dioxide (the main contributor to climate change) less sulphur dioxide (the primary precursor of acid rain), less nitrogen oxides (the primary precursor of smog) and less particulate matter (tiny soot that can affect health and visibility) than either oil or coal. Because of its high energy density, it is much more efficient to transport natural gas than electricity. Approximately 90% of natural gas produced is delivered to customers as useful energy, whereas if gas (or any other fuel) is converted to electricity and the electrical energy is then transported, less than a third of the energy in the fuel gets to the end customer. The inefficiency of the latter method of energy transport is a result of two factors: unrecovered heat from centralised power generation (up to 66%) and grid losses (often about 10%). In terms of energy transport, therefore, one could either, for about the same amount of money, build a high-voltage transmission line to transport electricity (generated from gas combustion) or a gas pipeline which could transport 50 times the energy to end users who would then have the option of burning the gas to generate power or directly for some other use. Unlike electrical energy, natural gas can also be easily stored for later use.

Piped gas is thus a convenient and efficient means of energy distribution that can be used to supply the fuel for local power generation needs.

● Gas in the power sector – benefits of the emerging decentralised generation paradigm

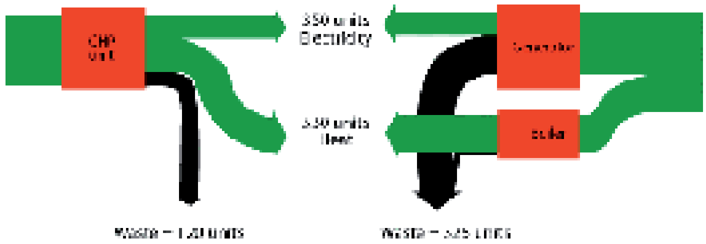
The building momentum for DE is a result of governments, multilateral institutions, financiers, insurers, utilities and, especially, end-users recognising the many benefits of using the premium fuel of gas in DE applications, rather than in less efficient power-only combined-cycle gas turbine (CCGT) applications. The most important benefits are outlined below.

Efficiency gains

Natural gas can be used to generate power in two ways: with or without heat recovery. To date the great majority of natural gas around the world has been burned in less efficient power-only applications. *Figure 1* shows how cogeneration (or combined heat and power – CHP) improves efficiency and environmental performance by putting to use heat that is normally wasted. With CHP only 120 units of the initial gas is wasted to meet energy demand. This is in contrast to separate production of thermal and electrical energy where almost three times as much energy is wasted to meet the same demand. The same principle applies no matter the scale.

Most CCGT applications cannot capitalise on the useful heat that is a by-product of combustion because they are typically sited too far from where thermal energy is required (either buildings where it could be used for space heating or factories where it could be used for process heat). If, on the other hand, the gas is burned to generate power on the same site as where heat is required, much more of the useful energy in the fuel can be put to use. These efficiency gains can be translated directly into economic gains because every unit of gas saved equals a unit that does not have to be purchased or a unit that can be sold elsewhere. As a general rule it requires roughly seven times more energy to move a megawatt-hour (MWh) of electricity as it does to move a MWh of chemical energy – fuel. But it also takes seven times more energy to move a MWh of thermal energy than to move a MWh of electricity. It therefore takes 49 times more energy to move a MWh of thermal

COGENERATION VERSUS SEPARATE PRODUCTION OF HEAT AND ELECTRICITY



Source: WADE.

ABOVE
Figure 1.

3 Guide to Decentralized Energy Technologies, WADE, September 2003.

4 The WADE Economic Model, Previous Results and Future Application, February 20, 2006.

energy than to move the same MWh of fuel or chemical energy.[3]

System-level economic savings

Research by WADE shows shifting investment from centralised to decentralised power generation could save anywhere between 15% and 40% of total delivered energy costs by displacing the need for generation capacity to meet peak electricity demand as well as grid capacity to move the displaced power[4]. Research by IEA, among others, corroborates these findings. A 2003 IEA study

For the same price much more energy can be moved through a pipeline (TOP) than electrical wires (ABOVE).


A long time ago,
Easter Island was a paradise.
Its inhabitants built great statues
to honour their ancestors.
They would sculpt them in rock
and carry them on wooden logs.
It is said that they cut down so many trees,
their little island became a desert.
Our planet is like Easter Island,
in the middle of the ocean: we can destroy it
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RIGHT
Table 1.

TYPICAL GHG EMISSIONS FROM VARIOUS GENERATION OPTIONS

CO_2 emissions, kg per MWh	
Heavy fuel	844
Coal (fluidised bed combustion)	815
Gasoil (diesel)	815
OCT (open cycle)	582
CCGT (combined cycle)	354
CHP (combined heat & power)	269
Biomass	0
Renewables (wind, solar etc.)	0

Source: IEA.

5 IEA Investment Outlook 2003.

6 IEA Natural Gas Market Review 2007.

estimated savings in excess of $125 billion as a result of increased DE investment up to 2030 around the world[5]. With the electricity sector expected to account for the majority of global energy related investments in the next 30 years, the savings realisable from increased DE investment become particularly important from a strategic point of view. The fact that DE runs at high load factors adds further to the argument that capital investment dollars are optimally spent. Much of the gas-fired power-only CCGT plants built in recent years typically operate at around a 35% load factor as a result of capacity gluts[6] – meaning that the per kilowatt-hour cost of that generation is even higher.

System-level environmental savings

Shifting gas use to CHP from power-only CCGT will also reduce pollution, both as a result of the efficiency improvement discussed above and also through reduced grid losses. WADE research estimates that overall CO_2 savings from increased investment in DE range from 10% to 90%. IEA data demonstrates that gas-fired CHP is among the lowest GHG emitting options (see *Table 1*), whereas Dutch research shows that CHP provides the most cost-effective means to reduce CO_2 emissions (see *Table 2*).

