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Texas Barnett shale gas drilling rig
19 April 2008 taken by David R Tribble
http://commons.wikimedia.org/wiki/File:BarnettShaleDrilling-9323.jpg

INTRODUCTION

The unconventional gas phenomenon has turned the world gas market on its head. Banished are the gloomy predictions of impending natural gas supply shortages that were common at the turn of this century. The estimates of massive deposits of unconventional gas in friendly locales or even one's own backyard suggest a future where the world will be awash with large, secure quantities of natural gas at low prices. This has led to exuberant pronouncements from several quarters about an increasing share of natural gas in the world's primary energy mix in the decades to come. Some go as far as predicting the dethroning of king coal. In light of these historic developments in the world gas markets, this issue examines unconventional gas, shale gas and coal bed methane (CBM), and the role that they could play in shaping world energy markets.

As the Nobel prize-winning physicist Nils Bohr aptly put it, "Prediction is very difficult, especially if it is about the future." This certainly holds true of predicting the evolution of the world gas markets. Professor Peter Hartley and Dr Kenneth Medlock take up this challenge in the first article of this issue where they employ the Rice World Gas Trade Model, a dynamic, spatial optimization model, to forecast the prices, inter-regional flows and supply and demand for natural gas from 2011 to 2040 taking into consideration the development of shale gas reserves. Underpinning the model are assumptions on population growth, economic growth, technological progress and cost-of-supply curves for all resources. They find that shale gas discoveries will indeed result in lower gas prices and increased demand, especially in Asia.

The heterogeneity of shale basins makes extracting shale gas a complex process. Dr Felicia Shaw walks us through the shale gas life cycle underscoring the differing technical competencies required at each stage of a shale gas project. Technological progress, which is generally subsumed in model assumptions, is a more nuanced phenomenon given the range of technologies involved in the

In this issue ...

development of shale gas. And given that the enthusiasm for R&D in the oil and gas industry has waned, there is uncertainty as to the drivers of the anticipated technical improvements. Although lower than expected R&D efforts will not serve as a spanner in the works, they might alter the timeline of development for the unconventional gas resources.

Dr. Lesley Sloss evaluates the development of CBM -- the other “unconventional” that is purported to have huge potential -- in Asia. Akin to shale gas deposits, there is considerable heterogeneity in the quality and quantity of gas in each CBM project necessitating extensive explorative studies prior to production. This raises the costs of investment. On the positive side, there are several uses for the different qualities of CBM and this fact is driving interest in CBM projects in Asia. There are several ongoing CBM projects in China and India. Indonesia’s vast CBM reserves are expected to be tapped in the coming years with several projects already underway. Countries such as Thailand and Vietnam are also scoping for CBM within their borders. High initial investment costs have in the past deterred the development of CBM projects. However, given the environmental benefits of using rather than venting CBM, funding can be obtained from supranational institutions such as the Asian Development Bank. Often, additional carbon funding can be obtained to make some CBM projects viable. It remains to be seen whether the momentum of CBM development can be maintained.

Given the near-universal agreement on the excellent prospects for natural gas, someone holding a contrarian opinion might seem like a real killjoy. However, as alluded to above, forecasting is a non-trivial exercise potentially fraught with huge errors by even the best and brightest. Michael Lynch provides a compelling account of the pitfalls of extrapolation. Over the past half century, perceived scarcity and concerns over energy security coupled with addled thinking have resulted in the backing of technologies that have yet to attain commercial viability. Most of the successful technologies that will go towards the “greening” of society have been developed independent of government backing; governments are ill-equipped to pick technology winners. In essence, the design of energy policy necessitates the understanding that bad policy can do much harm by distorting incentives. This message bears significance to the present natural gas excitement.

We hope that you enjoy reading this issue of the ESI Bulletin. We welcome your views and opinions.

Neil D’souza,
on behalf of the Bulletin Team.

Potential World-wide Effects of Shale Gas

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Over the last decade, the application of horizontal drilling with hydraulic fracturing, multi-well pads with longer laterals and improved stimulation techniques have substantially lowered the cost of producing natural gas from shale. While these developments all first occurred in North America, gas-bearing shale deposits have been identified elsewhere in the world. As technology allows these shales to become economically viable, the world supply of natural gas will become more elastic tending to lower prices and increase demand. In addition, the regional distribution of production will change, altering patterns of international and regional natural gas trade and expanding liquidity, which could in turn undermine traditional contract-dominated pricing regimes. In this article we examine these trends and look at some possible implications.

Conventional versus Unconventional Production

In conventional reservoirs, gas is trapped in sands and carbonates under high pressure with interconnected pore spaces that allow gas to flow to the wellbore. In contrast,

Natural Gas Vehicle Opel Zafira 1,6 CNG ecoflex at filling station in Rovereto, Italy, 4 August 2010

http://commons.wikimedia.org/wiki/File:Bild_1_Rovereto.jpg

unconventional reservoirs generally have very low permeability and do not naturally facilitate flow to the wellbore, meaning reservoir stimulation is needed. Unconventional resources generally fall into three broad categories: tight gas, where gas is trapped in a reservoir with very low permeability; coal bed methane (CBM), or coal seam gas (CSG), where the coal is both the source and reservoir for gas; and shale gas, where the gas is trapped in a low permeability hydrocarbon source rock.

Production from shale involves hydraulic fracturing ("fracking") along horizontal laterals connected to a single wellbore. In contrast to a conventional well, shale gas production has begun to mimic a "just in time" manufacturing process because well completion can be timed to maximise expected return. Rapid innovation in shale development for producing oil as well as natural gas has continued to increase initial production rates and well productivity.[1]

Despite characterisations in the media, fracking is not new, with the first commercial "frack" performed by Halliburton in 1949. The application in horizontal wells, however, is a new innovation, and it has contributed to continuing increases in productivity. However, public concerns about the environmental impact of fracking on groundwater are threatening to derail the shale gas boom and have led to much debate. Shale formations are typically between 5,000 and 8,000 feet deep, which is generally much deeper than the water table. The fracking fluid (known as "slick water") is primarily water and sand, with some chemical components (usually less than 2 per cent of the fluid volume) added to improve performance. While some fracking chemicals remain in the shale formation, the majority of the fluid (known as "produced fluid") returns through the wellbore. Things such as improper disposal of produced fluid and production casing failures can threaten groundwater. In response to these concerns, the industry is developing non-toxic chemical cocktails and evolving improved procedures for handling produced fluid.[2] Nevertheless, in response to concerns about groundwater safety, the EPA Office of Research and Development is conducting a study "to identify potential risks associated with hydraulic fracturing" and "the possible relationships between hydraulic fracturing and drinking water".[3]

Shale Gas Resources

The shale gas resource assessment for North America is large and the state of knowledge has been growing rapidly. In 2003, the National Petroleum Council (NPC) placed the resource at about 38 trillion cubic feet (tcf). By 2005, with realisations of the potential in the Barnett, Fayetteville and Woodford shales, estimates increased to about 140 tcf. Recent estimates are much higher. Navigant Consulting, Inc. (2008) estimated mean technically recoverable resources of about 520 tcf, the Potential Gas Committee (2009) put them at over 680 tcf, and Advanced Resources International (Kuuskraa and Stevens, 2010) estimated over 1000 tcf. The Rice model (discussed below) includes technically recoverable shale gas resources of 686 tcf.

Since shale gas has not yet been produced outside North America, resource assessments for the rest of the world are more speculative. Rogner (1997) estimated over 16,000 tcf of shale gas resources in-place globally, distributed as in Table 1, although less that 10 per cent was deemed technically recoverable and even less economically recoverable at current costs and prices.

