25th world gas conference
“Gas: Sustaining Future Global Growth”
Kuala Lumpur, Malaysia
4 - 8 June 2012

# best practices and IGU awards

INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

KUALA LUMPUR
2012
WORLD GAS CONFERENCE

**2009 – 2012 Triennium Work Report**

**June 2012**

# Best Practices
# and IGU Awards

**Produced by:**

**International Gas Union**

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# Foreword

An important mission of the International Gas Union (IGU) is to improve the competitiveness of gas in the world energy markets. This is achieved by promoting the development and application of new technologies and best practices which will help optimize the economics of the entire gas chain, while emphasising sound environmental performance, safety and reliability.

Best practices have always been regarded as an important component in the work of the Technical Committees and these are highlighted and incorporated in the Committee reports and presentations. The Malaysian Presidency has continued the excellent work initiated by the Argentine Presidency in compiling a list of best practices within the industry that will serve as a good reference document for both the industry practitioners and interested observers.

In addition, IGU has also introduced two awards – the Gas Efficiency Award and the Social Gas Award, in 2008 and 2009 respectively. The Gas Efficiency Award aims to capture new ideas and projects in order to achieve better efficiency in the use of gas. IGU considers energy efficiency as one of the most important ways to achieve a more sustainable energy future, to reduce greenhouse gas emissions, to enhance security of supply and to reduce energy related costs. The Social Gas Award focuses on behavioural change that leads to effective use of gas that impacts society and the environment. Both these awards have been continued under the Malaysian Presidency as a triennial award.

This document provides a listing of all the best practices covering the entire gas chain as shortlisted by our panel of experts. In addition, we have also included the abstracts of the finalists for the Gas Efficiency Award and the Social Gas Award. The full papers are all available in the disk attached to this report.

We hope that the information provided will be helpful in promoting the greater use of natural gas, increase overall efficiency and thereby improve the overall competitiveness and environmental aspects of this noble energy source.

International Gas Union
June 2012

# Acknowledgements

The sourcing of Best Practices for the 2009-2012 Triennium was made through two sources:

- Identification by Technical Committees of IGU which in this triennium were participated by more than 900 professionals drawn from the membership of IGU.
- Submissions by the international community through the Call for Papers for the 25th World Gas Conference which attracted a total of 286 submissions.

All the submissions were evaluated by the Technical Planning Committee (TPC) of IGRC. This Committee has undertaken the arduous task of selecting the top 18 papers and the final 3 winners. We would like to extend our grateful thanks to the Committee, comprising of:

1. Marc Florette, GDFSuez, France  (Chair)
2. Marie-Jose Fourniguet, GDF Suez, France (Secretary)
3. Peter Hinstrup, DGC, Denmark
4. Gerald Linke, EON. Ruhrgas, Germany
5. Florian Linder, EON. Ruhrgas, Germany
6. Isamu Yasuda, Tokyo Gas, Japan
7. Kangwon Lee, KOGAS, Korea
8. Zainab Kayat, Malaysia, PETRONAS
9. Serguey Rassokhin, Gazprom, Russia
10. Pierre Bartholomeus, KEMA, the Netherland
11. Jack Lewnard, GTI, USA

We would also like to thank the Evaluation Committee for the IGU Gas Efficiency Award and the Social Gas Award, as follows:

1. Datuk Rahim Hashim, IGU President (Chair)
2. Maria van der Hoeven, Executive Director, IEA
3. Prof Dr-Ing. Rainer Reimert, Engler-Bunte-Institut, Karlsruhe University, Germany
4. Ho Sook Wah, Chairman, IGU Coordination Committee
5. Torstein Indrebø, Secretary General, IGU

Finally, we would like to pay tribute to all the members of the IGU Technical Committees for their support and encouragement to complete this work.

International Gas Union
June 2012

# Best Practices of the Natural Gas Industry

Natural gas was first produced from coal to light houses and streetlights in the 1780s. Such manufactured gas was less efficient and less environmentally friendly than modern natural gas from underground wells, which was first produced in the 19th century and used almost exclusively as a source of light.