Reliability – reduced downtime

As DE is added to the generation mix, in either grid or off-grid applications, there is the added benefit of increased system reliability and the creation of a more robust and flexible network. Not only does the presence of DE in a grid greatly reduce the need for contingent/emergency generation capacity, but when there is an interruption those who have decided to invest in on-site gas generation often do not even notice the blackout. There was a good example of this during Hurricane Katrina in 2005 at the Mississippi Baptist Medical Center in Jackson, Mississippi. As a result of the on-site CHP system the hospital was able to maintain operations during the entire 52 hours that the surrounding grid was down as a result of the storm. Furthermore, under normal grid conditions it is possible to almost eliminate the need for reserve margin plant where DE has reached high

RIGHT
Table 2.

COST EFFECTIVENESS OF VARIOUS CO_2 MITIGATION OPTIONS

Measure	*Costs (€/t CO_2 saving)*
CHP	25
Animal waste combustion	50
Co-combustion of biomass	75
Double glazing	160
High-efficiency domestic boilers	160
Home insulation	160
High-efficiency household appliances	160
Onshore wind power	200
Pure biomass	200
Solar boilers	250
Offshore wind power	250
Wave and tidal energy	250
Solar cells	250
Hybrid cars	1400

Source: Rijksinstituut voor Volksgezondheid en Milieu/ Energieonderzoek Centrum Nederland, April 2004.

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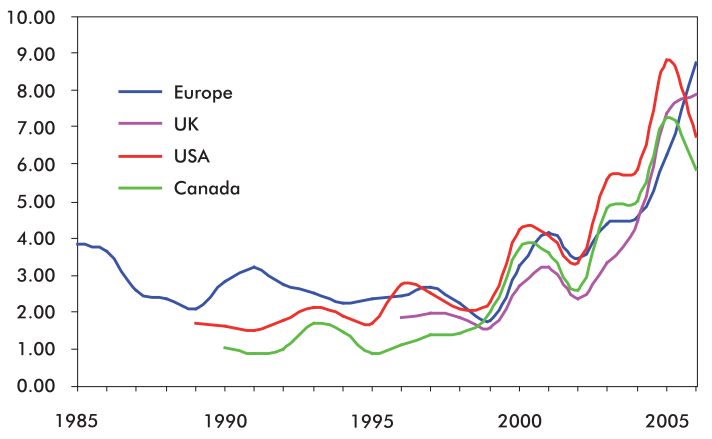
HISTORIC NATURAL GAS PRICES ($US MILLION/BTU)



Source: WADE based on data from BP Statistical Review of World Energy June 2007.

ABOVE
Figure 2.

volatility in natural gas commodity markets. Skyrocketing gas prices (see *Figure* 2) have scuttled plans for new gas-fired plants as well as limited the hours that existing plants are allowed to run.

The economics of providing thermal energy and power from natural gas are dependent on the ratio of the price of grid power and natural gas, often referred to as the "spark spread". Research by WADE shows that as gas prices rise, gas-fired CHP becomes a more attractive investment proposition relative to power-only CCGT plants. *Figures 3 and 4* show that as gas prices increase, electricity prices increase more slowly for customers who get their power from gas CHP compared to those who rely on CCGT for their power. The cost advantages of CHP may be further enhanced as legislative and regulatory incentives are created that reward efficiency. Such programmes are already in existence in regions as diverse as Portugal and New York State.

market penetration. When there is grid stress (including extreme weather, an overworked grid and grid sabotage) "the reliability advantages of most distributed systems are demonstrably higher than a centralised system of standard design".[7]

7 Hisham Zerriffi, *Electric Power Systems under Stress. An Evaluation of Centralized versus Distributed System Architectures*, dissertation submitted to Carnegie Mellon University, September 2004.

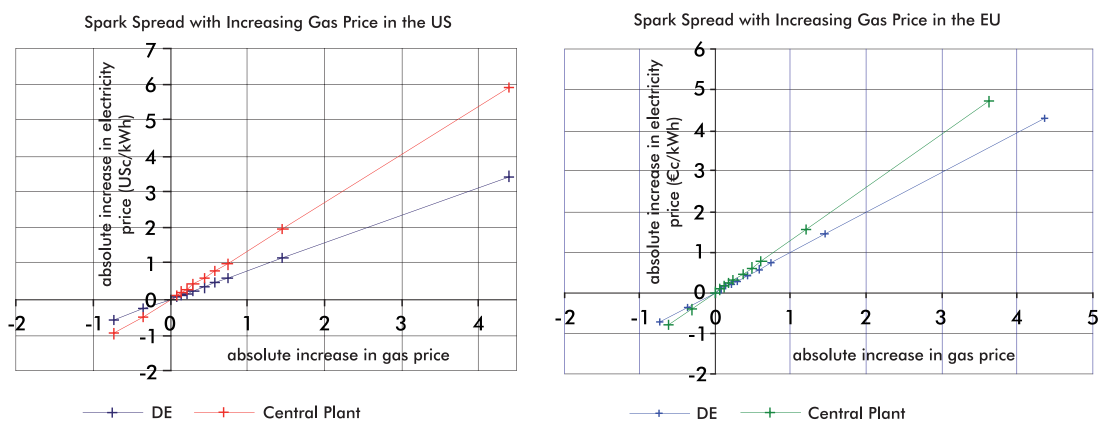
Reliability – price risk

The high efficiency of on-site gas-fired power plants means that they are less vulnerable to price

Security benefits

Another factor driving the decision to use gas in either CHP or CCGT applications is energy security. As discussed above, infrastructure security and reliability can be enhanced through the addition of