Alaskan gas pipeline, 19 April 2006

http://commons.wikimedia.org/wiki/File:0904_-_alaskan_pipeline.jpg

Table 1: Rogner (1997) Estimates of Shale Gas Resources In-place (tcf)

North America	3,842	Australasia	2,313
China and India	3,528	Latin America	2,117
MENA	2,548	Former USSR	627
Europe	549	Rest of World	588

The International Energy Agency (IEA) recently estimated that up to 40 per cent of Rogner's estimates would ultimately be technically recoverable. In the Rice model, technically recoverable shale gas resources outside North America are: Austria 40 tcf, Germany 30 tcf, Poland 120 tcf, Sweden 30 tcf, China 45 tcf and Australia 50 tcf.[4]

Hydraulic fracturing of a Marcellus Shale Gas Well

http://buildaroo.com/news/article/hydraulic-fracturing-natural-gas-primer/hydraulic-fracking-well3/

The Rice World Gas Trade Model (RWGTM)

The RWGTM was developed to examine potential impacts of geopolitical, technological and other influences on the development of a global natural gas market. The model predicts prices, supplies from more than 120 regions, demands in more than 290 regions and inter-regional flows. The model, which is constructed using the MarketBuilder software from Deloitte MarketPoint LLC, is a dynamic, spatial equilibrium model linked through time by Hotelling-type optimisation of resource extraction. Capacity expansions are determined by anticipated profitability. The model is non-stochastic, but allows many different scenarios.

In North America, demand is separated into residential, commercial, power generation and industrial sectors. Natural gas demand functions are estimated using longitudinal state and provincial data. In the rest of the world, demand is separated into power generation and direct use. The estimated demand functions allow the natural gas share of total energy demand to increase with energy use, reflecting an assumption that natural gas is a premium fuel. To capture rigidities associated with capital, price elasticity is decreasing in natural gas share.

To project demand, population growth estimates are taken from the United Nations median case projection to 2050. Economic growth rates are based on International Monetary Fund forecasts through 2015 and then a conditional growth convergence model. The latter implies, for example, that real Chinese per capita growth will gradually fall to around 4 per cent per annum in 2030.

Natural gas supplies are developed from the median technically recoverable conventional, CBM and shale resources in North America, China, Europe and Australia, and conventional resources elsewhere. Cost-of-supply curves are estimated for all resources, allowing economically recoverable resources to be determined endogenously. Resources are separated into proved reserves, growth in existing fields and undiscovered resources. North American cost-of-supply estimates were econometrically related to play-level geologic characteristics and the resulting functions were used to generate cost curves for all regions. Technological change reduces mining costs long-term, while short-run adjustment costs endogenously curtail a "rush to drill".

In regions with substantial coal, we allow integrated gasification combined cycle (IGCC) to compete with gas at a real gas price of $7.50/mmbtu (one million BTU) from 2015. We also allow for unspecified new technologies to displace natural gas demand from 2020 at a price of $9/mmcf (million cubic feet). Adoption of IGCC is not prevalent prior to 2025 and the generic backstop is not used much until after 2040.

The RWGTM also includes a detailed transportation network. Pipelines are aggregated into corridors where appropriate, and the model chooses to develop new pipeline links when profitable. The required return on investment in new infrastructures varies by region and project type (using ICRG and World Bank data). Capital costs are based on an analysis of over 100 pipeline projects relating project cost to various factors. Tariffs are based on posted data, where available, and rate-of-return recovery, otherwise. Liquefied natural gas (LNG) trade is represented as a hub-and-spoke network, reflecting an assumption that swaps will occur when profitable, and shipping rates are based on lease rates and voyage times.

Reference Case Results

From 2010 to 2040, the compound annual growth rate for

Rallying outside a North American Shale Gas Conference

Picture taken by Toban Black, 19 May 2011

http://www.flickr.com/photos/tobanblack/5740549346/in/set-72157626640443833/

global natural gas demand is projected to be around 2.5%. Regional compound annual growth rates range from around 1% for the US and the EU15 to more than 5.8% for India and over 6.5% for China. Demand in Asian and Pacific countries, the Middle East and Latin America is projected to grow at just over 3.0% per year, while growth in Japan and the Former Soviet Union countries is less than 1.0% per year.

The Middle East is projected to have the highest annual growth rate in production as LNG and, subsequently, pipeline gas exports from the region expand both east and west. In fact, exports from the Middle East are predicted to expand substantially, with the compound annual growth rate in Middle East supply from 2010 to 2040 at almost 5.5%, with the fastest growth in Iraq (after 2020), Iran and Qatar.

Since Russia also has substantial resources, its production is projected to grow over the next three decades, with most of the increase destined for Asia. Given the large current production, however, the compound annual growth rate in production is only slightly above 2.0%.

The 3.7% annual compound growth in production in Central and South America is above the world average and above demand growth in the same region of around 3% per annum, thus allowing for considerable longer term growth in regional exports. An average annual compound growth rate in supply from Australia, Papua New Guinea and New Zealand of almost 6% also allows for substantial expansion of exports from these countries.

Asian imports are projected to grow at an average annual compound rate of more than 12.8%. This is far above the corresponding European rate of almost 2.5% per annum, while North America as a whole is projected to switch from near balance of demand and supply to becoming an importer about half the size of Europe and one-third the size of Asia by 2040. While rapid growth in shale production in North America is projected to allow total North American production to increase until around 2030, after that time, shale gas production stabilizes and increased production from Alaska is insufficient to offset continued declines in output from onshore and offshore conventional fields. Production from shale resources in Europe is projected to do no more than offset declines in output from the North Sea, leaving total European production roughly constant over next the three decades.

Some Effects of Excluding New Shale Gas Production

Another way of assessing the consequences of increased shale gas production is to ask what would happen if shale gas resources beyond those exploited to date were excluded. The RWGTM predicts that shale gas production in North America would be more than 13.5 tcf lower by 2040. In Europe, it would be more than 2.7 tcf lower in 2040. The reduction in shale production in North America and Europe is partly compensated by increased production from other domestic sources, but, as in other regions with shale gas, the resource endowment without shale is neither large enough nor available at low enough cost to completely offset the loss.

The largest positive supply responses from eliminating new shale production are in Russia (peaking at slightly above 2.5 tcf by 2040) and Middle East exporting countries (peaking at slightly below 2.5 tcf by 2040). Increased annual exports from both Russia and the Middle East both peak just before 2040. The peak occurs before 2040 because almost 3.5 tcf of demand for natural gas is lost to alternatives as a result of higher gas prices.

The substantial reduction in North American production in the no new shale case results in a large increase in North American LNG imports, increasing by more than 8 tcf per annum by 2040. By contrast, LNG imports into Europe decline slightly in the no new shale versus reference case. The increased European demand for imports is instead met by increased pipeline imports mainly from Russia. Some of the increase in North American LNG imports is met by reduced imports into Asia consequent upon higher natural gas prices. The majority of the increased demand for LNG in North America is met, however, by dramatic increases in LNG exports, more than half of which come from the Middle

East (especially Iran and Qatar), with Nigeria, the exporting countries of North Africa, Venezuela, Trinidad and Russia supplying much of the rest.

Concluding Remarks

As a result of high projected economic growth rates, Asia will be the largest source of growing demand for natural gas, although demand elsewhere will also increase. Gas prices are predicted to rise steadily as a result of depletion and, around 2035, other energy sources become competitive thus dampening gas demand growth. Supply growth is fastest in the Middle East and, to a lesser extent, Russia. If new shale gas resources are not developed, prices rise faster and the tendency for supply to become concentrated in these regions is accentuated.

By the mid-2030s LNG is expected to account for over 50% of all internationally traded natural gas, with exports from the Middle East and Australia growing the fastest. Largely as a result of increases in shale production in North America, US re-gasification terminal load factors remain low through the 2020s. Declines in production from other sources eventually stimulate growth in US LNG imports beyond 2030. If shale resources are not developed, North American LNG imports would be dramatically higher. Moreover, although lower shale gas production in North America *directly* affects the Atlantic Basin LNG market, reductions in Asian imports in response to higher prices liberates some LNG from the Pacific Basin to satisfy increased demand from North America. A small shift in European supply towards pipeline gas also allows some LNG to be redirected to North America.