Once the transportation of natural gas was made possible in the early 20th century, new uses for natural gas were discovered. Today, natural gas has many applications across different sectors:

- Residential (for heating, cooling, cooking etc)
- Commercial (for space heating, cooling in public and private enterprises)
- Industrial (fuel for industrial boilers, combined heat and power, waste treatment among others or as feedstock for a variety of products such as plastics, fertiliser and fabrics)
- Transportation (NGV, CNG, LNG for cars, commercial vehicles, ships and planes)
- Power generation (gas turbines, combined cycle units, micro turbines etc)

Over the last few decades, the industry has transformed into one of the most technologically advanced industries, with new innovations across the entire value chain, resulting in greater efficiency, competitiveness and growth of the industry. New technologies, techniques, tools and processes have resulted in greater productivity, shorter cycle time, higher success rates, higher dependability, less impact on the environment and more effective cost management.

It is against this backdrop that IGU encourages the sharing of technologies and best practices.

**What is a Best Practice?**

- A Best Practice Idea or Proposal is an innovative approach, policy, technology or tool that has been developed and implemented by an organisation that has yielded significant results.
- A Best Practice can be in areas such as safety, reliability, improvement in cost efficiency, reduction of environmental footprint, revenue generation, regulatory and organisational efficiency.

**Objectives**

The publication of the top Best Practices has the following objectives:

1. Actively share and encourage the exchange of superior company experiences and best practices among members
2. Help identify and escalate innovative ideas and technologies that can improve effectiveness of operations
3. Provide a platform for discussion to promote improvements in gas industry performance

The objective is not to identify the best organisation. It is to identify the best practices that exist within the organisation that will serve as a learning for other similar organisation. IGU hopes that the compilation and sharing of these gas industry best practices by knowledgeable and experienced companies will be able to assist members with advice regarding the topic considered, help identify innovative ideas that can reduce member's costs and improve their effectiveness in operations across the gas value chain and delivering natural gas safely, reliably and in an environmentally responsible manner.

**Evaluation Criteria**

**1) Best Practice**

The following criteria were adopted in evaluating the Best Practices papers:

- Relevance to the gas industry / reproducibility
- Benefits / impacts on the gas industry / cost savings
- High quality (study, research, technology)
- Original / innovative / advanced progress demonstrated
- Recognised by other parties from the gas industry

**2) Gas Efficiency**

The following criteria were adopted in evaluating the Gas Efficiency Award:

- Innovation: What is "new" about the proposal (technology, process, methodology)
- Improved efficiency
- Energy savings (per project and on "global" basis)
- Cost feasibility (realised benefits/savings of project vs. project costs/investments)
- Practical applicability
- Status of project implementation
- Contribution to the image of the gas industry
- Quality of the proposal

**3) Social Gas**

The following criteria were adopted in evaluating the Social Gas Award:

- Innovation: What is "new" about the proposal
- Educational and behavioural aspects
- Energy savings/environmental benefits
- Cost feasibility (realised benefits/savings of project vs. project costs/investments)
- Practical applicability
- Contribution to the image of the gas industry
- Quality of proposal

**Conclusion**

It is with interest and hope that these collections of Best Practices of superior performing and innovative ideas and work practices will be referred, used and shared among members to improve effectiveness in their operations at work. It could also help to jump start a company's benchmarking efforts and/or reduce their cost of operations through adoption of these best practices hence further promote the progress of the gas industry.

# Listing of Shortlisted Best Practices

The following 17 papers have been selected as the top Best Practices. The full paper submissions are contained in the disk attached to this report.

**UPSTREAM**

| Code | Company | Title |
|---|---|---|
| 399 | Petrobras | Optimisation of Natural Gas Plant – Gains in Profitability, Stability and Energy Efficiency |
| 722 | GTT | Reduction of boil-off generation in cargo tanks of liquid natural gas carriers – recent developments of Gas Transport & Technigaz (GTT) cargo containment systems |
| 922 | Osaka Gas | Development and realisation of large scale LNG storage tank applying 7% nickel steel plate |
| 942 | Osaka Gas | The accomplishment of 100% utilisation of the LNG cold energy |

