also attempted to benchmark other LNG projects but acknowledged that very limited data was available. The chart below in Figure 3.1 shows the greenhouse gas emissions intensity associated with LNG processing for LNG projects currently in production as dark grey bars.

The medium grey bars show the estimated LNG processing emissions intensity for the two Australian LNG projects that are currently under construction and the light grey bars show the estimate LNG processing emissions intensity for other Australian LNG projects that are currently undergoing environmental impact assessment. The estimated LNG processing emissions intensity of the Wheatstone Project is shown in dark blue. Where data is available, the white bar shows the emission intensity of the associated gas production operations. Projects where publicly available data on gas production emissions is not available are indicated with a blue circle.

Figure 3.1. Greenhouse Gas Emissions from Major LNG Projects

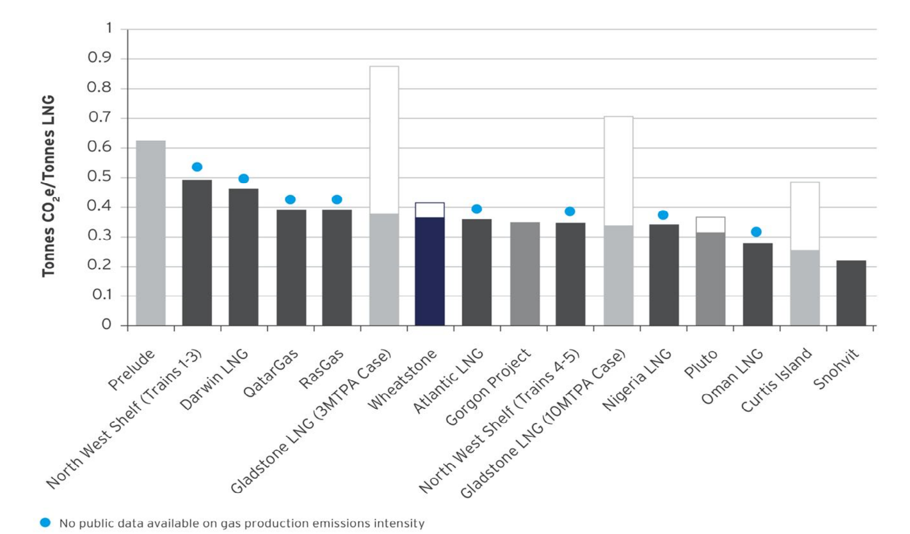

Figure 4.5: Benchmarked Greenhouse Gas Emissions Intensity

More recent articles have begun to highlight the greenhouse gas emissions from several major projects in Australia with preliminary analysis showing that as a result of the booming LNG sector, Australia's greenhouse gas emissions are "set to grow sharply."[80] While LNG is a cleaner fuel than coal, extracting, processing, chilling and then shipping LNG (life-cycle) releases large amounts of greenhouse gas emissions, particularly carbon dioxide.[81]

3.2.5. Should Emissions Be Considered On a Global or Local Basis?

In terms of countering claims that the new LNG projects planned for Australia will increase Australia's emissions, for it's part, the industry maintains that LNG can actually reduce overall emissions on a global basis with the contention that for every ton of greenhouse gas emissions generated by LNG production in Australia, between 4.5 and 9 tonnes are avoided in Asia when this gas is substituted for coal in electricity generation.[82] In support of its position, the LNG industry primarily relies on the WorleyParson's study referenced in the Wheatstone Draft EIA and most recently modified for public release in March 2011.

The study, entitled, "Greenhouse Gas Emissions Study of Australian LNG, "provides a comparison of Australian LNG versus Australian black coal in terms of lifecycle greenhouse gas emissions, which includes the entire process from extraction and processing in Australia through to an end use of combustion in China for power generation.[83]

The study found that the displacement of coal with LNG for use for power generation in China results in substantial reductions globally in greenhouse emissions, albeit at the expense of some additional Australian greenhouse emissions. According to the study, between 5.5 and 9.5 tonnes of CO_2-e are reduced globally by LNG replacement of coal for every 1 tonne of CO_2-e released in Australia in the LNG process.

While the measurement of emissions on a global basis has some merit, it is far from clear that this is the consensus view. In addition, as discussed above, the IEA's Golden Age of Gas Report indicated that absent additional actions, the world's increased use of natural gas would not result in the agreed upon reduction of greenhouse gas emissions. More recently, at an energy conference in Australia, Christof Ruhl, chief economist at BP, told the conference that although natural gas is the fastest growing fossil fuel, it is unlikely to reduce emissions enough to reduce climate change. Mr. Ruhl also noted that while the replacement of coal by gas would have some effect, it won't be enough to stave off greenhouse emissions that can cause climate change. He indicated that BP's 2030 projections indicate CO_2 emissions will continue to increase despite advancements in energy efficiency. Moreover, "The problem of energy security won't

[80] David Fogarty, *Factbox: Projected CO2 emissions from top Australia LNG projects*, Reuters, May 10, 2011, http://www.reuters.com/article/2011/05/10/us-australia-lng-carbon-fb-idUSTRE7491FU20110510.
[81] Id.
[82] Australian Petroleum Production & Exploration Association (APPEA) http://www.appea.com.au/policy/climate-change/how-gas-minimises-greenhouse-emissions.html.
[83] WorleyParsons, WOODSIDE ENERGY LIMITED GREENHOUSE GAS EMISSIONS STUDY OF AUSTRALIAN LNG, Originally prepared August 7, 2008, Modified for public release, March 2011, available at http://www.woodside.com.au/our-approach/climatechange/documents/worleyparsons%20(2008)%20greenhouse%20gas%20emissions%20study%20of%20australian%20lng.pdf.

subside—just shift," with India and China relying on imports for up to 80% of their oil consumption.[84]

3.2.6. Enhancing Environmental Sustainability in the LNG Industry

While the Australian projects offer valuable insight into LNG emissions, much more analysis is needed of those projects, as well as other new projects around the world. Looking ahead, it is important that the LNG industry continue to utilize best practices to optimize energy efficiency and reduce greenhouse gas emissions.

Although the numerous ways in which the LNG industry can enhance environmental sustainability varies project by project, in general, some of the most significant advancements can be achieved with methane mitigation and improved efficiencies in processing and transportation.

3.2.7. Australia's Proposed Carbon Tax

Throughout the world, national and regional policymakers are considering a variety of legislative and regulatory options to mitigate greenhouse gas emissions. Assessing these options requires understanding their likely effectiveness, scale, and cost, as well as their implications for economic growth and quality of life.

For its part, the Australian Government has acknowledged that the oil and gas industry is an important contributor to Australia's economy and employs about 12,000 people. LNG exports alone were valued at $7.8 billion in 2009-10 and are projected to increase to over $8.4bn in 2010-2011.[85] While recognizing the economic benefits from the energy industry, the Australian government has also been seeking to import a carbon tax on the industry in an effort to reduce emissions.

In July 2011, Australia's government unveiled its proposed plans for a carbon tax. Not surprisingly, the plans were not well received by the Australian LNG industry, which argues the tax will make the industry less internationally competitive.[86]

The plan as proposed by Prime Minister Julia Gillard's government, includes an initial carbon tax of A$23($24.74) per tonne from 2012, rising by 2.5 percent a year, moving to a market-based trading scheme in 2015. The plan could lead to the largest emissions-trading scheme outside Europe as Australia tries to cut its emissions by 159 million tonnes by 2020, or by 5 percent based on 2000 levels.[87]

Because the Australian LNG producers will receive a supplementary allocation of emissions permits for 50 percent effective assistance on the tax, many industry analysts feel the impacts

[84] Rick Wilkinson, "WorleyParsons: LNG has lower GHG-emission benefit," Oil&Gas Journal, April 21, 2011, http://www.ogj.com/articles/2011/04/worleyparsons--lng.html.
[85] Global Methane Initiative, citing Australian Bureau of Statistics, '8155.0 – Australian Industry', 2008-9.
[86] Rebekah Kebede, "Q+A-Australia's carbon tax and the LNG industry," Reuters, July 11, 2011, http://uk.reuters.com/article/2011/07/11/carbon-tax-lng-idUKL3E7IB1CY20110711
[87] Id.

will be minor to moderate. Moreover, since the bulk of the costs for an LNG project are capital expenditures, the carbon tax may end up being a significant part of the operating cost, but a relatively small portion of the overall project costs. Nonetheless, there is some concern that the tax will add yet one more additional cost to projects that are already considered to be some of the world's most costly and have gained a reputation for running over budget. Although the carbon tax may erode the profit margins of some LNG projects, so far it appears that no major Australian project will become uneconomic as a result of the tax.[88]