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[1] Similar techniques are used to produce oil from shale oil formations, such as the Bakken shale in North Dakota, while high oil prices have continued to encourage natural gas exploration in some shales, such as the Eagle Ford in Texas and Marcellus in Pennsylvania, that have high liquid content.

[2] CBM fracking can be more problematic than shale fracking because the coal seam can coincide with water aquifers.

[3] In 2004 the US EPA conducted a study of fracking in CBM wells, and found no evidence that fracking contaminates groundwater. Nevertheless a memorandum of agreement was signed with CBM developers to eliminate the use of diesel fuel in fracking fluids in CBM wells.

[4] Ongoing work will likely add technically recoverable resource assessments and costs in Croatia, Denmark, France, Hungary, Netherlands, Ukraine and the United Kingdom, but estimates are currently too preliminary.

Digging Deeper: Innovation in Shale Gas Development

Felicia Shaw, ESI Adjunct Fellow

Trucking operation on a Marcellus Shale Gas Well

http://buildaroo.com/wp-content/uploads/2011/01/hydrofracking-site.png

There is a scene in the documentary film *GasLand* where a man leans over the kitchen sink, lighter in hand.[1] He turns on the tap, flicks his lighter, and fire erupts from it instead of water – a scene both comical and nightmarish. What turned his faucet into a flamethrower? *GasLand* points a finger at companies exploiting shale gas deposits beneath beleaguered communities, and one technology is repeatedly named and shamed: *hydraulic fracturing* – "fracking" or "fracing" for short.

Put simply, fracking employs pressurised fluids to create artificial fissures in subterranean rocks and release the gas trapped within. Energy commentators credit the technology for ushering in a golden age of gas. Activists paint a picture of irresponsible tampering with the sub-surface, resulting in toxic substances entering the water supply and leaks of gas to the surface. But both these narratives mask the fact that fracking is only one component of a much larger innovation landscape for shale gas and other unconventional sources.

This article outlines the exploration and characterisation technologies that come into play before the boreholes are drilled and the gas is induced to flow.

No Two Shales Are Alike

What constitutes a shale? The compacted and altered clay from rivers, lakes and oceans, a shale starts as fine sediment falling out of suspension in a quiet watery environment. Millions of years of compaction and alteration later, these emerge as layered, brown-black rock. By this description, shales are extremely common, and at a first reading there might seem little distinction between one rock and the next.

The reality for exploration and production (E&P) operators is that every shale basin (what geologists evocatively call the contents of ancient sites of deposition) is unique. Each basin has its own developmental history, leading to variations not only in its gas-bearing potential, but also the engineering challenges of producing it. The heterogeneity of shale prospects was emphasised in a report by the US Energy Information Administration examining 48 basins in 32 countries.[2] The EIA concluded that technically recoverable resources in the world stood at a "vast" 6,622 trillion cubic feet (tcf).[3] The caveat to this report was that EIA estimates made no account for cost of production and/or local impact, which would require detailed, on-the-ground data.

Certainly, not all shales can replicate the productivity of the Barnett Shale, the current showcase for shale gas production.[4] Illustrating this is a formation situated very near to the Barnett at the Texas-Louisiana border but formed about 100 million years later: the Haynesville. Gas from the Haynesville Shale is inherently more problematic to extract due to the basin's depth below the surface (3-4km) and highly laminated nature. This requires drilling and production equipment able to withstand higher temperatures/pressures. Extraction is also a more water-intensive process than in the Barnett.[5] The economic payoffs here are less certain and the environmental implications weightier.

Such heterogeneity in the global family of shale formations

Methane wells in western Colorado with access roads, containment ponds, and drill sites. Photo by Rebecca Claren, courtesy of High Country News.

http://meic.org/water-quality/coal-bed-methane

means that trial-and-error drilling (known as "wildcatting") is not a viable strategy. Instead, identification and development take place using a suite of technologies, each contributing towards minimised risk, an extension of the lifespan of the resource and in the long-run, an increased return on investment.

Cradle to Rebirth: Stages in the Shale Gas Lifecycle

The life of a potential hydrocarbon resource, known as a "play", is an eventful one. It can be divided into five broad stages, each involving different innovative approaches.[6]

Exploration. This stage begins with an understanding of the ancient setting in which the basin formed, helping the operator to constrain its size, shape and properties. Three-dimensional seismic surveys and other geophysical methods, ubiquitous in the conventional oil and gas industry, are indispensable for complex, unconventional resources. Seismic attributes can provide certain tell-tale indicators of higher productivity (e.g. high total organic content, TOC), although traditional forms of source rock analysis are difficult in shales.[7]

Appraisal. If the first hurdle is crossed, the project enters the next stage. Using data from logging (and rock cores where available), analysts zoom into the small-scale, petrophysical properties of the rocks. These provide an idea of the ease of fracturing, potential performance of wells and guide the strategy for exploiting the potential "reservoir".

Development. Here, operators undertake hydraulic fracturing, commonly in horizontal wells to maximise contact with the reservoir. Geomechanical modelling -- taking in the physics of the reservoir's behaviour under stress -- allows operators to define the orientation and length of fractures, as well as overall pattern and planned phasing of fractures. As fracking takes place, micro-seismic monitoring is conducted on the fly (with instruments effectively listening to the sound of rocks breaking to determine the success of the process).

It is important to note that technologies for drilling and fracking are not at a developmental standstill. Novel stimulation processes, involving multiple stages and configurations of equipment, as well as different strategies for keeping fractures open, are an area of active research. The objective is to achieve greater control in the extent and pattern of fracturing, with associated improvements in both productivity and environmental integrity.

Production. At this stage, a new set of challenges arises. Many issues are evolutionary and involve maintenance of equipment, e.g. arresting the corrosion of equipment, addressing build-up of deposits on the wellbore, repairing breaches or perforations. Chemicals may be used to control the growth of microbes, inhibit certain reactions or lubricate components.

Rejuvenation. Over time, the reservoir may need a new lease of life, and methods of enhanced recovery may be pursued. This involves a re-tread of technologies/processes used in earlier stages of the lifecycle. Re-assessment of the reservoir, re-fracturing and a re-designed placement of wells are carried out.

The Future of Shale Gas is... Green?

Efforts to spur further R&D in unconventional gas have been the subject of many high-level state and industrial committees.[8] One clear signal from their recommendations is that more emphasis should be placed on the health, safety and environmental aspects of shale gas production, instead of simply depressing production costs.

Many of the technological improvements that have been motivated by cost reduction can be augmented to minimise environmental impact (helped along by appropriate legislation). An improved understanding of the sub-surface, particularly through real-time monitoring, diminishes the risk of sinking unproductive wells, but also reduces the risk of trespassing into surrounding formations that could result in seepage to the surface. This can be coupled with increased control and effectiveness of the fracturing process, so as to perturb as little of the sub-surface as possible. The technologies/protocols designed to improve well integrity, thereby improving yield, simultaneously minimise water usage and gas leaks. Recognising that there is a continuum between best practice, incremental innovation and game-changing technology, recommended investment into R&D casts a wide net across the full shale gas development lifecycle.

In its report to the US Secretary of Energy, the Unconventional Resources Technology Advisory Committee identified that higher priority should be given to well integrity, water usage and methods to reduce air quality impacts in the 2011 research programme.[9] This recommendation surely resonates with the irate residents featured in *GasLand*. With federal monies being diverted to developing unconventional resources, what remains to be seen is whether funding/intent can be matched with technology transfer, implementation and results.

One impediment to technology development and implementation may be the very structure of the oil and gas industry.[9] The US shale gas industry was kick-started by small, independent operators, which traditionally have had a limited appetite for R&D. Even for the oil and gas majors, attention to R&D (measured in terms of both spending and activity) has waned since the 1980s, driven in large part by decisions to "buy versus build". Broadly, oil service companies have taken up the slack by increasing their innovation activities, but it remains to be seen who will drive technology development in the specific area of unconventional gas.