SPARK SPREADS WITH INCREASING GAS PRICES IN THE US AND EU



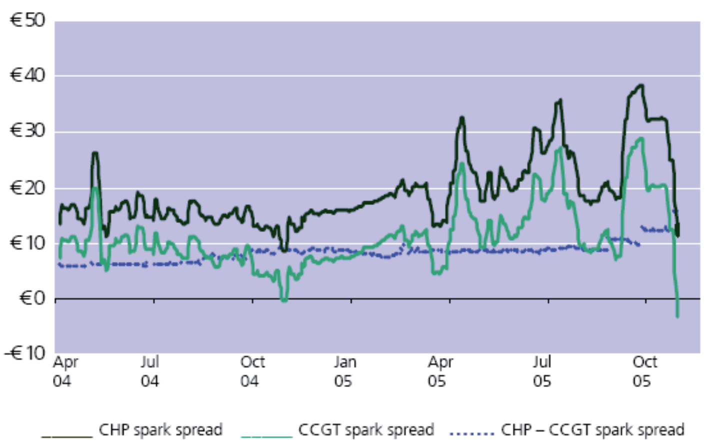
Source: WADE 2004.

RIGHT
Figure 3.

BELOW
Figure 4.

BOTTOM
Figure 5.

EUROPEAN SPARK SPREADS FOR A 10 MW CHP PLANT AND A CCGT POWER-ONLY PLANT



Source: Delta Energy and Environment.

local generation. A 2001 study following the September 11 attacks suggested that a system based more on gas-fired DE plants may be five times less sensitive to systematic attack than a central power system[8]. In addition, because decentralised power systems are more fuel efficient, there is considerable opportunity for gas importing countries to reduce their reliance on imports. With gas disputes – such as those witnessed last year between Russia and Ukraine – becoming increasingly common, the strategic importance of more efficient gas use should not be underestimated.

8 Hisham Zerriffi, Hadi Dowlatabadi and Neil Strachan, "Electricity and Conflict – Reliability Advantages of a Distributed System", *Cogeneration and On-site Power Production*, Vol. 3 Issue 1 January-February 2002.

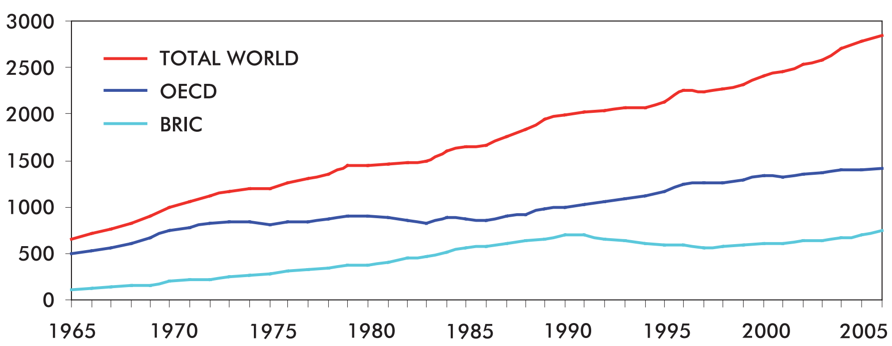
Gas to power – a look back

Total gas use increased from 702 bcm in 1965 to more than 2850 bcm in 2006 (see *Figure 5*) and the trend of increasing overall demand for gas is expected to continue. Gas use is increasing most quickly in emerging economies such as Brazil, Russia, India and China. *Figure 6* shows the total overall growth in demand for gas as well as the evolution of fuel use in the power sector. The share of natural gas in the power sector increased from about 12% in 1970 to 20% in 2004. The power generation sector accounted for about half of the growth in gas markets between 1990 and 2004.[9]

With commercial electricity making its debut in 1882, natural gas has only emerged as an important player in the power sector over the last 30 years. The emergence of gas as a fuel in the power sector in the early 1970s helped revolutionise the industry, triggering waves of restructuring, the ripples of which continue today to stir controversy and create opportunity in countries around the world.

The entry of gas into the power sector coincided with the introduction of a new generation of affordable and clean engines and turbines. The units had great appeal to utility professionals because they could be up and running quickly, were powered by natural gas (which at the time was a relatively inexpensive fuel) and offered maximum flexibility to meet peak loads. An unanticipated, but important, effect of the introduction of new gas-fired units was that it led to the erosion of the traditional assumption that electric utilities needed to be monopoly entities and helped reintroduce competition into the electricity sector. A wave of investment by non-utility generators began which continues to gain momentum to this day.

HISTORIC NATURAL GAS CONSUMPTION (BCM)



Source: WADE based on BP Statistical Review of World Energy June 2007.

9 IEA, Natural Gas Market Review 2007.

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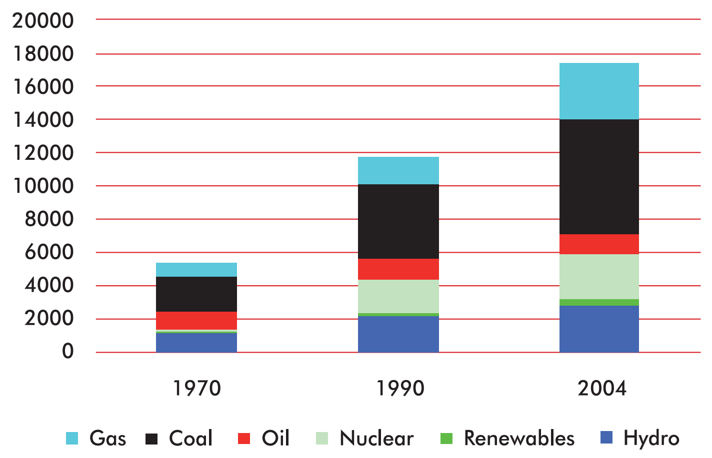
TOTAL WORLD ELECTRICITY GENERATION (TWh) BY SOURCE FOR THREE YEARS