The Australian Petroleum Production & Exploration Association (APPEA) has opposed the tax claiming that the proposal does not do enough protect the competitiveness of Australia's growing LNG industry. The industry also rejects the claims that it is “the ‘big polluter’ when for every tonne of emissions produced in liquefying natural gas, up to 9.5 tonnes are removed from the atmosphere when substituted for coal in customer countries.” The industry also maintains that the carbon tax proposal would give Australia's competitors in LNG production-- Qatar, Malaysia, and Indonesia-- an edge over Australia, which is already suffering from a high cost environment.[89]

At this stage, it appears the proposed tax scheme will impact each project differently since carbon emissions vary for each project. For example, some projects in the Browse Basin off Western Australia have as much as 10 percent carbon dioxide by volume, which is extracted at the same time as the gas. Coal seam gas projects in Australia's eastern state of Queensland may produce more greenhouse gas due to the amount of energy required to extract the gas. In addition, some LNG trains are more energy and carbon-efficient than others. Yet another difference is that some projects are limiting or offsetting carbon emissions. For example, Chevron plans to sequester some of the carbon it emits at its Gorgon projects, while Woodside's Pluto LNG will be offsetting its carbon emissions over 50 years by planting millions of trees at a cost of A$100 million.[90]

While the impact of Australia’s proposed carbon tax will require closer analysis as more details are worked out, at lease one analyst has said that for the moment, the carbon tax is less of a worry than current labor shortages in Australia.[91]

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[88] Id.

[89] Id.

[90] Id.

[91] Myles Morgan, “Labour shortage tops gas industry carbon tax fears,” ABC News Australia, October 07, 2011, http://www.abc.net.au/news/2011-10-07/20111007-lng-conference-carbon-tax/3347750. Poten and Partners representative Stephen Thompson told a South-East Asia Australia Offshore petroleum industry conference in Darwin that "The shortage of labour and how to get enough people to do all of the projects Australia is currently embarked on is probably the most significant problem people have in mind." However, the conference expressed concerns that the carbon tax would hurt Australia’s thriving LNG export business.

4. Is Shale Gas A Global Energy "Game Changer"?

One of the most promising recent developments in the energy sector has been the dramatic increase in the production of natural gas from shale formations, or shale gas.[92] Although experts have known for years about the vast deposits of shale gas found throughout the world, technological difficulties and the high costs of producing shale gas made it impractical to consider as a serious energy source.[93] However, recent technological innovations combining hydraulic fracturing and horizontal drilling technologies[94] has resulted in a tremendous boom in shale gas production in the United States over the past five years.[95] This boom seems likely to continue with leading energy experts proclaiming shale gas an energy "game changer" that will "revolutionize" global gas markets and help bridge the gap between conventional resources and the development of renewable energy sources.[96]

Thus far, the United States has been the undisputed leader in unlocking the vast tracts of gas-bearing shale found throughout the lower forty-eight states, but Canada is also emerging as a potential major source of shale gas.[97] However, the so-called "shale gale" is not limited to North America.[98] Since shale formations exist in almost every region of the world, the potential for shale gas development is enormous and global in scope.[99]

Since the hydraulic fracturing is an essential part of developing global shale gas resources,[100] it is imperative that the industry ensures that the process is safe and environmentally sound

[92] *See Facts about Shale*, AM. PETROLEUM INST., http://www.api.org/policy/exploration/hydraulicfracturing/shale_gas.cfm (last visited Apr. 5, 2011).
[93] *See* HALLIBURTON, U.S. SHALE GAS: AN UNCONVENTIONAL RESOURCE, UNCONVENTIONAL CHALLENGES 1 (2008) http://www.halliburton.com/public/solutions/contents/Shale/related_docs/H063771.pdf.
[94] The hydraulic fracturing technology has been so successful that energy experts have called this the "most significant energy innovation so far of this century." Mary Lashley Barcella & David Hobbs, *Fueling North America's Energy Future*, WALL ST. J., Mar. 10, 2010, at A10.
[95] *See Hydraulic Fracturing*, AM. PETROLEUM INST., http://www.api.org/policy/exploration/hydraulicfracturing (last visited Apr. 5, 2011); *see also Advanced Drilling Techniques*, AM. PETROLEUM INST., http://www.api.org/aboutoilgas/natgas/drilling_techniques.cfm (last visited Apr. 5, 2011) (explaining "horizontal drilling" techniques).
[96] *See* Tom Fowler, Energy *Game-Changer?*, HOUS. CHRON., Nov. 1, 2009, at A1.
[97] *See generally Facts about Shale*, *supra* note 1; *see also What is the Current Status of Shale Gas in Canada*?, CAN. SOC'Y FOR UNCONVENTIONAL GAS, http://www.csug.ca/index.php?option=com_content&task=view&id=60&Itemid=66#shale_state (last visited Apr. 5, 2011).
[98] Barcella & Hobbs, *supra* note 4, at A10; *see also* Luis E. Cuervo, *OPEC from Myth to Reality*, 30 HOUS. J. INT'L L. 433, 454 (2008) ("The petroleum industry in the 21st century will focus on production of oil and gas from unconventional sources such as heavy oils, tar sands, oil shale, renewables, nuclear power, biomass, and clean coal technologies such as coal liquefaction in a potential transition into a hydrogen based economy.").
[99] *See* Leta Smith & Peter Jackson, *Is Unconventional Gas Going Global?*, WALL ST. J., Mar. 10, 2010, at A14, *available at* www2.cera.com/ceraweek2010/NAm2010-03-10.pdf. A new EIA sponsored study on global shale gas resources reports an initial assessment "of 5,760 trillion cubic feet (Tcf) of technically recoverable shale gas resources in 32 foreign countries, compared with 862 Tcf in the United States." Today in Energy, "Shale gas is a global phenomenon," US. Energy Info. Admin. (2011), http://www.eia.doe.gov/todayinenergy/detail.cfm?id=811.
[100] *See* HALLIBURTON, *supra* note 2, at 1; *see also Hydraulic Fracturing*, *supra* note 3.

before applying the technology to more areas of the world.[101] In the United States, numerous concerns have been raised about the potential environmental impacts of hydraulic fracturing with a particular focus on the injection of hydraulic fracturing fluids in wells located near drinking water sources,[102] the quantity of water used in the hydraulic fracturing process, and the disposal of the waste or flowback water.[103] Since similar concerns have been raised in many regions of the world, the U.S. response to these concerns is being closely watched and a well-crafted regulatory regime could serve as a model for foreign countries looking to responsibly develop their shale gas resources.[104]

So far, the U.S. Congress has introduced legislation known as the "FRAC Act" that, if passed, will place stricter regulations on the shale gas industry.[105] Additionally, in March of 2010, the U.S. Environmental Protection Agency (EPA) announced that it would conduct a comprehensive research study to investigate the potential adverse impacts that hydraulic fracturing may have on water quality and public health.[106] In the meantime, however, the hydraulic fracturing process continues to draw criticism from environmentalists.[107]

Although the U.S. regulatory and EPA investigative process will take some time, the U.S. has nonetheless sought to take the lead in helping other countries find the right balance between energy security and environmental concerns through the Global Shale Gas Initiative (GSGI).[108] The United States launched the GSGI in April 2010 as part of an effort to "promote global energy security and climate security around the world."[109] Recognizing that shale gas has been a "terrific boon" that many countries would want to replicate, the GSGI seeks to share information about the "umbrella of laws and regulations" that exist in the United States.[110] This intricate set of federal and state laws and regulations helps ensure shale gas development is "done safely and efficiently."[111] Whether or not the US will be the role model for global shale gas development remains to be seen due to the significant differences that exist between US