**MIDSTREAM**

| | | |
|---|---|---|
| 546 | GrDF | Development of safety-management processes: feedback, analysis of human and organisational factors and creation of a simulator to enhance collective competences in operational activities |
| 649 | Rosen Swiss | Field experience with a novel pipe protection and monitoring system for large offshore pipeline construction projects |
| 788 | Gazprom | Development and application of high strength pipes for Gazprom's truck gas pipelines |
| 806 | Korea Gas Union | Weld properties of X70 pipeline girth welds for manual and mechanized welding processes |
| 778 | Gazprom | New approach to increasing the energy efficiency of a large gas transportation system |
| 761 | Gasunie | $8^{th}$ report of the European gas pipeline incident group 1970-2010 |
| 654 | Compaňia Operadora de Gas del Amazonas | Managing geotechnical risk in Andean pipelines: Monitoring, computational modelling and assessment |
| 649 | Rosen Swiss | Field experience with a novel pipe protection and monitoring system for large offshore pipeline construction projects |

**DOWNSTREAM AND OTHERS**

| | | |
|---|---|---|
| 929 | National Iranian Gas Company | Gas load forecasting of Tehran, based on intelligent and statistical modelling systems, comparing results with actual data |
| 1110 | GDF SUEZ | A prototype of CNG cartridges powered scooter: A solution for a sustainable mobility into city centres |
| 822 | Eustream | Opportunities of waste heat recovery at natural gas transmission systems |
| 863 | RWE Effizienz | Fostering local and wide area efficiency by home power as distributed and intelligent micro-generation |
| 965 | GDF SUEZ | A smarter gas for the future |
| 950 | GDF SUEZ | Approach for the implementation of AMR system for gas meters in France - GrDF Project |

# ABSTRACTS OF THE TOP 3 BEST PRACTICES

## PAPER 1

### OPTIMIZATION OF NATURAL GAS PLANT - GAINS IN PROFITABILITY, STABILITY AND ENERGY EFFICIENCY

Mario Campos[1], Marcos Gomes[2], Antonio Souza[3], Adriano Barros[4]

[1] Senior Equipment Engineer – PETROBRAS/CENPES
[2] Senior Chemical Engineer – PETROBRAS/CENPES
[3] Senior Computer Technician – PETROBRAS/UO-BA-ENGP-EIPA
[4] Equipment Engineer – PETROBRAS/SMSE-GGEE-EFEN

### INTRODUCTION

This article will describe the results of a Petrobras' program to increase stability, profitability, energy efficiency and sustainability of its Natural Gas Processing Units (NGPUs). Due to the crescent demand for more efficient and sustainable processes, it becomes increasingly important to use new methodologies and tools to diagnose and optimize NGPUs operation and control performances. The gains obtained in this program are related to the implementation of a new integrated methodology that focus on permanent evaluation of key performance indicators associated with operational and control parameters throughout the implementation projects. The actions aim to improve both regulatory and advanced control systems, and also enhance the philosophy that guides the process unit operation. Usually, plants are designed assuming certain feed composition, feed flow rates and environmental conditions. However, the actual operating conditions might be very different from the design case. Therefore, it is of utmost importance to apply new control and operating strategies, in order to keep the NGPUs at the operating points where the efficiency of processes and available equipments of the gas plant are at their maximum. This paper will show that control and monitoring technologies are important tools to increase energy efficiency, profitability and sustainability.

### METHODOLOGIES AND TOOLS TO DIAGNOSE AND OPTIMIZE OPERATION

This paper presents a detailed discussion on the methodology used in the optimization program, covering the following subjects:

- Assessment of instrumentation and the regulatory control loops of various gas plants using a specialized tool. This software is able to identify many different problems like PID tuning, process variability due to defective or super-sized control valves, etc.
- Definition of the best key performance indicators associated with operational and control for natural gas plant (variability, profitability, energy efficiency and sustainability).
- Tuning of PID controllers using another specialized tool. During this work more than 310 control loops were analyzed and 50% had problems related with tuning.