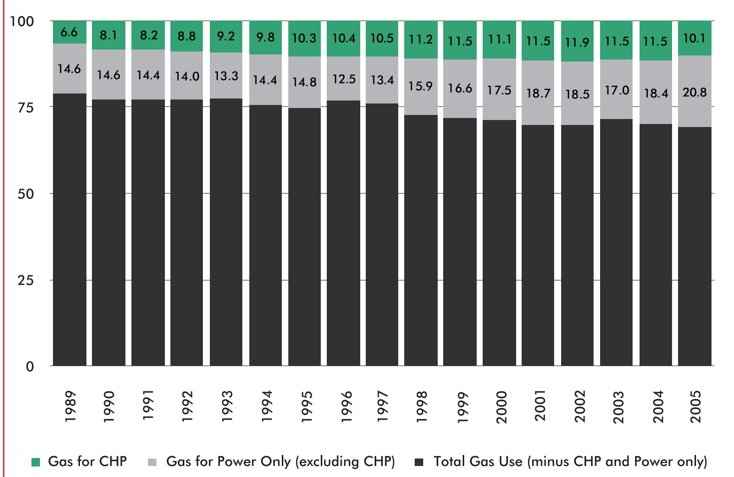
Source: IEA World Energy Outlook, 2006 and 1994.

ABOVE
Figure 6.

BELOW
Figure 7.

The size of power plants peaked in about 1976[10], with large coal plants, hydro plants and nuclear plants losing popularity in favour of smaller gas-fired CCGT generating plants. The traditional assumptions about economies of scale for power plant design were shattered because of the efficiencies realised by manufacturing smaller plants on an assembly line model which were then transported to end users. In the early 1990s the average plant built in the US was smaller than the average plant built in the early 1950s. Smaller units are more appealing to investors for various reasons. Smaller gas units offer increased flexibility during operation making it easier to ramp up and down to meet peak demand. Perhaps even more attractive is that the modular nature allows users to get new capacity on line quicker and more effectively as demand increases incrementally. Long lead times, high capital costs and uncertainty about future demand can all be mitigated with smaller generators.

PERCENTAGE OF TOTAL US GAS USED FOR CHP AND POWER ONLY OVER TIME



Source: WADE based on EIA Annual Energy Review 2005 data.

For local gas distribution companies (LDCs) the opportunity offered by gas-fired DE is especially important because most of the on-site power projects flow through the LDC meter, whereas larger gas power-generation projects (such as CCGT plants) do not.

Gas in the power sector – the future

Decentralised energy remains a secondary market for gas retailers around the world despite the fact that there are, for example, already some 84,700 MW installed at 3,275 sites[11] in the United States, 75,514 MW in the EU15[12] and 8,622 MW in 6,948 sites across Japan[13]. Gas is already the predominant fuel for DE application and its use has been increasing (albeit slowly) over time (*see Figures 7 and 8*). The American Gas Association has predicted that DE energy installations will soon account for 20% of all new capacity in the United States, or 5% of total power generation. WADE research from 2006 found that nearly a quarter of all electricity

10 Philippe Dunsky, "1920-1995 and Beyond: Trending Downwards", *Cogeneration and On-site Power Production*, Vol. 1 Issue 6 November-December 2000.

11 Current CHP Status. Bruce Hedman, Energy and Environmental Analysis, Inc.

12 Benchmarking Report: Status of CHP in EU Member States, Cogen Europe, June 2006.

13 Japan Cogeneration Centre data, June 2007.

Performance and Risk Management of Ageing Infrastructures

OXAND is an independent international consulting company providing specialised services in risk management of civil engineering and subsurface infrastructures. Based on its expertise in ageing materials (e.g. concrete, steel), OXAND operates its own tools and data bases for predictive diagnosis and prognosis of ageing infrastructures. With a unique experience in decision-making criteria based on performance and risk assessment methodologies, OXAND is developing its activities all over the world for increasing the life of existing oil & gas assets and promoting new sustainable technologies.

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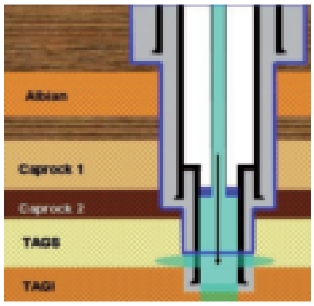
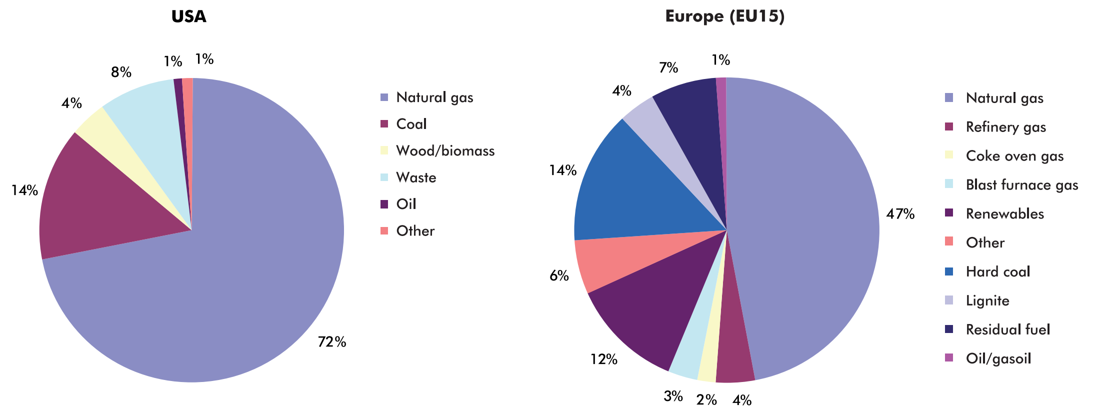
- Marine structures durability (maintenance plans of jetties, durability analysis, etc.);
- Subsurface gas storage reservoirs (CO_2, LNG, acid gas).



RIGHT
Figure 8.