[101] *See* Hannah Wiseman, *Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation*, 20 FORDHAM ENVTL. L. REV. 115, 116 (2009).
[102] *See generally* ENVTL. PROT. AGENCY, HYDRAULIC FRACTURING RESEARCH STUDY (2010) http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf [hereinafter HYDRAULIC FRACTURING RESEARCH STUDY].
[103] *See id.*
[104] *See, e.g.*, Adam J. Bailey, Comment, *The Fayetteville Shale Play and the Need to Rethink Environmental Regulation of Oil and Gas Development in Arkansas*, 63 ARK. L. REV. 815, 843 (2010) ("[U]ltimately Arkansas should revamp its system into a model for other states to follow.").
[105] *See, e.g.*, S.1215, 111th Cong. (2009); H.R. 2766, 111th Cong. (2009) The FRAC Act did not reach the floor during the 111th Session of Congress and has been re-introduced in the 112th Session of Congress as S. 587, 112th Cong. (2011); H.R. 1084, 112th Cong. (2011).
[106] HYDRAULIC FRACTURING RESEARCH STUDY, *supra* note 11.
[107] Christoper Swann, *Shale Gas Needs to Allay Environmental Doubts*, N.Y. TIMES, Mar. 7, 2011, at B2.
[108] David L. Goldwyn, Special Envoy for Int'l Energy Affairs, U.S. Dep't of State, Briefing on the Global Shale Gas Initiative Conference (Aug. 24, 2010), *available at* http://www.state.gov/s/ciea/rmk/146249.htm [hereinafter Briefing on GSGI Conference]; s*ee also* David L. Goldwyn, *Global Shale Gas Initiative: Balancing Energy, Security, and Environmental Concerns*, DIPNOTE (Sept. 3, 2010), http://blogs.state.gov/index.php/site [hereinafter *GSGI: Balancing Concerns*].
[109] Briefing on GSGI Conference, *supra* note 17.
[110] Briefing on GSGI Conference, *supra* note 17.
[111] *Id.*

shale gas development and shale gas development in other regions of the world.[112]

In order to appreciate the significance of shale gas as an "energy game changer" that could dramatically impact global energy supplies, energy security, climate change mitigation, geopolitics, and the global gas markets overall, the following sections provide some important background on the opportunities and challenges for global shale gas development.

4.1. Shale Gas Development and Resources in the United States

Over the past decade, natural gas production from unconventional gas resources has increased significantly with production from shale gas formations rising almost 65 percent from 2007 to 2008 alone.[113] This rapid development of unconventional gas resources, particularly North American shale gas, has dramatically transformed the global gas markets and led many experts to proclaim shale gas an energy "game-changer."[114]

The game-changing nature of shale gas in North America is not just due to increased production but also due to significant increases in the estimated natural gas resource base. An influential study done in 2008 estimated that North America has 2,247 Tcf of natural gas resources, which is "about 100 years of production at current levels."[115] In June 2009, the Potential Gas Committee established by the University of Colorado School of Mines estimated the U.S. natural gas resource base at 2,074 Tcf, the highest estimate ever released by that group.[116]

In it's most recent Annual Energy Outlook (AEO), the US Energy Information Agency (EIA), the estimate for technically recoverable unproved shale gas resources in the is 827 Tcf, although this number may change as more information becomes available from developing shale plays.[117]

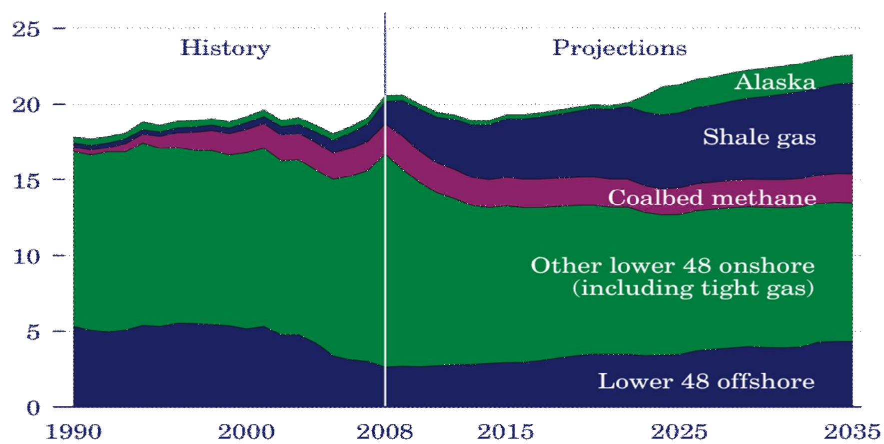
More recently, the US EIA has noted that there is uncertainty regarding the ultimate size of technically recoverable shale gas due to a number of factors. First, because many shale gas wells are only a few years old, their long-term productivity is untested and consequently, the long-term production profiles of shale wells and their estimated ultimate recovery of oil and

[112] Susan L. Sakmar, THE GLOBAL SHALE GAS INITIATIVE: WILL THE UNITED STATES BE THE ROLE MODEL FOR THE DEVELOPMENT OF SHALE GAS AROUND THE WORLD?, Houston Journal of International Law (Vol. 33, No. 2), Spring 2011, available at http://ssrn.com/abstract=1927593.
[113] American Clean Skies Foundation, http://www.cleanskies.org/resources-supply.html.
[114] Press Release, Int'l Energy Agency, The Time Has Come to Make the Hard Choices Needed to Combat Climate Change and Enhance Global Energy Security, Says the Latest IEA *World Energy Outlook* (Nov. 10, 2009), http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=294**.** *See also* Amy Myers Jaffe, *Shale Gas Will Rock the* World, WALL ST. J., May 10, 2010, *available at* http://online.wsj.com/article/SB10001424052702303491304575187880596301668.html; Fowler, *supra* note 5.
[115] Id., citing the July 2008 study, "North American Natural Gas Supply Assessment," done by Navigant Consulting.
[116] POTENTIAL GAS COMMITTEE REPORTS UNPRECEDENTED INCREASE IN MAGNITUDE OF U.S. NATURAL GAS RESOURCE BASE, June 18, 2009, available at http://www.mines.edu/Potential-Gas-Committee-reports-unprecedented-increase-in-magnitude-of-U.S.-natural-gas-resource-base.
[117] United States Energy Information Agency, Annual Energy Outlook 2011, (US EIA AEO 2011), available at http://www.eia.gov/forecasts/aeo/pdf/0383(2011).pdf.

natural gas are uncertain. Second, in emerging shale plays, production has been confined largely to those areas known as "sweet spots" that have the highest known production rates for the play. If the production rates for the sweet spots are used to infer the productive potential of entire plays, their productive potential probably will be overstated. Third, many shale plays are so large (e.g., the Marcellus shale) that only portions have been extensively production tested. Fourth, technical advancements could lead to more productive and less costly well drilling and completion. And lastly, currently untested shale plays, such as thin-seam plays or untested portions of existing plays, could prove to be highly productive.[118] As a result of these factors, estimating the technically recoverable shale gas resource base in the United States is an evolving process that is likely to continue for some time. Nonetheless, it appears for the moment that as more production information becomes known, the resource base in the US continues to grow.

The production of shale gas has expanded particularly rapidly in the United States.[119] According to the U.S. Energy Information Administration (EIA), during the last decade U.S. shale gas production increased eight-fold and now accounts for ten percent of U.S. gas production and twenty percent of total remaining recoverable gas resources in the United States.[120] According to the EIA, shale gas represents the largest source of growth in the U.S. natural gas production for the coming decades.[121]

Figure 4.1. Natural gas production by source, 1990–2035 (TCF)[122]



[118] US EIA, "Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays", Release date: July 8, 2011, available at http://www.eia.gov/analysis/studies/usshalegas/

[119] *Global Shale Gas Initiative (GSGI)*, U.S. DEP'T OF STATE, http://www.state.gov/s/ciea/gsgi/index.htm (last visited Apr. 5, 2011).

[120] *Id.*

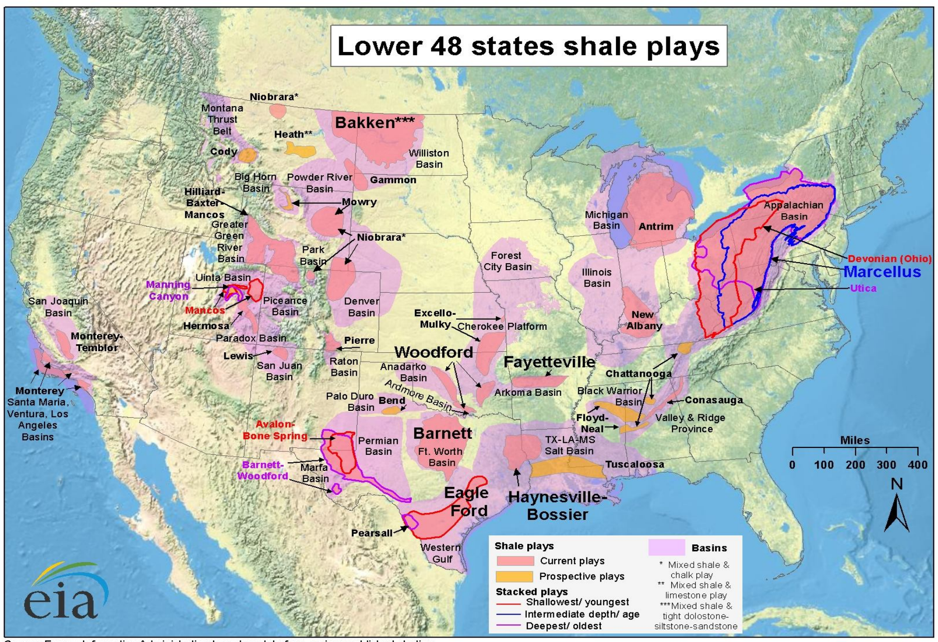
[121] *See infra* Figure 3.