- Maintenance of the instrumentation, and changes of regulatory control strategies, when needed, in order to minimize instabilities, process variability and improve the overall process performance.
- Use of process simulators to evaluate the best operating strategies.
- Identification of dynamic models and development and implementation of soft-sensors (inferences or virtual sensors) based on first-principles or empirical models.
- Implementation of multivariable predictive controllers (MPCs) in order to increase NGL (natural gas liquid) recovery, reduce energy consumption and waste material. These control algorithms are crucial to optimize complex processes, like Natural Gas Processing Units (NGPUs), due to challenging dynamic responses (significant time delays, non-minimum phase responses, control loop interaction, etc.), nonlinearities, disturbances (feed flow and composition, energy integration, etc.) and the management of many process constraints. The most important issue during the implementation of these advanced control systems is the conceptual design, where the optimization objectives to be achieved are defined.
- Training operators and engineers in order to maintain and operate the new control system (final documentation).
- Evaluation of results obtained in each phase of the project based on the key performance indicators. Special techniques have been developed and used in order guarantee that performance indicators are computed with consistent data, and therefore leading to reliable results and conclusions.
- A long-term plan must also be done to assure that the acquired benefits are kept and expanded. The use of key performance indicators (variability, profitability, energy efficiency and sustainability) in a real-time system for monitoring and identifying the need for improvements in instrumentation and controls.

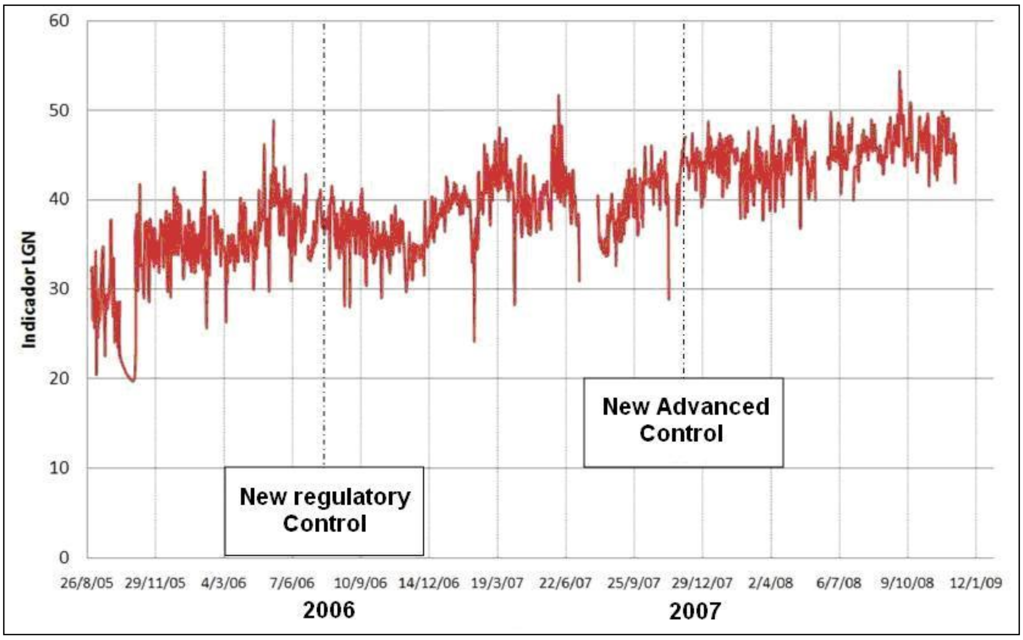


Figure 1 - Greatest recovery of NGLs during the project.

## RESULTS

The final results of this project will also be shown in this paper, for example:

- Economic gains (for example, at one unit it was obtained an increase in NGL (Natural Gas liquids) recovery of about 30%, which generated an increase in profit of about US$ 13 million per year), see figure 1.
- Increases in energy efficiency (for example, fuel gas consumption in furnaces was decreased by 18% in a Natural Gas Unit, resulting in a reduction of $CO_2$ emission of 1600 tons/year).
- Minimization of emissions in flares due to higher process stability (for example, at one unit the gas flow to flare was reduced and decreased $CO_2$ emissions of some 230 tons/year).
- Minimization of the required equipment maintenance due to higher operational stability.
- Minimization of production losses was obtained in a NGPU where the number of shutdown events (unscheduled trips) was reduced on 33%, and the continuous reduction of NGL losses in the fuel gas (see figure 2).
- The percentage of regulatory control loops with good performance increased from 29% to 68%.
- Qualitative gains due to increased training of operators and engineers about the best operating practices and process understanding.
- The experiences of the implementation team have led to the conception and proposition of new technologies that might aid implementation, assessment and maintenance of new and existing MPC applications.