1 The American documentary film, *GasLand*, was written and directed by Josh Fox in 2010. It examines the impact of fracking on US local communities.

2 US Energy Information Administration. *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States.* EIA, 2011.

3 For context, world proven reserves of natural gas stood at 6,609 tcf as of 1 January 2010.

4 The Barnett Shale Formation is located in Texas. Covering some 13,000 square kilometers, it may be the largest onshore natural gas field in the United States.

5 Halliburton, *U.S. Shale Gas: White Paper*, Halliburton, 2008.

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8 See "Research Partnership to Secure Energy for America", *RPSEA 2011 Draft Annual Plan.* RPSEA, 2010; and W. H. Neal, M. R. Bell, C. A. Hansen and R. W. Siegfried, *Oil and Gas Technology Development: Working Document of the NPC Global Oil and Gas Study.* NPC, 2007.

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Coalbed Methane: Development and Prospects in Asia

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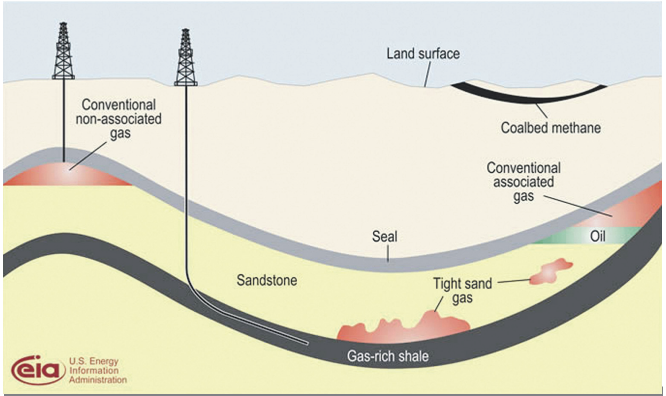
Schematic Geology of Natural Gas Resources



Natural gas is the fuel of choice in many countries since it is cheap and it burns far more cleanly than coal. What is surprising is that, despite the fact that natural gas resources are dwindling, the coal mining activities in some countries still vent high quality natural gas needlessly into the atmosphere. This is coalbed methane (CBM) - methane leaking from coal mines. However, things are changing, the news is spreading and more and more coal companies are beginning to realise that what used to be a fire hazard is now a potential source of additional power. Add to that the fact that methane has a global warming potential of 21 times that of CO_2 and now you have a tempting target for a greenhouse gas reduction project.

There are huge quantities of CBM available worldwide. The US Department of the Interior estimates that 25 trillion cubic feet (tcf) of natural gas could be obtained from the Powder River Basin in the US alone. Similarly large resources and potential CBM hotspots have been identified in Australia, China, India, Ukraine, Romania and Russia.

So why isn't everyone capturing CBM? Because it is just not that simple. No two CBM projects are the same. Some mines have minimal methane whereas others have so much gas in situ that the value of the gas within the coal seam exceeds that of the coal. Money must be invested to determine whether each individual CBM project is viable. Gas does not stay trapped underground unless it is deep and covered with non-porous rock. Thus, capturing CBM involves deep drilling through difficult substrates. Even then the gas is not sitting in one nice little pocket waiting to be withdrawn. It is spread through the coal which itself may be distributed in non-uniform seams which are deep and widely dispersed underground. Determining where the gas is positioned and how to get to it involves a significant amount of investment in pre-drilling, investigation and modelling. On top of that is the cost of drilling rights, land use rights and the impact assessment for the local habitat. Therefore, before a whiff of gas hits the surface, a large investment is needed. Some companies are spending millions on explorative studies in advance of any CBM production.

Despite the risks, significant amounts of money can be made, especially from virgin coalbed methane (VCBM), where high concentrations of methane from untouched mines are obtained by deep and targeted drilling. VCBM projects generally happen in advance of coal mining or even instead of, if the coal itself is deemed to be not worth mining. High quality methane can be sold directly to natural gas pipelines, depending on the availability of a local gas system to supply. Due to the geography of mines and their proximity to pipelines and users, the most common use of CBM in the US is for gas pipelines. The US has a large existing gas infrastructure and so new projects find a ready market waiting for them. This is not the case in other areas such as Australia where gas projects must identify and secure long-term gas sales agreements. China is working to maximise rapid CBM development by building pipelines in targeted areas and providing grants and other benefits (see below).

Not all CBM is at a high enough concentration to replace natural gas in pipelines or turbines. Coal mine methane (CMM) is released before and during coal mining activities (as a safety measure) and, although it is not suitable for introduction to a gas pipeline, it can still be used locally. CMM systems are commonly determined by the kind of end-user available. Low grade methane will be used at the mine for drying or heating systems. More concentrated gas may

Workers extract shale gas at Chesapeake's natural gas site in Fort Worth, Texas Photo: Matt Nager/Bloomberg
http://www.telegraph.co.uk/finance/newsbysector/energy/oilandgas/7199259/Gazprom-scorns-shale-gas-as-danger-to-drinking-water.html

be sold to local industry or for local heat and power if there are suitable commercial areas nearby. In China, there are more than ten town gas projects where the gas from operational or abandoned mines is delivered to over 100,000 households in each project.

Even ventilation air methane (VAM -- the methane that flows through the access and ventilation shafts of the mine), at concentrations of 1% or below, can be used to provide heat or power. Some specially designed VAM systems can cope with methane concentrations as low as 0.6%, turning leaking ventilation air into energy via purpose-built lean-burn engines or oxidation processes. VAM systems are currently being developed in the US and China. However, perhaps the most ingenious VAM system was that used in the Vales Point Power Plant in NSW Australia where the ventilation air from the disused mine (0.3% at a rate of 250 cubic metres per second) was fed via a 500-metre pipe and fan system from the mine shaft into the intake air for the coal-fired plant. The simple system provided free over-fire fuel for the coal-fired plant, reduced the coal intake and avoided 25 kilo-tons of carbon dioxide equivalents per year.

So there are many ways of using the different concentrations of methane released from unmined coal, working mines and even abandoned mines. The high initial investment gamble is still the major hurdle that most developers face. As times change, however, and the search for new clean sources of energy intensifies, CBM projects start to become more feasible. As a result, we are now seeing a sudden surge in CBM project development in Asia. To date, the Asian Development Bank has invested $200 million in CMM projects in China. In 2006, China obtained only 3% of the country's natural gas from CBM but aimed to increase this to 10% by 2010. Although it does not appear to have achieved this yet, the activity is increasing with plans to double the current output of 7.5 bcm (billion cubic metres) by 2015. This would still be nowhere near the shortfall of 160 bcm expected to arise over the next five years in the country.[1] In order to promote CBM projects, the development companies have been "showered with tax breaks and subsidies", including waived import duties on equipment.[2] $375 million is being invested in two main gas pipelines for CBM transmissions. The Chinese National Development and Reform Commission have issued a notice on price management which ensures that electricity produced by CBM/CMM operators is given priority to the grid.[3]

In early 2011, the first five CMM blocks in Jharia and East-Bokari coalfields in India were offered for tender. The project is a joint initiative between Coal India Ltd, India's Coal Mine Planning and Design Institute and the US EPA's Coalbed Methane Outreach Program (CMOP).