[122] U.S. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2010, 72 Figure 73 (2010), *available at* http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2010).pdf.

The tremendous growth in U.S. shale gas production seems likely to continue with the EIA recently stating that the "development of shale gas plays has become a 'game changer' for the U.S. natural gas market" with estimates of technically recoverable U.S. shale gas resources increasing to 862 Tcf.[123]

In the United States, shale gas exists in most of the lower forty-eight states.[124] The most active shale basins to date are the Barnett Shale, the Haynesville/Bossier Shale, the Antrim Shale, the Fayetteville Shale, the Marcellus Shale, the Eagle Ford, and the New Albany Shale.[125]

Figure 4.2. Map of U.S. Shale Basins[126]



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

4.2. Shale Gas Development and Resources in the Rest of the World

The shale gas "revolution" that is transforming the North American natural gas market is not just limited to that region.[127] It has been widely recognized that there is enormous unconventional gas potential in other parts of the world.[128] As in the United States, shale gas appears to be the most promising type of unconventional gas around the world, but some countries are also

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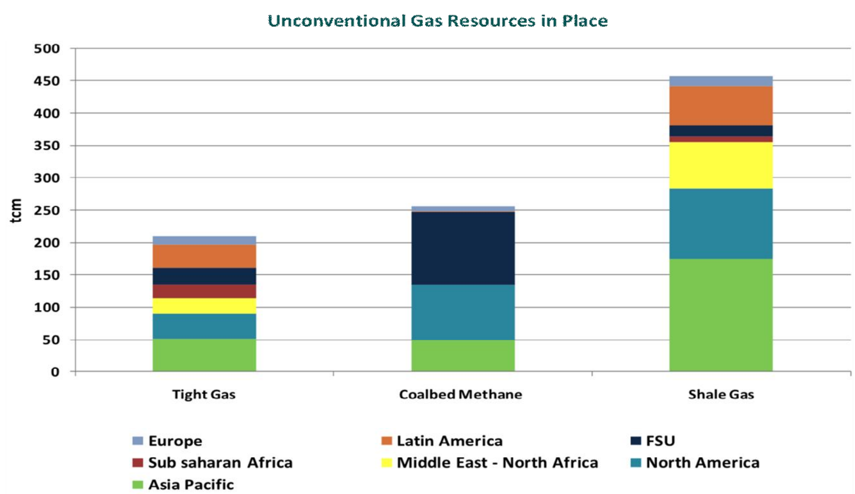
[123] EIA "World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States," http://www.eia.gov/analysis/studies/worldshalegas, citing, EIA Annual Energy Outlook 2011.
[124] *Infra* Figure 4.
[125] GROUND WATER PROT. COUNCIL, *supra* note 21, at ES-2.
[126] *See generally Shale Gas Plays, Lower 48 States*, U.S. ENERGY INFO. ADMIN., http://www.eia.doe.gov/oil_gas/rpd/shale_gas.pdf. (depicting the U.S. Shale Basins).
[127] Smith & Jackson, *supra* note 8.
[128] *Id.*

developing tight gas and CBM.[129] There are many challenges to the development of all three types of unconventional gas outside the United States, but the primary challenge so far is estimating the potential resource base.[130] According to the International Energy Agency (IEA), there are only limited studies estimating global unconventional gas resources and "major work is still needed to refine and expand [the] data."[131] With few exceptions, unconventional gas resources around the world have "largely been overlooked and understudied" and most "have not been appraised in any systematic way."[132]

In terms of existing regional estimates of global unconventional gas potential, Asia Pacific and North America have the highest, "with 274 TCM and 233 TCM respectively followed by [the former Soviet Union] with 155 TCM, Latin America [with] 98 TCM and [the Middle East-North Africa region with] 95 TCM."[133] Though significant attention has been devoted to Europe's potential unconventional gas resources, so far, they are estimated at only 35 TCM.[134] The IEA notes that "shale gas represents half of this global potential and is especially present in Asia and North America while CBM is mainly in [the former Soviet Union] and tight gas is quite evenly distributed between the regions."[135] The agency indicates these numbers "should be considered with caution" as not all of this gas will be recoverable.[136]

Figure 4.3. Worldwide Unconventional Gas Resources in Place[137]



Source: World Energy Outlook 2009, IEA.

[129] *Id.*
[130] *See* INT'L ENERGY AGENCY, MEDIUM-TERM OIL & GAS MARKETS 185 (2010) [hereinafter MTOGM].
[131] *Id.*
[132] *Id.* at 186.
[133] *Id.* at 185; *see* Susan L. Sakmar, *The Status of the Draft Iraq Oil and Gas Law*; 30 HOUS. J. INT'L L. 289, 295 n.35 (2008) (noting Iraq's "fairly significant gas reserves"), available at SSRN: http://ssrn.com/abstract=1931874.
[134] MTOGM, *supra* note 100, at 185.
[135] *Id.*
[136] *Id.* The IEA has estimated that "around 380 tcm would be recoverable based on current data and knowledge." *Id.* at 186.
[137] *Id.* at 185.

In terms of country-specific developments, Australia ranks first among the countries able to develop its unconventional gas resources in the short-term.[138] CBM has been at the "mature market stage in Australia for some time, but shale gas is still in its infancy."[139]

China has potentially significant unconventional gas resources and has expressed considerable interest in developing these. Historically China's focus has been on CBM, but recently its focus has shifted towards developing their shale gas resources. Although these are estimated at 26 TCM, the country has never appraised its shale gas reserves but is expected to do so in the near future.[140] China's Ministry of Land and Resources (MLR) "has announced a strategic goal of reaching a production target of 15–30 bcm (billion cubic meters) by 2020."[141] In this regard, it will be critical for China to acquire technology to meet these production goals. China's Sinopec has already engaged in dialogue with international oil companies in furtherance of this goal. In November 2009, China and the United States signed a Memorandum of Understanding to jointly cooperate in assessing China's shale gas resources and, consequently, promote investments in this area.[142]

Similar to China, India has historically focused on CBM but is now turning to shale gas, which is rapidly gaining the attention of industry players.[143] In April 2010, India's Reliance Industries Ltd. invested $1.7 billion in the U.S. Marcellus shale play. This was viewed as an indication that Indian companies are looking to acquire expertise and technology to develop shale gas resources, both at home and abroad.[144] The two major obstacles for India are a lack of clarity regarding upstream regulation for shale gas and a lack of data as most of India's shale gas potential remains underexplored.

Compared to Australia and India, Indonesia has been slow to develop its unconventional gas resources and foreign companies have been reluctant to invest there largely because of the legal and regulatory uncertainty.[145] Indonesia's outlook may change, however, in light of its estimated shale gas potential of approximately 30 TCM and its plans to launch a tender of shale gas fields.[146]

Europe has received the most attention with many countries in the region looking to replicate the U.S. shale gas revolution. While there are "many challenges that could prevent an unconventional gas boom happening in Europe," recently, there has been a lot of activity and interest in shale gas in Austria, Bulgaria, France, Germany, Italy, Poland, Romania, Spain, Sweden, and the United Kingdom. International oil companies, which were largely absent from early shale gas development in the United State's, have been more proactive in Europe. Many major oil companies, including ExxonMobil, Shell, Chevron, ConocoPhillips marathon, and Total

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[138] *Id.* at 187.
[139] *Id.* at 188.
[140] *Id.* at 188–89.
[141] *Id.* at 189.
[142] *Id.* at 188.
[143] *Id.* at 189.
[144] *Id.*
[145] *Id.* at 190.
[146] *Id.*

are present in one or more European countries.[147]

Figure 4.4. Unconventional Gas Activities in Europe[148]

Unconventional Gas Activities in Europe

	CBM	Tight gas	Shale
Austria			OMV
Belgium	European Gas, Transcor Astra Group		
Bulgaria	CBM Energy		
France	European Gas Ltd		Total, Egdon Resources, Mouvoil, Schueppbach Energy LLC, Dale Gas Partners, Eagle Energy Ltd, Bridgeoil Ltd., Diamoco Energy
Germany	Exxon Mobil	Wintershall	ExxonMobil,
Hungary		MOL, Falcon, Exxon Mobil	Exxon Mobil
Italy	Ind. Resources plc		
Poland	Composite Energy, EurEnergy	Aurelian	ExxonMobil, ConocoPhilips, Lane Energy, Talisman, Chevron, Aurelian, FX Energy
		FX Energy	
Romania	Falcon, Galaxy		Aurelian, FX Energy
Sweden			Shell
UK	Island gas, Composite Energy		
	BG, Nexen, Marathon		
Turkey			TransAtlantic Petroleum, TPAO

Preliminary work, exploration, assessment of seismic data
Wells drilled
Production

Note: the list of companies is not exhaustive.
Source: IEA, based on press releases, news reports.