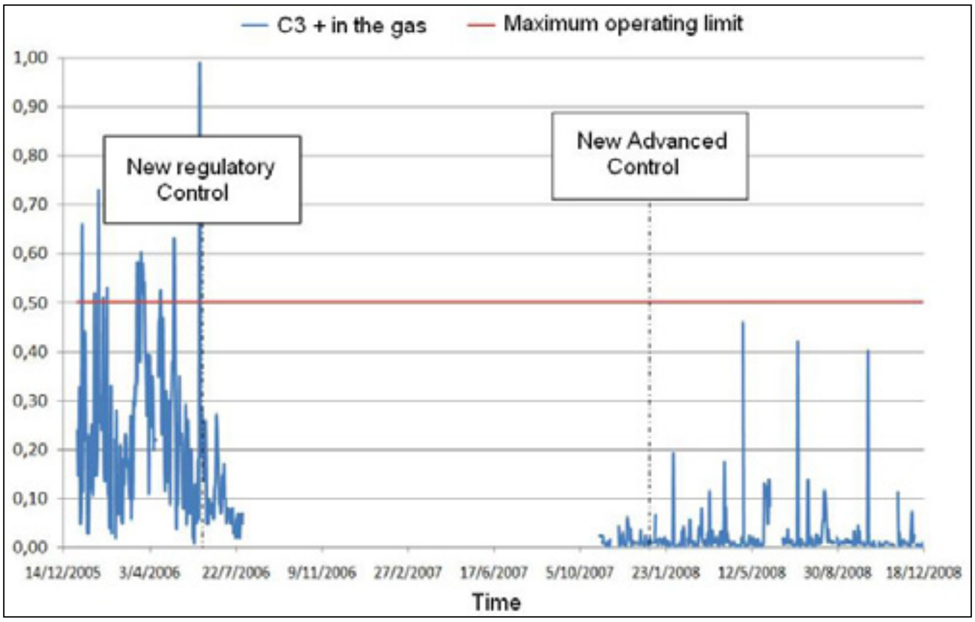


Figure 2 - Reduction of NGL loss

## CONCLUSION

This paper will present the methodology and results of a program to improve operation and control of several Natural Gas Processing Units (NGPUs). The great advantage of these methodologies and control systems is to operate more efficiently the equipments available in order to increase energy efficiency, profitability and sustainability of these industrial processes. Experience gained in this process showed that the methodology used to conduct the project deployment is critical to the success. It was observed that a continuous process of training and involvement of teams of operation, maintenance and engineering (like Process analysis, Production and Planning Program, Optimization and Automation, IT, Instrumentation, Laboratory and Production) are critical to minimize the impact of "culture shock" caused by the introduction of a new tools and operating philosophies, ensuring their continued use and the actual achievement of the benefits envisaged during the design phase. The implementation strategy adopted will also be discussed in this article, which included a partnership with a specialized company, in addition to research and development projects with Brazilian Universities associated with specific points of the project.

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**PAPER 2**

## APPROACH FOR THE IMPLEMENTATION OF AMR SYSTEM FOR GAS METERS IN FRANCE – GRDF PROJECT

Isabelle DROCHON: GrDF, Project Manager, Automated Gas Meter Reading Project

Pascal VERCAMER: GDF SUEZ, Research and Innovation Division, Research Program Manager for distribution and gas networks – member of Working Operating Committee 4 of IGU triennium 2010-2012

This paper deals with the preliminary studies and experimental roll out of Automatic Meter Reading (AMR) for gas consumptions which is being studied and performed by GrDF in France since 2008, involving all the stakeholders concerned by gas metering for end users. It examines also the possible applications regarding the operation of networks and new services in relation with the development of such a system.

This presentation will deal with the following topics:

- A short overview of the current position of gas metering for French consumers
- The definition of functionalities of a future AMR system
- The experimentation of the roll out of AMR in four French towns and their feedback on technical, operational and organizational aspects
- The planning of future operations
- A discussion about the use and the integration of a gas metering system for future networks in the town of tomorrow, including economical aspects.

### 1. Back ground: Current position of gas metering for French consumers

France comprises about 11 300 000 gas consumers. More than 95% of them are supplied through the network operated by the main Distribution System Operator (DSO) GrDF, Gas distribution affiliate. According to French law, DSOs are in charge of the installation and the maintenance of meters and is also responsible for meter reading on behalf of the suppliers.