Indonesia is thought to represent one of the largest CBM resources in the world with a potential of over 450 tcf. This is more than double the country's natural gas reserves. The CBM Asia Development Corp, a Canadian-based company working in Indonesia, aims to secure just under 60,000 hectares in the South Sumatra Basin and 76,000 hectares in the Kutai Basin in East Kalimantan. Together these projects represent almost $9 million in exploration investment. The American company, General Electric, has also invested in a 1 megawatt (MW) pilot plant in Sangata field in East Kalimantan to demonstrate CMM to power using GE gas engine technology with a view to branching out to 21 CBM production sharing contracts in the future. Commercial operation is predicted for late 2011. On 24 June this year, British Petroleum confirmed that it has signed up for four CBM projects in the Barito Basin of South Kalimantan.[4]

In many situations, commercial investment and government subsidies are still not enough to make CBM projects viable and this is where greenhouse gas funding and carbon credits

Natural Gas Separation Plants (Map Ta Phut, Rayong, Thailand) Taken on 8 October 2007 by Love Krittaya

http://commons.wikimedia.org/wiki/File:Natural_gas_separation_plants.jpg

Cavitation Burning Pit, San Juan Basin in New Mexico

Courtesy http://www.energyjustice.net/naturalgas/cbm

come into play. For example, the 120 MW Jincheng project in China's Shanxi Province, the largest CBM project in the world, would not have been viable without carbon credits. Carbon credits have also been banked for smaller CMM projects including abandoned mine methane (AMM) projects such as at the Cambria 33 mine in Pennsylvania. Methane from the abandoned mine is collected, upgraded and then injected into the local natural gas pipeline. Another carbon offset project is due to commence operation in July 2011 at the Enlow Form mine in southwest Pennsylvania using VAM technology to stop the equivalent of 190,000 Mt of CO_2 seeping from the largest underground coal mine in the US. In the UK, "green energy credits" are being obtained from the combustion of recovered AMM methane in internal combustion engines (3.2 MW in total) at the closed Gedling Colliery and is one of nine AMM projects run by Alkane Energy in the UK. Other financial incentives such as the feed-in tariff used in Germany guarantees a minimum energy sale price from CMM projects.

Other countries in Asia with no current CBM activity are beginning to show interest. Methane deposits have been identified in coalfields in the Mae Lamao Basin in Thailand and Vietnam is said to have 25 gassy mines. Scoping studies are underway.

The major barriers to CBM appear to be the lack of an appropriate policy framework, limited and tentative investment, and the need for more widely available expertise. International initiatives such as the US EPA's CMOP are improving the coordination between developers, financiers and those wishing to take advantage of what can only be regarded as one of the ultimate versions of clean energy from waste.

This was adapted from IEA Clean Coal Centre publications:

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L. L. Sloss, *Coalbed Methane Emissions: Capture and Utilization*. CCC/104 (London, IEA Clean Coal Centre, Nov. 2005), 56pp.

With updated information from:

United States Environmental Protection Agency, *Coalbed Methane Outreach Program* at <www.epa.gov/cmop>.

CMB Asia Development Corporation at <www.cbmasia.ca>.

[1] "China CBM Output Tops 20 Bln Cubic Meters by 2015", *Chinamining.org*, 31 May 2011 at <http://www.chinamining.org/News/2011-05-31/1306803565d46052.html>.

[2] "China Looks to Coal Bed Methane", *Bloomsberg Business Week*, 3 Jan. 2008 at <http://www.businessweek.com/globalbiz/content/jan2008/gb2008013_784582.htm>.

[3] IEA, *Energy Sector Methane Recovery and Use: The Importance of Policy* (Brochure), 2009 at <http://www.iea.org/papers/2009/methane_brochure.pdf>.

[4] "BP Accesses Four Coalbed Methane Production Sharing Contracts in Indonesia", *Ordons.Com*, 1 Apr. 2011 at <http://www.ordons.com/asia/southeast-asia/24193-bp-accesses-four-coalbed-methane-production-sharing-contracts-in-indonesia.html>.

Four Decades of Bad Energy Policy (and counting)

Michael Lynch, President and Director of Global Petroleum Service, Strategic Energy and Economic Research Inc

Since soaring energy usage in the late 1960s led to fears about resource depletion and rising pollution, energy policies have become much more prominent, but with minimal success and even negative impacts. Sadly, governments appear to be repeating these errors, due primarily to very simplistic and misguided analyses.

Like any government policy, energy policy suffers from 'regulatory capture' where politicians use energy policies as an excuse to subsidize their friends and supporters, most ridiculously in the case of the US politician who insisted that the US government buy coal from his district for US soldiers stationed in Berlin to protect them from vulnerability to Soviet disruptions of supply. The 1985 US Food Security Act, which meant higher food prices and stockpiles of surplus food, was similar both in using security as a rationale and creating market disequilibria.

Fear of resource depletion has often driven energy policy, despite the fact that scarcity is typical only for renewable resources. In one curious case, President Carter pursued the economically efficient policy of deregulating US natural gas prices, but he did so in order to conserve what he considered to be a rapidly depleting resource. This misguided thinking led both the US and the International Energy Agency to discourage use of natural gas for power generation, arguing it should be used for 'noble' purposes such as home heating and petrochemical production, and thus increasing the use of coal for power generation.

Many other policy-makers in the 1970s believed that markets were myopic, as various academic studies supposedly 'proved' that shortages would only worsen in the future, and governments needed to support energies that were not yet economic, such as petroleum in the Canadian Arctic, US shale oil and fast breeder reactors in several countries. Not only did they not prove imminently viable, but even after three decades, none of these is economic.

Similarly, fears about 'crowding out' from soaring demand have been primarily driven by transient periods of market tightness, where asset bubbles have been misinterpreted as representing a 'new paradigm' rather than cyclical behaviour. This was true of the 1920s US stock market, the 1980s Japanese 'bubble economy, the dot-com industry in the 1990s, and various real estate markets in recent years. Commodity cycles in the 1970s and now, have been misinterpreted as representing 'peak oil', ever-rising mineral prices, imminent long-term hunger, etc.

Energy security is the most obvious example of governments learning the incorrect lessons from history. The 1941 Anglo-American oil embargo against Japan made many think that control of oil supply by domestic corporations would provide energy security. The Second Arab Oil Embargo in 1973/74, which was targeted against the US, when much of the internationally traded oil was still controlled by US oil companies, revived these fears. Yet there was little evidence that these companies acted to favour the US-or any other country. Still, the increase in control of oil by state mineral enterprises made many think that 'good relations' would be needed to acquire supplies in the future, and diplomacy, military sales and aid were use to curry such.

Of course, since the 1979 Iranian Oil Crisis, when oil exporters largely ceased to sell oil to their former operators, the market has become atomized, and there are numerous sellers and large amounts of oil sold on the spot market. As a result, it has become almost impossible to deny supplies to any buyer, or prevent a supplier from finding customers. For example, sanctions against Iran have prevented some companies from investing there, but the country has had no trouble maintaining sales. Sanctions against Iraq succeeded only because of military force.

In fact, the primary threat to energy supplies since World War II has come from exogenous events that disrupted operations in producing areas, such as the Iranian Revolution, the two Gulf Wars, or the PDVSA strike against Hugo Chavez. All of these could be addressed only by having surge capacity available, something finally achieved in the 1980s. Sadly, the effectiveness of these strategic reserves has been reduced by the decision of governments and the IEA to use them to replace "shortages" rather than alleviate price spikes.

And this highlights another major mistake: governments' tendency to focus on quantities to the exclusion of prices. Again and again, governments have paid for 'access' to oil supplies, paying above-market prices -- usually in the form of thinly-disguised foreign aid -- to be allowed to develop oil fields or sometimes just to buy oil. France, Korea, Japan, China and others have all pursued this policy egregiously, and with minimal effect since oil has remained available to all buyers on open markets.

Aside from the perverse logic involved in paying 'extra' for the privilege of buying supplies at market prices, a change in regime or political instability will inflict losses on the 'favoured' customer. A new government will almost certainly regard deals made by the previous regime as corrupt, and seek to modify or cancel them. Again, the accession of the Ayatollah Khomeini's government serves as a primary example, where the good relations that the US had with the Shah of Iran turned into lengthy, bitter enmity.