In most European countries, most of these developments are at the very early stages and seismic data is just barely being compiled.[149] The IEA notes that "only a few European countries are actually producing unconventional gas, and then only in small quantities."[150] Of these, Poland is worth noting as shale gas has received significant attention in that country.[151] In its report, the IEA also notes that, "Poland has approved approximately 45 exploration licenses for shale gas [and] ExxonMobil has five concessions in the Podlasie and Lublin basins representing 1.3 million acres."[152] According to estimates by Wood Mackenzie, an oil and gas research

[147] *Id.* at 190–91.
[148] *Id.* at 191.
[149] *Id.* at 190.
[150] *Id.*
[151] *Id.* at 191.
[152] *Id.*

group, Poland's unconventional gas reserves could be as high as 48 TCF.[153] If confirmed, this would significantly increase "the European Union's proven reserves of natural gas and . . . make Poland, which imports 72 per cent of its gas, self-sufficient for the foreseeable future."[154] Significant shale gas production in Poland could also alter the gas geopolitics for the entire European region, which has historically been dependent on Russian supplies of natural gas.[155] In light of this, there "is a land grab under way"[156] in Poland with several major energy companies investing in nascent shale gas industry including Chevron, ConocoPhillips, and Canadian-based Talisman.[157]

France, Germany, and Hungary are also just emerging as potential shale gas players while other countries are starting to assess their potential reserves.[158] The IEA notes that, "many initiatives are underway such as the Gas Shales in Europe ('GASH'), coordinated by the German GeoForschungsZentrum (GFZ) and The Institut Français du Pétrole (IFP). In other regions, [international oil companies (IOCs)] and National Oil Companies (NOCs) have been carrying out exploratory work [on unconventional resources,]" yet the results remain to be seen.[159]

While assessments are underway in Europe, the US EIA recently released a study commissioned by an external consultant to assess the potential of international shale gas resources. [160] The report assessed 48 shale basins in 32 countries containing almost 70 shale gas formations. Figure 4.5. shows in red the location of assessed shale gas basins for which estimates of the risked gas in place and technically recoverable resources were provided.

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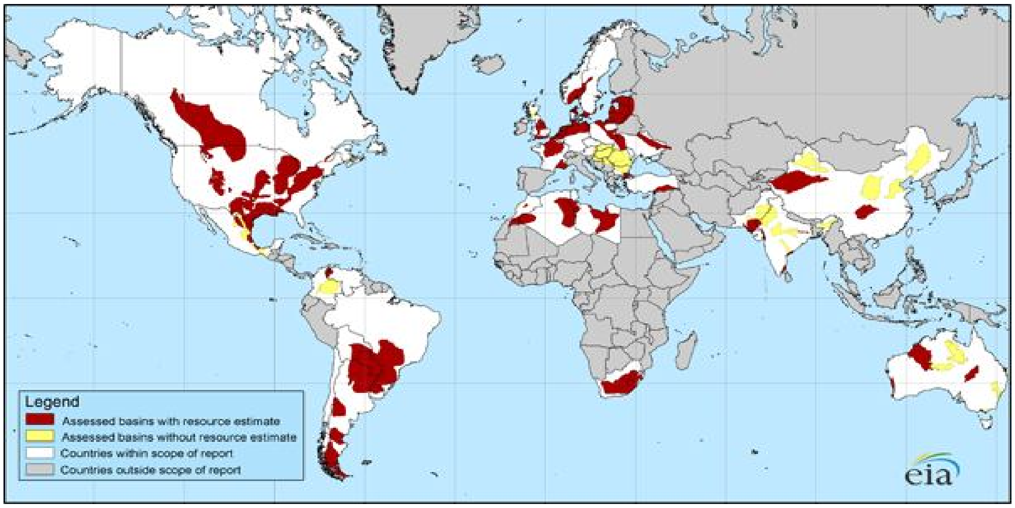
[153] Robin Pagnamenta, *Dash for Poland's Gas Could End Russian Stranglehold on Supplies*, TIMES (London), Apr. 5, 2010, at 33.
[154] *Id.*
[155] *See id.*; *see also* Kim Talus, *Access to Gas Markets: A Comparative Study on Access to LNG Terminals in the European Union and the United States*, 31 HOUS. J. INT'L L. 343, 354 (2009).
[156] Pagnamenta, *supra* note 132 (quoting Oisin Fanning, executive chairman of San Leon Energy, a British company that has secured three license areas in Poland); *see also* Dinakar Sethuraman, *Exxon, Chevron 'Land Grab' for Europe Shale Gas, JP Morgan Says*, BLOOMBERG BUSINESSWEEK, Feb. 11, 2010, *available at* http://www.businessweek.com/news/2010-02-11/exxon-chevron-land-grab-for-europe-shale-gas-jpmorgan-says.html.
[157] MTOGM, *supra* note 100, at 191.
[158] *See generally id.* at 192.
[159] *Id.* at 186.
[160] US EIA, *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States*, Release date: April 5, 2011, http://www.eia.gov/analysis/studies/worldshalegas/.

Figure 4.5. Worldwide Shale Basins



Although the shale gas resource estimates will change over time as additional information becomes available, the report shows that the global shale gas resource base is vast. The initial assessment of technically recoverable shale gas resources in the 32 countries outside the US is 5,760 Tcf (trillion cubic feet). When the US shale gas resource bas of 862 Tcf is added to this, the total global shale gas resource base is 6,622 TCF.

Figure 4.6. Country Listing Technically Recoverable Shale Gas Resources

Continent		Technically Recoverable (Tcf)
North America (non U.S.)	Canada, Mexico	1,069
	U.S.	862
Total North America		1931
Africa	Morocco, Algeria, Tunisia, Libya, Mauritania, Western Sahara, South Africa	1,042
Asia	China, India, Pakistan	1,404
Australia		396
Europe	France, Germany, Netherlands, Sweden, Norway, Denmark, U.K., Poland, Lithuania, Ukraine, Turkey	624
South America	Colombia, Venezuela, Argentina, Bolivia, Brazil, Chile, Uruguay, Paraguay	1,225
Total		6,622
Total without U.S.		5,760

Source: EIA ARI World Shale Gas Resources

The report noted that these estimates are relatively conservative and likely to go up as more information becomes known and this has certainly been the case in the US. However, it is also important to note that the report estimated "technically recoverable" resources, which does not mean commercially viable resources. In other words, it may not make commercial sense to produce all of these resources.

The report also noted that there were two country groupings where shale gas development might be most attractive. The first group consists of countries that are currently dependent upon natural gas imports and have at least some gas production infrastructure and where their estimated shale gas resources are substantial relative to their current gas consumption. This group includes France, Poland, Turkey, Ukraine, South Africa, Morocco and Chile.

The second group includes those countries where the shale gas resource estimate is large and there already exists a significant natural gas production infrastructure. In addition to the US, this group includes Canada, Mexico, China, Australia, Libya Algeria, Argentina and Brazil.