Gas distribution is ruled by the French Gas Regulator implemented by the national law of 2004. The regulator proposes tariffs, examines the investment plans of network operators and is now a major player for defining rules to be applied in gas markets.

Automatic Metering for gas consumptions has been implemented by GrDF between 2008 and June 2012 for the 100 000 customers, mainly industrial or commercial, consuming more than 300 000 KWh per year (about 27 000 cubic meter/year). Beyond these big consumers, GrDF is conducting a new project to examine the technical and economical feasibility of the implementation of AMR system for all consumers, including domestic ones whose reading by employees at a 6-month frequency, in common with electricity consumptions. From 2007, the main electricity DSO is studying the possibility of remote meter reading by PLC (PowerLine Communications). Logically, gas DSOs have examined the possibility of implementing remote automatic reading with the different technical options existing.

## 2. Aims: definition of functionalities of a future AMR system: a collective work including important choices

In order to define functionalities of the future system, a national working group has been created. Placed under the umbrella of the French Regulator, it has gathered the main stakeholders concerned by metering: DSOs, Gas Suppliers, Consumers organizations, meter manufacturers… All could express their needs which were analyzed on the point of view of technical feasibility, value and costs, in order to define basic specifications and possible options.

Finally, the choice was made of an infrastructure:

- based on a fixed network that relies on radio technology
- targeting a remote system to collect meter read-outs
- with no remote interruption or reconnection of the supply of gas
- interoperable

Another important choice to be made was the position of gas metering versus electricity measurement. Was it more efficient to couple the two systems by using the electricity meter as a gateway for data collection or to build two independent systems for electricity and gas?

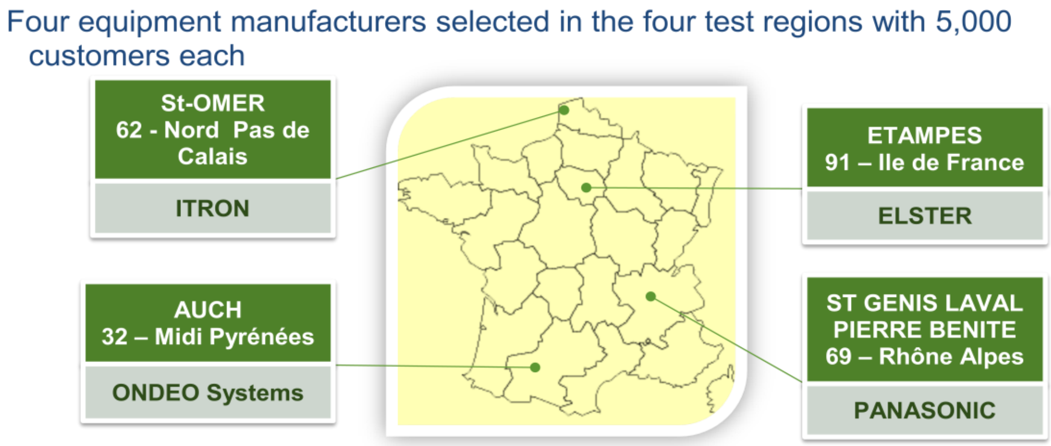
A study ordered by the French regulator, underlined that due to the specificity of the French energy market and the different kind of metering installation, technical mutualisation couldn't be implemented.

## 3. Experiments of roll out and results

### 3.1. Principles of experimentations – description

Four experiments in four different towns have been settled by GrDF, with a total of 18 500 meters installed. The principles were to give as much as possible freedom to the contractors, by imposing very few basic requirements. Therefore, contractors could propose:

- their communication architecture
- Additional options they considered as useful
- their organization for the roll out.