CHP BY FUEL FOR THE USA AND EUROPE



Source: WADE based on Energy and Environmental Analysis and Cogen Europe data.

generated from new capacity added in 2005 could be traced to decentralised (CHP) installations.

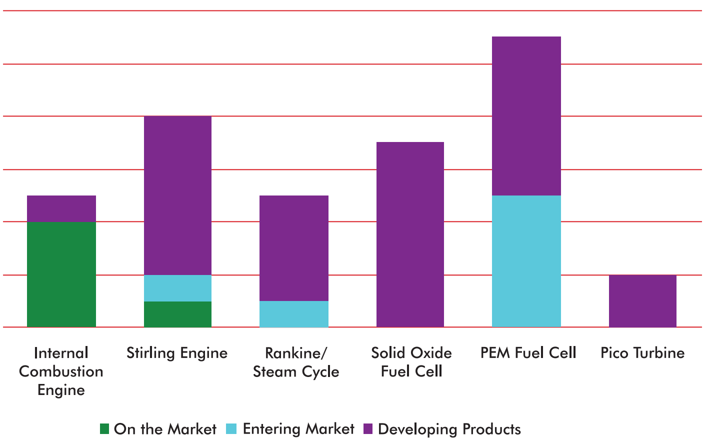
While the same drivers that led to the emergence of gas as a power sector heavyweight will continue to create demand for gas-fired heat and power, new voices are now adding to the momentum. The UN's Intergovernmental Panel on Climate Change, in its long-anticipated May 2007 report on climate change mitigation strategies, pointed to DE as an important tool that reduces the need for costly transmission systems, allows for shorter lead times, reduces grid losses and improves reliability, all while reducing CO_2 emissions dramatically. At the conclusion of the recent G8 Summit in Germany, the OECD, recognising the urgency of converging energy and climate security, called for the "adoption of instruments and measures to significantly increase the share of combined heat and power in the generation of electricity". The UK recently devoted a chapter to DE in its overall energy strategy and is currently implementing the lengthy list of actions to improve the market for DE – including small-scale gas-fired DE. The United States Department of Energy in turn is currently reviewing public comment on its own DE study "The Potential Benefits of Distributed Generation and Rate-Related Issues that May Impede Their Expansion".

Smart utilities are already building business plans around the potential for new DE markets for gas. For example, in May 2007 the two main electricity and gas utilities in Toronto, Canada, announced a joint venture to "target a wide range of opportunities relating to cogeneration, district energy, grid 'peak shaving' and other distributed generation models fuelled by either natural gas or renewables". In the UK, Powergen (of E.ON UK) has a deal with WhisperGen to sell small CHP units to individual homes.

The logical endpoint of this vision of increasingly small generators – a vision that is already a reality in a growing number of European communities, especially in Germany – is a network of small gas customers all burning gas for both their local heat and electricity needs. Micro-CHP units are very small cogeneration units that are scaled for individual houses or small apartments. With capacities of 1-5kW they are similar in size to a household freezer and are designed to replace boilers.

BELOW
Figure 9. Micro-CHP units are similar in size to a household freezer.

SELECTED MICRO-CHP DEVELOPERS IN THE EUROPEAN MARKET BY TYPE



Source: Cogeneration and On-site Power Production Magazine, July-August 2006.

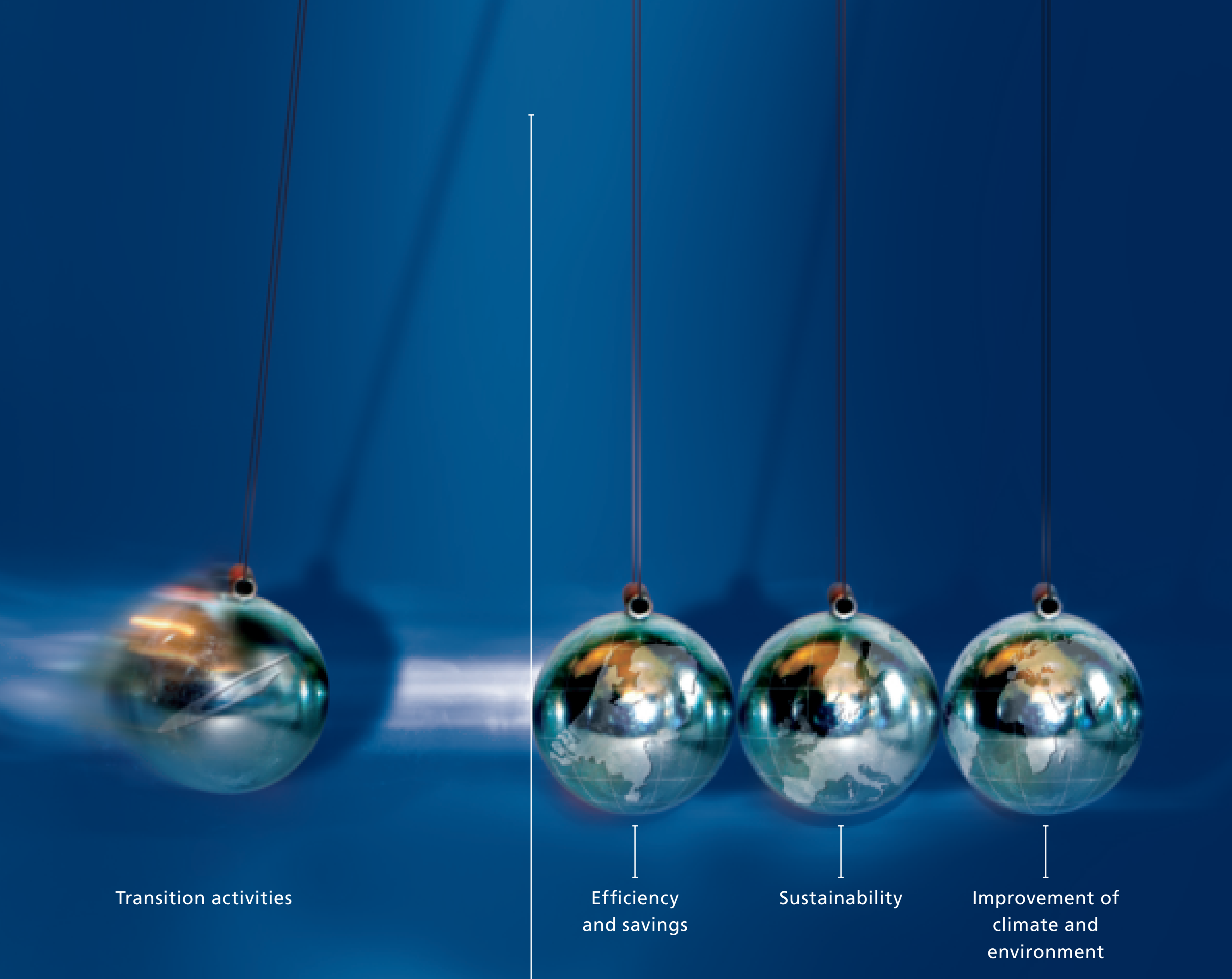
Figure 9 shows the diversity of micro-CHP products that are either already commercialised or close to being available in the European market.