4.3. Challenges to Developing Global Unconventional Gas

The IEA has recognized that there are numerous challenges to replicating the success of the U.S. unconventional gas revolution overseas.[161] The issues raised by the IEA that may impact the development of global unconventional gas resources include:[162]

1) Limited studies on unconventional gas potential around the world,
2) Environmental concerns,
3) Fiscal conditions,
4) Landowner acceptance,
5) Interference from local authorities,
6) Pipeline and infrastructure issues,
7) Availability of technology, equipment and skilled labor force, and
8) Gas players' experience.[163]

Of these, environmental concerns and landowner acceptance are worth noting since these two areas have been the most challenging in the development of shale gas in the U.S.[164] Environmental concerns, which are discussed in further detail in Section ____below, span a wide range of issues from water usage to water pollution to intellectual property violations.[165]
In terms of landowner acceptance, this is likely to vary depending on whether the landowner stands to gain financially from the drilling activity.[166] In the United States, landowners often stand to benefit financially from drilling on their property—if they own the underground resources, they may receive a bonus or royalties upon leasing to an oil company in order to develop the resources.[167] For example, some U.S. landowners who own the underground

[161] *See id.* at 184–85.
[162] *Id.*
[163] *Id.*
[164] *See id.* at 186–87.
[165] *Id.*
[166] *Id.*
[167] *See id.* at 187.

mineral resources have received "up to $25,000 per acre, and sometimes up to 25% royalty" by leasing their property for shale gas development.[168] Although this financial incentive has been particularly helpful in the development of shale gas in the United States, it may not be as relevant in other areas of the world where landowners do not own the underground resources.

In its report, the IEA also noted the numerous environmental concerns that have been raised in the United States.[169] These concerns include the impact hydraulic fracturing might have on local water supplies in terms of potential contamination of underground drinking water sources and surface waters as well as issues related to the quantity of water used in the process.[170]

5. The Impact of Shale Gas On Global Gas Markets and the Prospects for LNG Exports from the United States

As discussed in the preceding sections, the tremendous boom in US shale gas production offers many benefits in terms of economic growth, energy security, and emissions reductions. As such, countries around the world are in the process of assessing their potential shale gas reserves and determining whether they can replicate the success of the US in terms of development of their own shale gas resources.

According to the IEA WEO 2010, the shale gas revolution in the US and the possibility of its replication around the world might have a significant impact on global gas markets in the coming years.[171] However, whether the rest of the world can replicate the success of US shale gas development remains to be seen and as previously discussed, there are many hurdles to the development of global shale gas. Even if such development picks up, it is likely that any significant increase in global shale gas production is at least a decade or more away. Nonetheless, the impact of shale gas has already been felt in a number of significant ways.

5.1. Potential Global Impacts

One of the most dramatic impacts of the US shale gas revolution that has impacted the global gas markets is the surprising shift of the world's top gas producing countries. For over a decade, the Russian Federation held the top spot as the number one producer of natural gas in the world. According to the BP Statistical Review of World Energy 2011,[172] in 2010, the US surpassed Russia as the world's top natural gas producer for the second consecutive year!

[168] *Id.*
[169] *See id.* at 186–87.
[170] *See id.*
[171] IEA WEO 2010
[172] BP Statistical Review of World Energy, June 2011, available at www.bp/com/statisicalreview. BP issues its statistical review of world energy every year and it is an excellent source of statistical data for all energy sources, including natural gas and LNG.

Figure 5.1. World's Top 10 Natural Gas Producers 2005-2010 (in billion cubic metres (bcm))

Rank	Country	2010	2010 share of total	2009	2008	2007	2006	2005
1.	United States	611.0	19.3%	582.8	570.8	545.6	524.0	511.1
2.	Russia	588.9	18.4%	527.7	601.7	592.0	595.2	580.1
3.	Canada	159.8	5.0%	163.9	176.4	182.5	188.4	187.1
4.	Iran	138.5	4.3%	131.2	116.3	111.9	108.6	103.5
5.	Qatar	116.7	3.6%	89.3	77.0	63.2	50.7	45.8
6.	Norway	106.4	3.3%	103.7	99.3	89.7	87.6	85.0
7.	China	96.8	3.0%	85.3	80.3	69.2	58.6	49.3
8.	Saudi Arabia	83.9	2.6%	78.5	80.4	74.4	73.5	71.2
9.	Indonesia	82.0	2.6%	71.9	69.7	67.6	70.3	71.2
10.	Algeria	80.4	2.5%	79.6	85.8	84.8	84.5	88.2

Source: BP Statistical Review of World Energy, June 2011

Over time, and given the vast shale gas resource base, increased global shale gas production could have numerous other implications in terms of geopolitics and energy security. For example, European shale gas production could result in a reduced dependence on Russian natural gas imports if production is sufficient to offset the continuing decline in reserves. Whether or not enough European countries will develop their shale gas resources remains to be seen and at least one study has suggested that shale gas is not likely to significantly increase European gas supplies, outside perhaps, of a few select countries such as Poland that seem to have the commitment to develop the resource.

According to a 2010 study published by the Oxford Institute for Energy entitled CAN UNCONVENTIONAL GAS BE A GAME CHANGER IN EUROPEAN GAS MARKETS?[173], unconventional gas development will not be a game changer for European gas markets overall but it could have a significant impact on individual countries over time. That study found that much more stringent European environmental standards and the difficulties of access to land and fresh water, as well as the lack of incentives for landowners to allow companies to drill will require a completely difference business model for unconventional gas development in Europe as compared to that

[173] Florence Geny, CAN UNCONVENTIONAL GAS BE A GAME CHANGER IN EUROPEAN GAS MARKETS?, Oxford Institute for Energy Studies (2010), available at http://www.oxfordenergy.org/2010/12/can-unconventional-gas-be-a-game-changer-in-european-gas-markets/.

in the US. The study also noted that although the impact of shale gas development could be greater in Poland and Germany, overall it would be surprising if unconventional gas provided more than 5% of European gas demand before the early 2020s.[174]

In terms of the impact of shale gas on LNG markets, it remains to be seen whether the global production of shale gas could ultimately displace some LNG production. At this point, this seems a distant possibility since LNG terminals have been and continue to be built around the world at enormous expense. Moreover, thus far, the shale gas revolution has been largely confined to North America with other countries still just assessing their own shale gas potential.

Over time, if shale gas production ramps up, it is possible that some LNG production could be displaced by shale gas depending on cost. However, it is also possible that increased production of global shale gas will, over the long run, actually strengthen the global LNG markets as increased shale gas supplies will lead to a further shifting of demand to natural gas. Moreover, increased shale gas production around the world could further strengthen LNG markets as more suppliers and buyers enter the market and the LNG market becomes more liquid.

5.2. Impact on the US LNG Markets and Knock-On Effects

While shale gas is not expected to become a global game changer in terms of production anytime soon, the North American LNG market has already clearly been impacted by the shale gas revolution that has swept through that region. The surge in production of shale gas in the US and Canada has essentially eliminated the need for the US to import LNG and most LNG originally destined for the US has had to be diverted to Europe or Asia.

The elimination of the US as a likely LNG importer has also had certain knock on effects for those countries that had planned LNG export projects with the US as the major destination. For example, the $9.9 billion Angola LNG liquefaction project sponsored by state-owned Sonangol, is the largest investment made in Angola to date and the Angola LNG project was expected to provide an economic boost for the country.

When the project was first envisioned years ago, Angola LNG expected the US to take the majority of production with expectations that the LNG would be imported through the recently opened Gulf LNG Energy import terminal located in Mississippi. Gulf LNG Energy is a partnership between El Paso Corp (50%), Crest Group (30%) and Sonangol USA (20%). Half of Gulf LNG Energy's terminal capacity is contracted out to US based Chevron, UK based BP, France's Total, and Italy's Eni. However the contracts for these companies have diversion clauses, which mean the companies can divert LNG cargos to the best markets.[175]

Angola LNG is expected to come online in early 2012 but many analyst's question where the LNG will be exported since the increase in shale gas production in the US has called into question whether the US will import Angolan LNG. A recent Economic Intelligence Unit report

[174] Id.
[175] Jessica Hatcher, "Questions remain over Angola LNG export plans to the US," Interfax, Natural Gas Review, Nov. 23, 2011.

on Angola reported that in more recent months, Sonangol has been considering other options such as exporting to the Asia-Pacific region.[176]

While the Angolan LNG will eventually find a home, it is unclear where and at what price. One analyst has suggested that Angola LNG will most likely be diverted to Europe.[177] With huge supplies of gas already, the US is only likely to import LNG if the price is extremely low. For now, it remains to be seen what the ultimate impact will be on the Angolan LNG project.