Tower for drilling horizontally for natural gas into the Marcellus Shale Formation. Photo taken from Pennsylvania Route 118 in eastern Moreland Township, Lycoming County, Pennsylvania, USA

http://commons.wikimedia.org/wiki/File:Marcellus_Shale_Gas_Drilling_Tower_1.jpg

Finally, efforts to promote technologies that are deemed 'improved' in one or many facets over existing products have repeatedly proved futile. Again, politics plays a major part; the US government has spent billions over the years on fluidized bed coal reactors to no effect other than to satisfy politicians from coal-producing areas. Shale oil, fast breeder reactors and electric cars have all been funded or subsidised because of fears about petroleum or uranium scarcity, yet the fuels remain abundant and the government-anointed technologies remain unattractive.

In fact, the most successful new technologies of the past three decades have been developed privately, with minimal government involvement. These include the hybrid-electric vehicle, natural gas turbine and shale gas. The latter two promise to greatly reduce emissions worldwide, far more than all of the expensive renewable technologies.

Many resort to the argument that subsidising renewable energies will accelerate their development, but this appears specious. By encouraging manufacturers to focus on technologies that are not viable in mass markets, they do not promote the development of new technologies. And by creating false hopes for progress, they then damage the reputation of those technologies.

There is naturally a desire on the part of policy-makers and politicians to "do something" about high energy prices, but most would profit from applying the surgeons' credo: First, do no harm.

Recent Events

28 June, "Energy Economics Modelling: Application to the Natural Gas Sector" Seminar

Due to its lower carbon content than other fossil fuels, natural gas is usually viewed as a fuel with good prospects in a carbon-constrained energy market. Indeed, many studies have highlighted its potentially pivotal role. Numerous economic and policy questions are connected with this unevenly distributed, non-renewable source of energy that involves costly infrastructure. In this seminar, Assistant Professor Oliver Massol, from the renowned French Institute of Petroleum School, presented the results of two models which demonstrated the capabilities of modelling strategies to generate new insights and policy-relevant recommendations. One model examined the motives of the Gas Exporting Countries Forum, while the other examined the planning problems faced by a small resource-rich economy that must choose a gas monetization policy including LNG exports and/or gas-based industries.

22 June, "China, Oil and Global Politics" Seminar

Dr Philip Andrews-Speed, Associate Fellow of Chatham House, sought to demystify Chinese energy policy and unpack oft-made remarks and discussion about Chinese national oil companies (NOCs) and their supposed neo-colonization of Africa. He adopted a broad and global approach to evaluating China's "fragmented authoritarianism" and suggested that multiple players in China's energy sector resulted in multiple motivations. He highlighted that security of energy supply is a top priority, but that the perennial challenge for the Chinese government (as well as for most other governments) is keeping energy at the top of the political agenda. He also discussed Sino-Russian, Sino-Kazakh and Sino-African relations in some detail, with particular focus on oil pipelines and upstream NOC investments, mergers and acquisitions.

Dr Philip Andrews-Speed

21 June, "A Glimpse into the Energy Future" Seminar

The Energy Market Authority of Singapore (EMA) and ESI co-organized the 2nd EMA Distinguished Speaker Programme in which Dr. Fatih Birol, Chief Economist at the International Energy Agency (IEA) presented highlights from the IEA's *World Energy Outlook 2011*, due to be released in November. A main topic discussed in this volume is the implications of the continuing unrest in the Middle East North African (MENA) region. He also spoke about how rising oil prices pose inflationary risks and represent significant redistribution of wealth from oil importers to exporters. He added that dangerously high oil prices could derail economic recovery. Dr. Birol was also deeply concerned about global climate change, and the "socially, economically and morally unacceptable" energy poverty that still exists in Sub-Saharan Africa and India.

21 June, "Are We Entering a Golden Age for Gas?" Seminar

Dr. Fatih Birol, Chief Economist of IEA, delivered a second presentation on 21 June on IEA's Special Report, *Are We Entering a Golden Age of Gas?* He discussed the combination of factors that must be met before the industry can usher in a "Golden Age of Gas", including ample availability of gas (much of it unconventional) which lowers average gas prices; implementation by China of an ambitious policy for gas use; lower growth of nuclear power due to renewed debate and uncertainties; and more use of natural gas in road transport. He highlighted the roles of China and Asia-Pacific players such as Australia and Indonesia in driving the demand for LNG. Dr. Birol also said that Singapore may well play the role of a regional hub, facilitating trade in this region. In the Q & A session following his presentation, Dr Birol fielded questions pertaining to gas-to-liquid technology, bottlenecks in global gas infrastructure and how long it will take before LNG is traded like oil.

Dr Fatih Birol in discussion with the attendees.

2 June, “Signals and Signposts: Further Thoughts on Shell’s Energy Scenarios to 2050" Seminar

Dr. Cho-Oon Khong, Chief Political Analyst of the Global Business Environment Team at Shell International presented Shell’s Energy Scenarios to 2050. Dr Khong explained that these scenarios are fundamental to Shell’s strategic planning and also contribute to the global public debate on energy and the environment. Since 2008, there has been a financial crash, the deepest economic slump in 70 years, and a patchy and fragile recovery including a range of dramatic developments affecting a shifting energy landscape, from the increasing prominence of natural gas, to most recently, political transitions in the Middle East and a nuclear crisis in Japan. Dr Khong outlined what these all meant for the global energy system and the signposts pointing the way towards a post-financial crisis world.

30 May, “Indonesia’s Green Growth Prospects: The Role of Renewable Energy and Carbon Capture and Storage” Seminar

Dr Pradeep Tharakan, Climate Change Specialist in the Southeast Asia Energy and Water Division of the Asian Development Bank (ADB), looked at the potential to curb emissions from Indonesia’s energy sector by means of large scale geothermal energy projects, carbon capture and storage (CCS) and renewable energy. He explained that Indonesia has the largest geothermal potential in the world, with over 27,000 MW of capacity. However, cost gaps, exploration risks and uncertainties, and lack of pricing efficiency and transparency, among other problems, hinder development of these energy resources. Citing ADB’s Geothermal Power Development Program initiated in Indonesia, he described the financing challenges and structural constraints faced, such as the need to declassify geothermal as a mining activity so as to gain access to key geothermal sites in forested areas. As for CCS, Dr Tharakan argued that it is important that coal-fired plants be at least open to retrofits, and that countries expanding coal-fired plant capacities should consider source-sink matches in the region and options to justify the costs of CCS such as through enhanced oil recovery or gas processing. The main obstacles are lack of financing and lack of expertise in implementation.

24-25 May, “National Energy Efficiency Conference 2011”

The National Energy Efficiency Conference, organised by the National Environment Agency, Economic Development Board and the Energy Market Authority, is a key annual event of the Energy Efficiency National Partnership. ESI is one of eight supporting organisations. The event brought together energy efficiency experts and industry energy professionals to share best practices and success case stories. On Day 2, ESI Senior Fellow Dr Elspeth Thomson moderated the “Waste Heat Recovery and Management” breakout track. ESI Energy Analyst, Ms. Catrina Yeo, gave a presentation on industrial waste heat and management strategies.

11 April, “ExxonMobil’s Outlook for Energy: A View to 2030" Seminar

Mr. Rob Gardner, Manager for the Energy and Economics Division of the ExxonMobil Corporate Strategic Planning Department examined two major shocks that occurred in the first quarter of this year: uprising and unrest in the MENA region and the Fukushima disaster. Beyond these, the issues discussed in his presentation were wide-ranging, spanning from the cost of carbon in climate policy, electricity demand and base-load capacity, carbon capture and storage and overcoming scale and other barriers to gas substitution in countries which pre-dominantly use oil or coal for power generation.

23 March, “Carbon Dimensions” Seminar

The first speaker at this event, co-organised by ESI and the High Commission of Canada, was Dr Don Lawton, Professor of Geophysics and Chair in Exploration Geophysics in the Department of Geoscience at the University of Calgary. He gave a detailed presentation on carbon capture and storage research and projects in Canada which has formally committed to reducing GHG emissions to 17% below the 2005 level by 2020. The second speaker, Mr Rahul Kar, Sustainability Advisory, KPMG Services Pte Ltd, focused on the market-based Clean Development Mechanism (CDM) for raising financing for GHG emission reduction projects. He provided insights into the policy framework, sectors covered, financing instruments and processes involved under the CDM and also highlighted the success of CDM in the Southeast Asian Pacific Region.