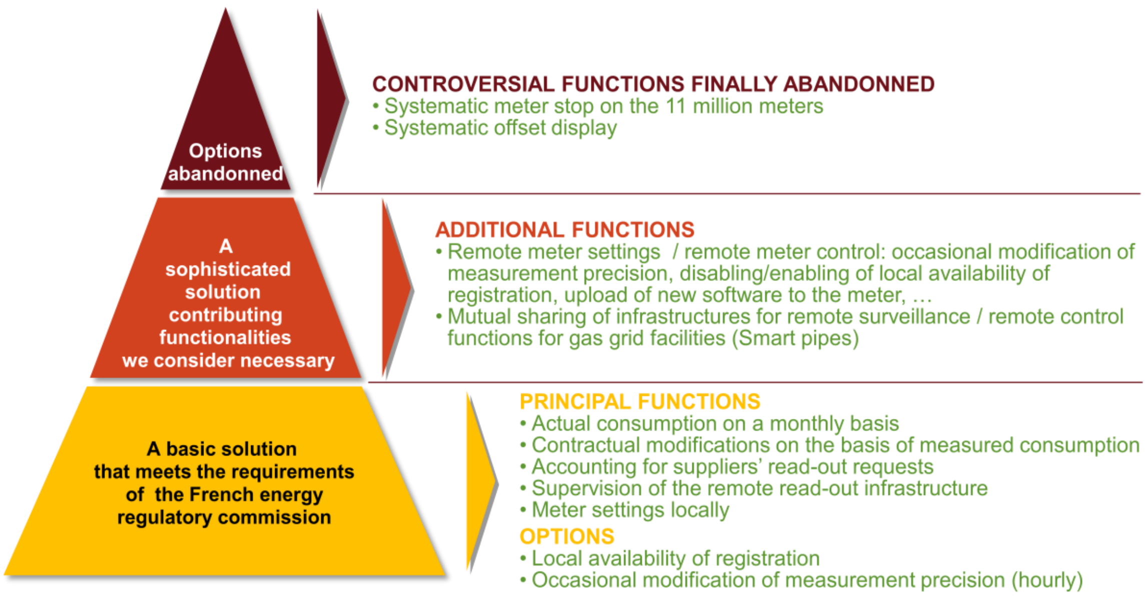

3.2. A lot of information analysed

The experiments took place from February 2010 to June 2011

Many aspects were analyzed:

- technical performance of the system (quality of communication, batteries…)
- conditions of preparation and installation of gas meters
- number, position and installation of concentrators and repeaters
- maintenance
- relationship with the different stakeholders and with the consumers

The paper will go through the main results of these different analysis.

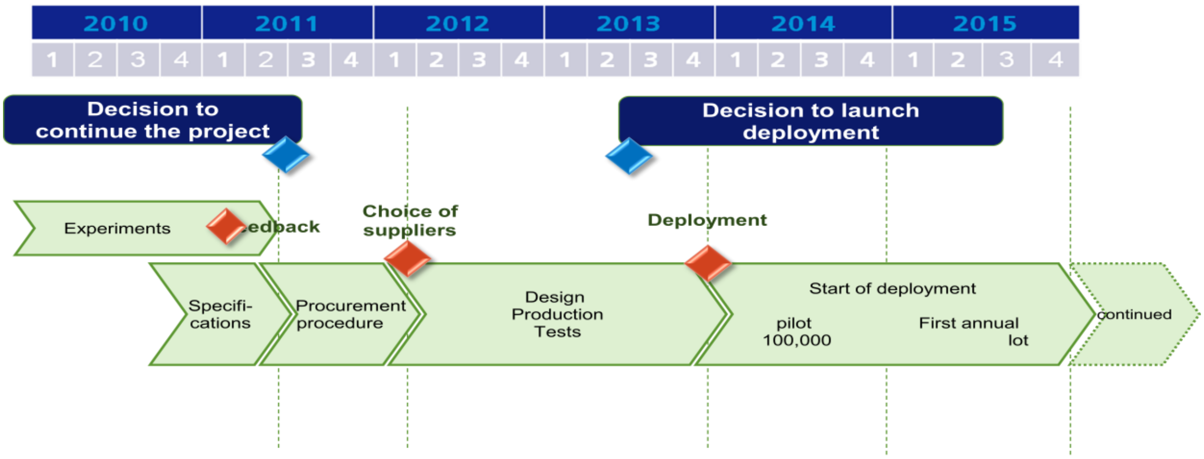


## 4. Planning for next steps

Two important events occurred in July 2011.