5.3. Will Shale Gas Enable the US to Become an Exporter of LNG?

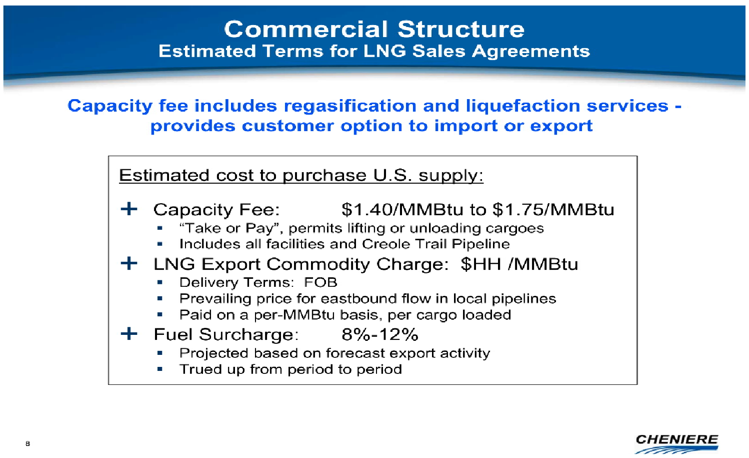
The surge in North American shale gas production has also led companies in the US and Canada to seek authorization to export LNG in order to take advantage of the current supply overhang of shale gas and price differentials between the global gas markets. This is a dramatic turn of events from just five years ago when it was widely expected that both the US and Canada would need to IMPORT LNG!

The market opportunity for US LNG exports started to become apparent in early 2010. At the time, LNG sold to Northern European markets was trading for about $3 per MMBtu more than gas traded at the U.S. Henry Hub in South Louisiana. The first company to publicly recognize this opportunity was Cheniere Energy, which announced in June 2010 that it was initiating a project to add liquefaction facilities to its existing Sabine Pass LNG import terminal, which would make Sabine Pass LNG a bi-directional facility capable of both importing and exporting LNG.

According to Figure 5.2, Cheniere expects to offer customers the bi-directional services for a capacity fee of approximately $1.40/MMBtu to $1.75/MMBtu, which provides customers the option to either import or export and offers “an attractive option to source US natural gas from the US pipeline grid at prices indexed to Henry Hub.”[178]

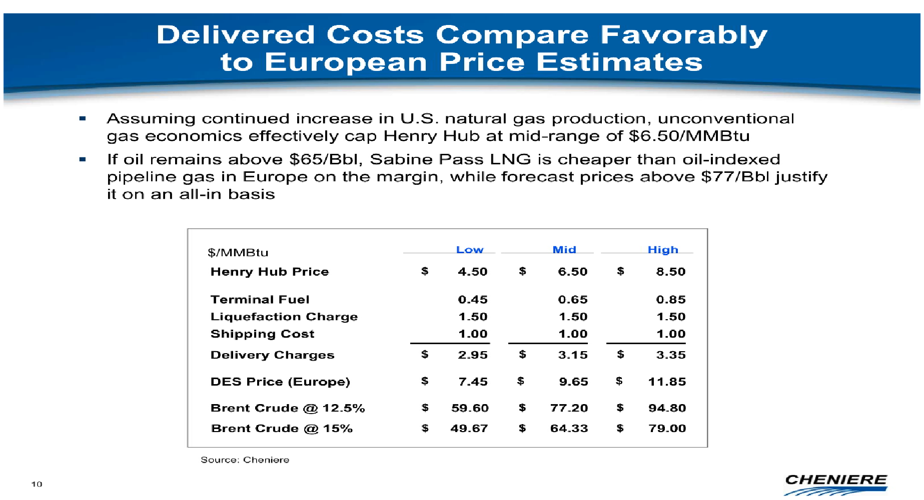
[176] Jessica Hatcher, “Questions remain over Angola LNG export plans to the US,” Interfax, Natural Gas Review, Nov. 23, 2011.
[177] Id.
[178] Cheniere Energy Partners, L.P., Press Release dated June 3, 2010, *Cheniere Energy Partners Initiating Project to Add Liquefaction Capabilities at the Sabine Pass LNG Terminal,* http://phx.corporate-ir.net/phoenix.zhtml?c=207560&p=irol-newsArticle&ID=1434470&highlight=.

Figure 5.2. Cheniere Commercial Structure for LNG Exports



With the existing market dynamics, Cheniere expected to be able to liquefy and ship LNG to Europe cheaper than oil-indexed pipeline gas in Europe on the margin. In its analysis, Cheniere assumed that the continued increase in US natural gas production driven by shale gas effectively capped Henry Hub prices at a mid-range of \$6.50/MMBtu. Cheniere also claimed that if oil remains above \$65/Bbl, Sabine Pass LNG is cheaper than oil-indexed pipeline gas in Europe on the margin, while oil prices above \$77/Bbl justify it on an all-in basis. Cheniere's estimates from June 2010 are as follows:[179]

Figure 5.3. Cheniere US LNG Exports - Delivered Costs to Europe



$/MMBtu	Low	Mid	High
Henry Hub Price	$ 4.50	$ 6.50	$ 8.50
Terminal Fuel	0.45	0.65	0.85
Liquefaction Charge	1.50	1.50	1.50
Shipping Cost	1.00	1.00	1.00
Delivery Charges	$ 2.95	$ 3.15	$ 3.35
DES Price (Europe)	$ 7.45	$ 9.65	$ 11.85
Brent Crude @ 12.5%	$ 59.60	$ 77.20	$ 94.80
Brent Crude @ 15%	$ 49.67	$ 64.33	$ 79.00

179 Cheniere Energy Partners, L.P., Presentation dated June 4, 2010, *Proposed Sabine Pass LNG Facility Expansion –Adding Liquefaction Capabilities*, http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9Mzg1NDE5fENoaWxkSUQ9Mzg3MTc2fFR5cGU9MQ==&t=1

5.4. The Future is Looking Brighter for US LNG Exports

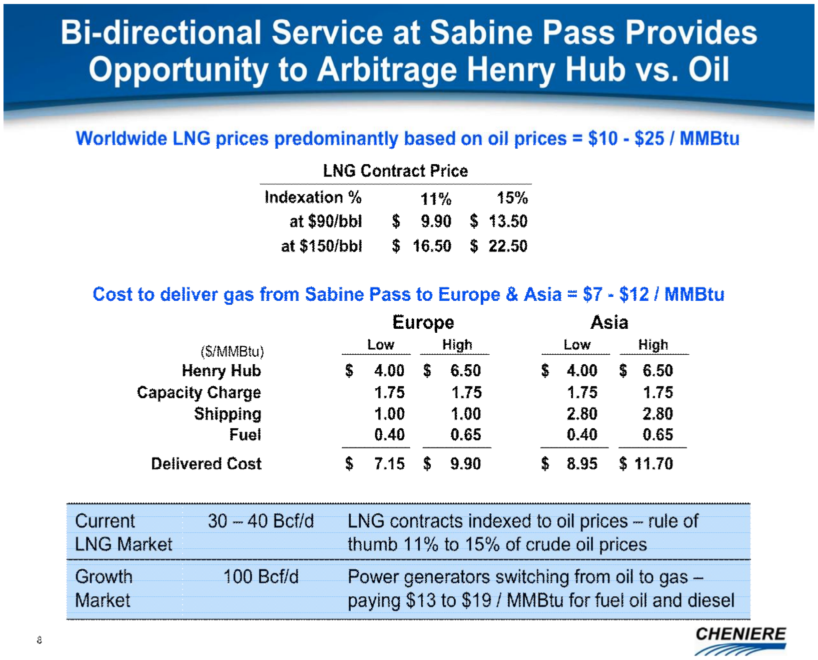
Initially there was much skepticism about the prospects of US LNG exports with analysts predicting that pricing and politics would hinder US export plans.[180] Analysts initially doubted that the "economic's work out in Cheniere's favor" calculating that European LNG prices would have to be about $8-$10 MMBtu in Europe to make the project economically feasible. More skepticism was raised about the project costs (Cheniere's original estimate was $2-$3 billion) and whether Cheniere's proposed capacity fee would have to be increased to reflect higher construction costs.[181] Doubts were also raised whether the DOE would authorize US LNG exports since there was little precedent and likely to be opposition.[182]

More recent articles have indicated that the prospects for US LNG exports is looking brighter as Asian demand for LNG has significantly increased due to nuclear accident in Japan with has resulted in Asian prices climbing 50 percent since March 2011. At the same time, US shale gas production has continued to grow keeping Henry Hub prices low at $3.60 MMBtu. US gas prices are now "much lower than the more than $15 MMBtu in Asia and over $10 MMBtu in Europe." These spreads make US LNG exports more attractive with at least one major consulting firm opining that "a spread of just $4 for Europe and $6 for Asia would justify the infrastructure investment."[183]

A more recent presentation from Cheniere indicates that the arbitrage opportunity for US LNG exports has become more attractive given market dynamics existing in mid-2011.[184]
As indicated in Figure 5.3 below, Cheniere expects to be able to deliver LNG from the US to Europe or Asia for $7-$12 MMBtu with LNG prices around the world linked to oil trading in a range of $10-$25 MMBtu making US exports competitive in most cases.