Dr Don Lawton

Mr Rob Gardner

Dr Cho-Oon Khong

18 March, "Policy Responses to Climate Change and Energy Security Post-Cancun: Implications for the Asia-Pacific Region's Energy Security" Conference

This conference, organized by ESI's Energy Security Division, brought together different perspectives on climate and energy security following the Cancun climate talks held in December 2010. In his keynote address, Professor Simon Tay, Chairman of the Singapore Institute of International Affairs, offered his perspectives on post-Cancun policy responses from the Asia-Pacific through an analysis of oil price fluctuation in light of, on the one hand, heavy, sustained demand from Asia and on the other, the Middle East conflicts. He argued that despite the Fukushima disaster, many countries cannot take nuclear energy off the menu. At the same time, he urged governments to come clean with the public in terms of information about existing and planned nuclear power plants. The conference involved participants from various academic institutions, government offices and companies from the Asia-Pacific Region, namely from Indonesia, Malaysia, Vietnam, China, India, Japan, South Korea, Australia and Singapore.

14 March, "Investigating the Role of Speculation in Recent Crude Oil Price Change" Seminar

Visiting scholar to ESI, Dr. Yue-Jun Zhang from the Center for Energy and Environmental Policy Research at the Beijing Institute of Technology, addressed the relationship between speculators' positions and crude oil futures. His analysis indicates that contrary to popular belief, the actions of speculators are not significant drivers of crude oil price changes. In fact, speculators follow crude oil price changes with the positions of speculators being linear in oil prices. However, the data supports the hypothesis of weak non-linearity between the positions of speculators and oil prices. Furthermore, the linear relationship between the magnitude of the positions taken and the different quantiles oil returns is unstable.

14 March, "Azerbaijan and the Challenge of Energy Security: The Geopolitics of Energy Exports from the Caspian Region" Seminar

Ms Gulmira Rzayeva, Research Fellow at the Center for Strategic Studies under the Office of the President of the Republic of Azerbaijan, explained why Azerbaijan is pursuing a policy of "harmonisation" of interests towards its neighbours, given the country's location between Russia and Iran, and near Turkey and Europe. She noted that her government envisaged participation in all possible gas-export routes, including East-West, North-South and South-North, as well as the Southern Corridor project (Nabucco).

10-11 March, "China-Middle East Political and Energy Relations" Conference

The Middle East is the single largest supplier of oil and LNG to China. Thus, the purpose of this conference, organised by ESI's Energy Security Division, was to examine China's political and energy relations with the region and to learn what were the perspectives of the neighbouring countries on China's growing influence in the region. There were speakers from China, Taiwan, Hong Kong, Singapore, the Middle East's Arab and non-Arab states (Iran and Turkey), the United States, Russia and Europe. The attendees came from academia, government, the private sector and the diplomatic corps.

8 March, "Russian Nuclear Education and Training: Sharing Experiences with Potential Recipients of Russian Nuclear Power Technology" Seminar

Professor Vladimir Artisyuk, Vice-Rector of Science and Foreign Affairs at the Central Institute for Continuing Education and Training (CICET), JSC "Atomic Energy Power Corporation", Russian State Atomic Energy Corporation (ROSATOM), shared his views on Russian nuclear education and training. He described his country's experience with nuclear energy, including the specifics of certain Russian nuclear reactors, and shared his insights on Russian university education and its system of continuing education and training for the operators of nuclear power plants. He also presented the results of a survey of Russian universities responsible for the education of nuclear specialists from the fields of reactor physics, thermo hydraulics, civil engineering and electrical engineering.

4 March, "India and Strategic Challenges of the 21st Century: The Geopolitics of the Land between North Africa and East Asia" Eminent Lecture

Air Marshall P K Mehra outlined the security environment of India and the Asian region as a whole, touching on the issues of political diversity and instability, demographic diversity, varying economic growth patterns and varying energy resource availability.

3 March, "Is Climate Change a National Security Issue?" Eminent Lecture

The guest speaker at this event, jointly sponsored by ESI and the Rajaratnam School of International Studies, was General (Ret.) Paul Kern, Senior Counsellor of the Cohen Group based in Washington, DC. General Kern questioned if climate change was a national security issue from the viewpoint of the US Department of Defence, where he had previously served as Commanding General of the Army Materiel Command. He argued that the connectivity among climate change, energy and water should receive much more attention by governments in their national security planning.

2-4 March, "Energy Economics" Course

Professor Carol Dahl, Director of the Colorado School of Mines, Division of Economics and Business in Golden, Colorado and the French Institute of Petroleum in Paris Joint International Program in Petroleum Economics Management, returned to ESI for a second time to deliver a training course on "Energy Economics". Over three days, she provided an overview of energy demand and supply, the regional and global structures of oil, gas, coal and electricity markets, and a review of the typical economic indicators used to measure energy security. The course was well attended by policy makers, scholars and industry practitioners with diverse interests in energy economics.

Staff Publications & Media Contributions

Internationally Referred Journal Articles

Ang Beng Wah, Zhou Peng and Alex Tay, "Potential for Reducing Global Carbon Emissions from Electricity Production - A Benchmarking Analysis", *Energy Policy* 39 (2011), pp. 2482 -489.

Guy C.K. Leung, Raymond Li and Melissa Low, "Transitions in China's Oil Economy, 1990-2010" *Eurasian Geography and Economics*, vol. 52, no. 4 (2011): 483-500.

Elspeth Thomson, "China's Nuclear Energy in Light of the Disaster in Japan", *Eurasian Geography and Economics*, vol. 52, no. 4 (2011): 464-482.

Edited Volumes

Hooman Peimani, (ed.) *The Challenge of Energy Security in the 21st Century: Trends of Significance* (Singapore: ISEAS Press, 2011), pp. 178.

Elspeth Thomson, Youngho Chang and Jae-Seung Lee, (eds). *Energy Conservation in East Asia: Towards Greater Energy Security* (Singapore: World Scientific, 2011), pp. 390.

Other Publications

Hooman Peimani, "What Lies Ahead," *World Pipelines* 11, no. 6, June 2011.

Hooman Peimani, "Fukushima's Incident & Energy Security in Asia-Pacific," *Journal of Energy Security*, May 2011.

Hooman Peimani, "Biofuel Production: From Environmental Mistake to Environmental Solution," *Akshay Urja 4* (Delhi), Issue 9, May 2011.

Hooman Peimani, "Politicking over Central Asia's Pipelines," *Journal of Energy Security*, March 2011.

Tilak K. Doshi contributed to "Are We Entering a Golden Age of Gas: Development of Regional Gas Trade in Southeast Asia", *International Energy Agency Special Report* (Paris: OECD/IEA, 2011).

Staff Presentations

21 June 2011, Neil Sebastian D'Souza presented, "The 'Asia Premium' in Crude Oil Markets and Energy Market Integration," at the *Final Economic Research Institute for ASEAN and East Asia (ERIA) Energy Market Integration Working Group Meeting*, held in Jakarta.

21 June 2011, Chai Kah Hin presented, "Systems Approach to Industrial Energy Efficiency", at the *34th International Association for Energy Economics (IAEE) International Conference*, held in Stockholm.

18 June 2011, Chang Young-Ho presented, "Forest Conservation and Deforestation: The Economics of Global Warming and Climate Change", at the *2011 Bayer Eco-Camp*, held in Singapore.

13 June 2011, Tilak K. Doshi presented, "Development Strategies, Emission Profiles and Policy Actions: Singapore", at the *Climate Change and Green Asia Workshop*, held in Beijing.