In many countries that depend on gas for heating but not for grid power and where population density is too low to justify district energy (such as the United States, Canada and parts of northern Europe), micro-CHP is a massive market opportunity for gas retailers. In many cases, especially in areas that rely on large-scale hydro or nuclear to meet peak power, it could also be a strategic entry point into the power sector.

Conclusions

The importance of the power sector for the gas industry has evolved considerably over the years. The relationship between the two promises to be even more closely intertwined going forward as local generation of gas-fired power continues to progress. Power-sector restructuring will continue to create new market opportunities for on-site gas-fired generators, where before there were barriers to grid entry. As gas prices climb, the strategic importance of decentralised gas generators compared to power only applications will be recognised by an increasingly demanding consumer. The issue of climate change has never been more prominent on the public agenda and will continue to put pressure on gas buyers and sellers alike to use resources as efficiently as possible. The combination of consumer interest and the maturation of the technology required to make it happen will allow an entirely new sector of the economy – residences and small businesses – to join the power market as they burn gas in their basements to generate clean, affordable electricity.

David M. Sweet is the Executive Director of the World Alliance for Decentralized Energy (WADE) and Jeff Bell is WADE's Program Director. For more information on WADE please see www.localpower.org.


Transition activities
Efficiency and savings
Sustainability
Improvement of climate and environment

Energy Delta Institute: knowledge junction on the gas roundabout

Nowadays there is no industrial sector that much on the move as the energy sector. Not only liberalisation causes a complete shift in our current structures, but the rising energy prices and the increasing concern for Security of Supply lead to big changes as well. Energy controls the international arena more and more whilst confrontation seems to replace cooperation. To be able to remain standing in this rapidly changing environment, we continuously need new knowledge and skills. Therefore in 2002 the Energy Delta Institute (EDI) was founded, a cooperation between N.V. Nederlandse Gasunie, GasTerra (formerly Gasunie Trade & Supply B.V.), OAO Gazprom and the University of Groningen, which was joined also by Shell in 2006 and by RWE in June 2007. EDI bundles knowledge about all kinds of aspects of the Gas Value Chain.

EDI's aim is to contribute to educating the current and future energy managers. Therefore EDI performs research and develops training programmes on all economical, management and geopolitical aspects of natural gas. Currently EDI organizes a number of education programmes:

- **Executive Master programmes:** Executive Master of Gas Business Management, Executive Master of Petroleum Business Engineering and Executive Master of Finance and Control for the Petroleum Industry
- **Executive programmes:**
  - **Natural Gas Strategy Course:** for profound insight in the most important forces and opportunities at the international energy market.
  - **Gas Liberalisation & Regulation Course:** about the influence and consequences of liberalisation on the energy market.
  - **Large-scale Gas Projects Course:** practical and theoretical handles to manage the financial, juridical, political and project management challenges of large and middle-large gas projects.
- **Short-tracks:**
  - **Underground Gas Storage Course:** for a far-reaching perspective on the various possibilities of gas storage, planning mechanisms and economical aspects.
  - **Strategic use of IT in the Gas Industry:** about the consequences for IT-structures within energy companies.
  - **The International Gas Value Chain:** an introduction programme for the starter in the European energy world.
- **Tailor-made training programmes and workshops**, e.g. about Gas trading, Gas dispatching, Gas contracting & pricing, Pipeline Integrity Management, Gas reserves estimations, Finance & Controlling and Energy Law.

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Study Group 5.3 Cooperates with IANGV and Regional NGV Associations