[180] Edward McAllister, *Pricing and politics to scupper US LNG export plan*, Reuters, June 16, 2010, quoting analysts calling into question the economics of Cheniere's export plan
[181] At least one analyst has cautioned that "Sabine Pass' projected in-service date of 2015 is unrealistic, that its $4 billion price tag for liquefaction facilities was 'to be taken with a grain of salt,' and that LNG buyers would be hard-pressed to find US producers willing to sell gas forward at prices below $6/MMBtu for 2015 or 2016."
Samantha Santa Maria, *"US LNG export proposals may be too optimistic: SocGen analyst,"* Platts, May 25, 2011, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/6135424, quoting Societe Generale analyst Laurent Key.
[182] Edward McAllister, *Pricing and politics to scupper US LNG export plan*, Reuters, June 16, 2010, quoting analysts calling into question the economics of Cheniere's export plan
[183] Christopher Swann and Neil Unmack, *Outlook Brightens for U.S. Gas Exports,* New York Times, Oct. 13, 2011, http://www.nytimes.com/2011/10/14/business/outlook-brightens-for-us-gas-exports.html, quoting consultancy firm IHS.
[184] Cheniere Energy Partners, L.P., Corporate Presentation dated June 20, 2010, http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9NDI5MjE5fENoaWxkSUQ9NDQ2NDY1fFR5cGU9MQ==&t=1

Figure 5.4. Cheniere Sabine Pass Arbitrage Opportunity



Under Cheniere's proposed plans, customers will pay a take-or-pay capacity fee plus a fuel surcharge with 1 Bcf/d capacity estimated at ~$640 million of contracted annual revenues. Customers are responsible for delivering their own feed gas for processing, sourced from pipeline interconnects (including Creole Trail Pipeline) and making shipping arrangements from the Sabine Pass LNG terminal.

5.5. Cheniere Signs Two Foundation Contracts Securing Capacity For Exports

In October 2011, Cheniere's export project received a significant boost when Cheniere entered into a contract with BG Group, a major player in the LNG world. Under the LNG Sale and Purchase Agreement (SPA), BG group agreed to purchase 3.5 million tonnes per annum ("mtpa") of LNG and will pay Sabine Liquefaction a fixed sales charge for the full annual contract quantity and will also pay a contract sales price for LNG purchases based on the applicable Henry Hub index traded on the New York Mercantile Exchange. LNG will be loaded onto BG's vessels. The SPA has a term of twenty years commencing upon the date of first commercial delivery, and an extension option of up to ten years. LNG exports are expected to commence as early as 2015, however it should be noted the SPA is subject to certain conditions precedent, including but not limited to Sabine Liquefaction's receiving regulatory approvals, securing necessary financing arrangements and making a final investment decision to construct the liquefaction facilities.[185]

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[185] PRNewswire, Press Release (Oct. 26, 2011), Cheniere and BG Sign 20-Year LNG Sale and Purchase Agreement, available at http://www.prnewswire.com/news-releases/cheniere-and-bg-sign-20-year-lng-sale-and-purchase-agreement-132606318.html.

In November 2011, Cheniere's project received another "shot in the arm" when it secured its second foundation customer for the project, Gas Natural Aprovisionamientos, a subsidiary of Gas Natural Fenosa. The 3.5 mtpa SPA with Gas Natural Fenosa is another milestone for the project, which has now reached its contract capacity target of 7.0 mtpa. With the two foundation contracts in place, Cheniere now plans to proceed towards making a final investment decision in order to start construction [186]on the first two liquefaction trains in early 2012.[187]

5.6. Will North American LNG Exports Impact the Global LNG Market?

According to some experts, global interdependencies among gas markets will continue over the next decade this trend will influence pricing in the global gas market. The North America Region is expected to remain disconnected as oversupply depresses Henry Hub prices, but it "will not be isolated." Moreover, North American movements towards becoming an LNG exporter could have an impact on price even before LNG exports become a reality.[188]

According to experts, North American LNG exports pose several questions for the global gas market: How much LNG volume can be exported before it becomes self-limiting? What will choke volumes first: rising US gas prices that make it uneconomic or the fear of price rises that might drive vested interests to persuade regulators to restrict exports? Will the threat of North American LNG exports impose a future ceiling for European gas prices?

More recently, some experts have opined that LNG exports from the US—if and when they happen— would have little if any effect on the European gas supply. While the immediate effect of shale gas development in the US was to divert LNG shipments away from the US, the markets have already absorbed that effect.[189]

Moreover, at the moment, natural gas is currently at a price disadvantage to coal in Europe and along with the likely demand-depressing effects of the ongoing financial crisis and the slow

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[186] In November 2011, Cheniere, through its subsidiary, Sabine Pass Liquefaction, entered into a lump sum turnkey contract with Bechtel Oil, Gas and Chemicals, Inc. ("Bechtel") for the engineering, procurement and construction of the first two liquefaction trains at the Sabine Pass LNG terminal. PRNewswire, Press Release (Nov. 14, 2011), "Cheniere Partners Enters into Lump Sum Turnkey Contract with Bechtel," available at **http://www.prnewswire.com/news-releases/cheniere-partners-enters-into-lump-sum-turnkey-contract-with-bechtel-133799293.html**

[187] PRNewswire, Press Release (Nov. 21, 2011), "Cheniere and Gas Natural Fenosa Sign 20-Year LNG Sale and Purchase Agreement," available at http://www.prnewswire.com/news-releases/cheniere-and-gas-natural-fenosa-sign-20-year-lng-sale-and-purchase-agreement-134267813.html.

[188] Warren R. True, "Gastech: WoodMac expects global gas dependencies to continue" Oil&Gas Journal, Mar. 28, 2011, available at http://www.ogj.com/articles/print/volume-109/issue-13/general-interest/gastech-woodmac-expects-global-gas.html, citing Wood Mackenzie's Noel Tomnay, head of global gas research, in remarks to the Gastech Conference in Amsterdam on Mar. 21, 2011.

[189] Warren R. True, "WPC20: US LNG exports to have little effect on Europe," Oil&Gas Journal, Dec. 8, 2011, available at http://www.ogj.com/articles/2011/12/wgc20-us-lng-exports-to-have-little-effect-on-europe.html, citing, E.On Energy Trading Chairman Klaus Schafer in comments to Oil & Gas Journal made on the final day of the 20th World Petroleum Congress in Doha, Qatar.

recovery from the 2007-08 global financial collapse, Europe is unlikely to attract much US-produced LNG, no matter how much or how little liquefaction eventually gets built there.[190]

Results and Conclusions: LNG and Shale Gas Will Power the Future

The global LNG industry has grown dramatically over the past decade and has proven to be a resilient industry in challenging economic times. While the pace and scope of the global economic recovery is difficult to predict, all expectations are that the world will continue to need more cleaner burning fuels which bodes well for the future of LNG as the global "glue" linking distant gas markets.

What impact will global shale gas development have on LNG? The tremendous boom in shale gas production in the United States over the past five years has indeed been a game changer with potentially significant implications in terms of energy security and supply, climate change mitigation, and energy policy. While shale gas presents an enormous opportunity for the US and perhaps the rest of the world, there remain numerous legal, policy and environmental challenges that must be addressed before the full potential of shale gas can be realized on a global scale.

Although the current outlook for global shale gas is quite optimistic, it is unclear whether the success of the United States can be replicated elsewhere and if so, in what time frame? Significant increases in production of global shale gas resources creates challenges for many in the LNG industry but also opportunities for others as in the case of potential US LNG exports. While it is difficult to predict the ultimate outcome, global shale gas is an important development to follow.

In the coming decades, the world must meet the challenge of producing more energy to meet growing worldwide demand while at the same time limiting and even reducing greenhouse gas emissions. This dynamic will create unprecedented challenges but also unprecedented opportunities for cleaner burning fuels and renewables. As a clean burning fossil fuel, natural gas – and in particular LNG and shale gas - have the potential to play a role in a carbon-constrained energy future. Nonetheless, the industry will continue to face an array of commercial, political, environmental and social barriers and these barriers must be overcome before the full potential of natural gas as a fuel for the 21st century can be realized. While these barriers may preclude development in some areas, the industry as a whole seems committed to meeting the challenges with LNG and shale gas well positioned to power the future!

[190] Id.