9 June 2011, Chang Young-Ho presented, "An Integrated Natural Gas Market in Asia: Policy Evaluation and Welfare Implications", at the *Asian Energy Summit* organized by the Independent Power Producers Association, held in Sri Lanka.

7 June 2011, Hooman Peimani presented, "Prospects of Development of Small Underground Nuclear Reactors in Singapore", at the *Small-Power Nuclear Plants Training Workshop for Foreign Specialists* organised by Rosatom's Central Institute for Continuing Education and Training, held in Obninsk.

6 June 2011, Hooman Peimani presented, "From Myth to Reality: Asia's Nuclear Energy Prospect in the Post-Fukushima Era", in the "Prospects of Nuclear Education in the Countries Embarking on or Expanding Their Nuclear Power Programmes" section of the *3rd International Forum ATOMEXPO 2011*, held in Moscow.

31 May 2011, Samir Nazir presented, "Energy Production and Its Usage", held at the National Library Building, Singapore.

27 May 2011, Chang Young-Ho and Euston Quah presented, "Low Carbon Economy and Carbon Pricing: A Bottom-up Approach", at the *Fudan University-NTU Joint Workshop*, held in Shanghai.

25 May 2011, Catrina Yeo presented, "Industrial Waste Heat", at the *Singapore National Energy Efficiency Conference 2011*, held at Suntec Convention Hall, Singapore.

23 May 2011, Hooman Peimani presented, "Nuclear Power Development in Asia Post Japan Nuclear Plant Incident", presented at the *Second Annual DB Access Conference 2011: Opening Doors, Unlocking Value*, organised by Deutsche Bank, Singapore.

18 May 2011, Catrina Yeo presented, "Realising Industrial Energy Efficiency: A Motivation-Capability-Implementation-Results Framework", at the *International Conference for Applied Energy 2011*, held in Perugia, Italy.

17 May 2011, SK Chou presented, "LTCC based Vapourising Liquid Microthruster for Microspace Applications", at the *International Conference for Applied Energy 2011*, held in Perugia, Italy.

12 May 2011, Hooman Peimani presented, "Global Energy Security after the Fukushima Accident of March 2011", at *Our Changing Ocean: Innovation & Opportunity International Symposium*, organized by the Korea Maritime Institute, Seoul.

12 May 2011, Tilak K. Doshi presented, "Asia Gas Scenarios", at the *Energy Industries Council* (EIC), held in Siemens Center, Singapore.

5 May 2011, Tilak K. Doshi presented, "How Can Better Power Grids and Gas Pipelines Contribute to ASEAN Integration?: What Are the Challenges and Policy Recommendations?", at the *ASEAN Roundtable 2011 Enhancing ASEAN's Connectivity*, held at the Shangri-La Hotel, Singapore.

19 April 2011, Neil Sebastian D'Souza presented, "The Energy Saving Potential of Singapore's Road Transportation Sector," at the *3rd Economic Research Institute for ASEAN and East Asia (ERIA) Working Group Meeting*, held at the Peninsula Excelsior Hotel Singapore.

18 April 2011, Belinda Salim presented, "Singapore's National Goals for Reducing Energy Intensity and Capping CO_2 Emissions", at the *3rd Economic Research Institute for ASEAN and East Asia (ERIA) Working Group Meeting*, held at the Peninsula Excelsior Hotel, Singapore.

18 April 2011, Michael Quah presented, "Integrated Sustainability Solutions (ISS) at NUS", at *Global Trends in Energy Technologies for Industries, A*STAR – IEA/IETS Workshop*, held at Fusionopolis, Singapore.

18 April 2011, Michael Quah presented, "Integrated Sustainability Solutions (ISS)", at the *Technology Commericalization Forum 2011*, held at Kent Ridge Guild House, National University of Singapore.

1 April 2011, Michael Quah presented, "Energy Security, Environmental Sustainability, Economic Development: Some Learnings from Singapore?", at the Energy, Environmental and Chemical Engineering Dept. of Washington University, St. Louis, MO, USA.

23 March 2011, Tilak K. Doshi presented, "Graduation and Deepening in Asia in the Post-Kyoto World" at the Institute of International Relations, Nihon University, Mishima, 2011.

18 March 2011, Chang Young-Ho chaired a session at ESI's *Policy Responses to Climate Change and Energy Security Post Cancun: Implications for the Asia-Pacific Region's Energy Security Conference*, held at the Orchard Hotel, Singapore.

18 March 2011, Nur Azha Putra Bin Abdul Azim and Nicholas Koh presented, "Singapore Climate Change Strategy: Turning Challenges into Opportunities", at ESI's *Policy Responses to Climate Change and Energy Security Post Cancun: Implications for the Asia-Pacific Region's Energy Security Conference*, held at the Orchard Hotel, Singapore.

18 March 2011, Hooman Peimani presented, "Climate Change, Energy Security, and Conflict?", at the *Policy Responses to Climate Change Post-Cancun: Implications for the Asia-Pacific Region's Energy Security Conference*, held at the Orchard Hotel, Singapore.

10 March 2011, Hooman Peimani presented, "China-Central Asia: Political and Energy Relations", at *ESI's China-Middle East Political and Energy Relations Conference*, held at the Orchard Hotel, Singapore.

Media Contributions

Catrina Yeo, "Re-thinking Energy Efficiency Potential", *Singapore International Energy Week 2011 Website*, 17 June 2011.

Melissa Low, "What the Golden Age of Gas Means for Singapore", *Singapore International Energy Week 2011 Website*, 17 June 2011.

Catrina Yeo, "Energy Efficiency: Look at the Whole Picture", *Straits Times*, 13 June 2011.

Tilak K. Doshi quoted in "OPEC Post-Mortem", *Foreign Reports Inc.*, 10 June 2011.

Michael Quah, interviewed by *Channel News Asia Prime Time Morning Live* on "The Future of Nuclear Power", 9 June 2011.

Hooman Peimani quoted in "Expert Says Nuclear Energy Safe, BNPP Decommissioning Should be Reconsidered" by Ellalyn De Vera, *Manila Bulletin* (Online Ed.), 7 June 2011.

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New Staff

Fellow

Dr Wu Fulan joined ESI as a Fellow in June 2011. She obtained her PhD in Economics in April 2010 from the National University of Singapore. The title of her thesis was "Imperfect Information and Quality Signalling". Before joining ESI, she was a senior lecturer at the Singapore Institute of Commerce. She did her Masters in Economics at Zhejiang University and her Bachelors in Economics at Yangtze University. She is currently working on an ENPEP model which is used for energy demand and supply analysis. Her main research interest is electricity markets.

Energy Analysts

Augustin Boey joined the Energy Studies Institute as an Energy Analyst in June 2011. Prior to joining full-time, Augustin interned at ESI, where he aided research in the field of energy security. During his undergraduate years, he took an active interest in issues and modules relating to environmental change, urban sustainability and the political economy of eco-development. He holds a Bachelor of Social Sciences in Geography (First Class Honours) from the National University of Singapore and will start an MA in Geography at NUS in 2012. His current research interests include the political economy of sustainable development, green governance and politics, eco-friendly buildings, green labelling and climate change.

Wong Rui Qing Rachel joined the Energy Studies Institute as an Energy Analyst in July 2011. She holds a Bachelor of Social Sciences (Honours) in Geography and Minors in Geographical Information Systems (GIS) and Sociology. Before joining ESI, she undertook GIS internships at Deloitte Petroleum Services Group (2009) and the Singapore Land Authority (2010). Her research interests include solar photovoltaic systems and sustainability issues.

Nahim Bin Zahur joined the Energy Studies Institute as an Energy Analyst in July 2011. Prior to joining full-time, Nahim interned at ESI, where he conducted research on climate change finance, modelling of climate targets and emissions trading schemes. He holds a Bachelor of Social Sciences in Economics (1st Class Honours) with a double major in Political Science from the National University of Singapore. His current research interests include climate change economics and carbon markets.

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