By Davor Matic

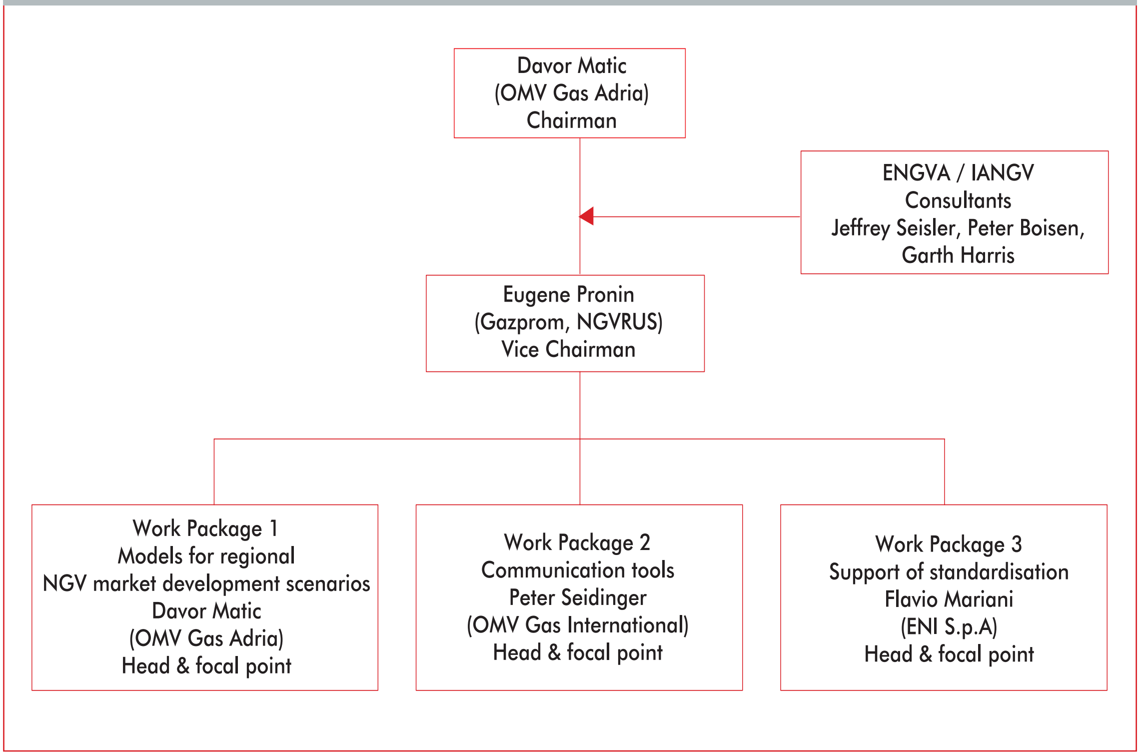
The IGU Working Committee whose remit covers NGVs is WOC 5 (Utilisation) and Study Group 5.3's work in the current Triennium builds on IGU's longstanding collaboration with IANGV. SG 5.3 is tasked with developing a global NGV strategy to answer the question: How to achieve 50 million NGVs on the road in 2020?

Model

One of the work packages for this strategy is the development of a model to provide a scenario of potential regional increases in mobility demand and potential natural gas penetration in the transport sector. Based on expected populations and economic development, this model will provide scenarios for five regions (Asia-Pacific, Europe, Latin America, North America, Russia and the CIS) covering the:

- projected increase in mobility demand (passengers and freight);
- modal split (road, rail, air, marine, inland waterways etc.);
- projected increase in the number of vehicles and fuel consumption;
- expected natural gas demand (consumption);
- reduction of polluting emissions as a result of natural gas use;
- investments required by the gas industry and third parties to achieve the level of market penetration projected; and
- possible social and economic impacts (such as the effect on employment).

SG 5.3 ORGANISATION AND THE ROLE OF EXTERNAL CONSULTANTS



SG 5.3 is collecting examples of the maintenance and lifecycle costs of natural gas buses (like this Mercedes-Benz Citaro) vs. diesel buses.

The purpose of this work package is to present to the gas industry natural gas sales potential in the transport sector together with costs and benefits. It will also show how 50 million NGVs on the road in 2020 could assist in satisfying part of the future mobility and energy demands in the transport sector, taking into account the expected development of the global economy. In addition, the package will demonstrate the increased security of supply. (Sources of natural gas in each region, both pipeline and LNG, will be identified in cooperation with other WOCs.)

The work programme will be undertaken with the cooperation of IANGV, which is providing inputs to and comments on the model, calculation and results. The regional NGV associations in Asia-Pacific (ANGVA), Europe (ENGVA), Latin America (ALGNV), Russia (NGVRUS) and the US (NGV America) are also being asked if they have their own projections for the growth of the regional NGV markets, whether they have set any targets and to comment on the independent calculation provided by SG 5.3. Does it put some new light on their assumptions, is it realistic and is it possible to convert figures into reality and, finally, what should be done to achieve that?

The model has been developed and a scenario prepared using 28 European countries as an example (EU27 + Switzerland); preparation of the scenarios for other regions is underway.

Communication

As part of a second work package, communication kits will be prepared with messages reflecting the real situation of different regions and people.

Furthermore, as a valuable communication tool, SG 5.3 has decided to develop an OEM (original equipment manufacturer) CNG database of costs together with adequate cost calculators for cars, buses and trucks, for private persons, small businesses and larger enterprises such as public transport companies.

The database will cover vehicle conversion to CNG/OEM costs (CAPEX), fuel costs, maintenance costs (i.e. cylinder inspections), taxes and subsidies, and regulations (conversion, maintenance, garages). It will include as many countries and cases as possible.

A model for different applications (fleet managers, OEMs, filling station owners) will also be developed from the collected data.

The database and models will be placed on the IGU website (www.igu.org) and will be available to the regional and national NGV associations for publication.

In parallel, real-life examples of the maintenance and lifecycle costs of natural gas buses vs. diesel buses will be collected, both in cases where NGVs were winners and where they were not so successful. If possible, the group will also collect case histories from operators preferring diesel buses to investigate their reasons for non-acceptance of NGVs.

To date, a survey "Key questions and problems in each region for further development of the NGV market" has been carried out among SG 5.3 members and partners involved in the development of NGV projects. The aim was to identify everyday problems NGV experts are facing in communication with the stakeholders and to provide proper "ammunition" in the form of appropriate communication tools. Experts from IANGV and the regional NGV associations made valuable contributions to this successful survey.

Standardisation

Finally, as a third work package, SG 5.3 is looking at possible contributions to support standardisation.

In November 2006 IANGV published the *Gap Analysis of International NGV Standards and Regulations*. The objective of this report is to identify relevant international standards and regulations pertaining to NGVs, to compare them and to identify key differences and areas where there are currently no published standards or regulations.

A number of national and international NGV standards and regulations are reviewed in the report (but not all). SG 5.3 proposes to collect national standards not covered so that these could make a contribution to the development of harmonised standards.

For example, according to the report, in the draft European standard prEN 13638 – CNG filling stations, safety management systems (procedures and staff practice) are missing. However, they are covered in the recently revised Austrian standard G97. Members of the group therefore provided a translation of the latter document to IANGV.

We expect that the successful cooperation between IGU and IANGV and the regional associations will continue to grow in the future.

Davor Matic of OMV Gas Adria is the Chairman of Study Group 5.3 and can be contacted via email (davor.matic@omv.com).


WE ARE DOING THIS FOR LIFE
In putting out gas flares in Nigeria, we are pursuing policies that support life, through improving the nation's energy and environmental challenges.
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PGC A Presents Norwegian Carbon Capture Developments

By Knut Barland and Kari Lindøe Hunsbedt

Programme Committee A (PGC A) is working on the issue of sustainable development. In this context, one of the most important challenges today is climate change and its possible consequences for future generations of the world. One way to fight climate change is to highlight and promote the best ways of reducing CO_2 emissions, and PGC A is exploring solutions where natural gas plays an important role.

In May we participated along with Working Committees 1, 2, 3 and 5 in a Joint Committee Meeting on CO_2 sequestration and storage. The expert speakers included Egil Sæl, Vice President for Business Development in Statoil's refining division, and Olav Kårstad, Statoil's CO_2 Coordinator. In this article we talk to Mr Sæl about an important Norwegian initiative to reduce CO_2 emissions at the Mongstad refinery near Bergen, while Mr Kårstad outlines the processes involved in CO_2 capture (*see box*).

● Major boost for energy efficiency

The Mongstad project entails the construction of a combined heat and power (CHP) station alongside the existing refinery, which will use the latter's surplus gas as part of its feedstock, and the

The modernisation of the Mongstad refinery is one of Norway's biggest energy efficiency projects.

CO_2 CAPTURE

By Olav Kårstad

Statoil has experience from the Sleipner field in the North Sea of capturing CO_2 from natural gas at very high pressure. At such pressures, we can theoretically clean the CO_2-rich natural gas using water, then extract the water and reduce the pressure to atmospheric level. We will then see that the CO_2 is sprayed out under pressure just like when we open a bottle of mineral water. In practice, when capturing CO_2 from natural gas, a mixture of water and a chemical from the amine group is used.

If the task is to capture CO_2 from the flue gas from a gas turbine, the process will be considerably more difficult because we then have atmospheric pressure and a high oxygen content. Current processes for capturing CO_2 from flue gas also consist of using a mixture of water and amine. This liquid is brought into contact with the flue gas in a large washing tower. The amine used must have a greater ability to bind CO_2 to itself than the amine used for natural gas. Nor can the amine be such that it deteriorates in an atmosphere containing oxygen. In this case, in order to release CO_2 from the amine, we must boil the water/amine mixture, a process that requires a great deal of energy and is costly.

Olav Kårstad is Statoil's CO_2 Coordinator.

Once CO_2 has been captured, it remains to dry out the water. The CO_2 can then be pumped into pipelines without causing corrosion.

introduction of CO_2 capture from the flue gas. This is one of Norway's biggest energy efficiency projects and it will put the ageing refinery in the front rank worldwide as regards the environment.

"This is where the combined heat and power station is going to be built," says Egil Sæl and points to a vacant plot of land beside the processing plant. Mr Sæl has nurtured the Mongstad energy project through to approval by the authorities and a decision by Statoil's board of directors.

The production capacity of the CHP station will be approximately 280 MW of electricity and 350 MW of heat, and it will meet a substantial proportion of the refinery's energy needs when it comes on line in 2010.

Mongstad, which is co-owned by Statoil and Shell and is a medium-sized refinery in the European context, refines 10 million tonnes of crude oil and condensate a year into products such as petrol, diesel and jet fuel. The refining process requires as much energy as the whole of Oslo, around 890 MW of heat energy and 60 MW of electricity.

The refining process generates large quantities of gas, which in turn is burned in large boilers and ovens to create heat for the processes. The ovens are outmoded and utilise the energy in the gas poorly. A lot of the energy is lost.

"If we increase the efficiency of these ovens, all we will achieve is to create a greater surplus of refinery gas. As of today, it is not possible for us to

Egil Sæl points out the plot of land on which the CHP station and the capture plant for CO_2 will be situated at Mongstad.

normal to build CHP stations together with modern refineries. There are around 135 similar facilities in Europe, attached to refineries and petrochemical and chemical plants. Shell, for example, has one such station in Fredricia in Denmark and one under construction at its refinery in Rotterdam, which is co-owned by Statoil. But neither of these refineries has CO_2 capture.

Refinery gas will account for a third of the gas fed into Mongstad. Natural gas from the Troll field in the North Sea will supply the remaining two-thirds via pipeline from a landfall plant at Kollsnes. The electricity generated by the CHP station over and above the refinery's requirements will be supplied to the land-based and offshore Troll facilities.

Staged CO_2 reduction

The Mongstad refinery currently emits approximately 1.75 million tonnes of CO_2 annually. Once the energy project is put into production, the emissions from the refinery will be reduced by 0.35 million tonnes, while the total emissions from Mongstad will increase to 2.7 million tonnes a year because of the Troll gas that is transported to the CHP station in addition to the surplus gas from the modified refinery.

An agreement has been entered into with the government on cooperation relating to the handling of CO_2 at Mongstad. The first step in the agreement is to build a plant capable of capturing

use this surplus gas, and we have to flare it," says the refinery's Vice President, Bjørn Kåre Viken.

"A combined heat and power station will utilise all the refinery gas. That is why it is the only way to solve the environmental challenge we are facing here," continues Egil Sæl. He points out that it is