First, with the positive opinion issued by the French Energy Regulator regarding the roll out of the electricity Automatic Meter (called Linky) all over the country. If the French ministries in charge of the energy and the consumption accept the regulator proposition (decision scheduled by September 2011), this could have of course a major influence on future decision about gas metering .Then, In parallel, the regulator, in its deliberation of July 21th 2011 proposed to the French ministries of the energy and the consumption to validate the building of the AMR system for gas consumers according to the GrDF project. The position of ministries and conclusions should be given in autumn 2011.

The schedule is as follows:




## 5. Future developments around automatic metering of gas consumptions

Different initiatives have been taken in France and in Europe in gas area to think for integrating a new gas metering system in the town of tomorrow and in the future.

Automatic Meter reading for gas consumptions can be considered as a more global system including:

- new services for the consumer aiming to a better energy management
- integration with other measurements included in a larger system of survey for buildings, multi site operators or towns
- possibility for network operators to optimize or improve the management of their network.

All these possibilities are examined on different aspects: social and economical interest, possible organization, including the constraints induced by regulation and separation between network activities and energy or service supplies activities.

## 6. Conclusion

This presentation, based on large experiments in an existing gas network gives a good example of a methodology for building an industrial strategy about a major change in metering. It shows the different debates that take place on this kind of new system, not only on technical performances, but also about organization, relationships between stakeholders.

## PAPER 3

# DEVELOPMENT AND USE OF ULTRA STRENGTH PIPES FOR GAZPROM'S TRUNK GAS PIPELINES

V.V. Rusakova, T.P. Lobanova, A.B. Arabey (Gazprom), V.I. Bespalov, T.S. Esiev (Gazprom VNIIGAZ)

To ensure transmission of natural gas from fields of the Yamal Peninsula to consumers till 2030 it is planned to develop unique gas transmission system of a new generation, which has no parallels in the world. In 2011 the first line of Bovanenkovo-Ukhta trunk line was commissioned. Its length amounts to about 1100 km. The year 2013 will see construction of the second line (in total 5-6 lines are planned). It is evident that cost-effectiveness of long-distance gas transmission from regions with extremely complex natural and climatic conditions and poor infrastructure can be achieved only by considerable increase of the working pressure in gas pipeline, increase of pipe diameter and improvement of its strength properties, significant increase of pipeline operation reliability and service life. According to given estimates for Bovanenkovo-Ukhta trunk line acceptable project effectiveness can be ensured only if pipe diameter is 1420 mm, its wall thickness exceeds 20 mm, strength grade is X80, and design working pressure 11,8 MPa. Lack of global experience in large-scale production of pipes with such properties determined the need to develop high-strength pipes of new generation as the most relevant and complex scientific and technical problems.
To tackle this problem Gazprom and its R&D departments in cooperation with Russian companies that produce pipes and metals, performed unique research and pilot studies, which results helped to:

- develop grounded approaches to specification of the main process requirements for X80 pipes, 1420 mm in diameter, which ensure reliability and safety of gas transmission at the same time maintaining the possibility of large-scale pipe production at modern steel works;
- determine the best technologies and modes of welding of X80 1420 mm pipes with 33,4 mm wall thickness, including low temperature conditions;
- carry out comprehensive pipe tests (laboratory, plant, hydraulic, field pneumatic) unique in scale and specified conditions.

In-depth scientific-based analysis of the results of field pneumatic tests of pilot lots of pipes manufactured by different companies laid the foundation for technical requirements for X80 pipes.

Performed works allowed in relatively short period of time develop and introduce production technologies for wide rolled sheets and electric-welded X80 pipes 1420 mm in diameter for construction of Bovanenkovo-Ukhta trunk gas pipeline. Today commercial supplies of pipes in Russia are provided by Izhora pipe mill, Vyksa steel works, Volga pipe mill and Chelyabinsk Tube Rolling Plant.

# ABSTRACTS OF THE FINALISTS OF IGU'S GAS EFFICIENCY AWARD

## PAPER 1

## SENSIBLE HEAT, LATENT HEAT AND WATER RECOVERY FROM WASTE HEAT EXHAUST STREAMS USING THE TRANSPORT MEMBRANE CONDENSER

Dr Dexin Wang, Gas Technology Institute, USA

**Abstract:**
Until now, there has been no practical technology available for simultaneously recovering waste heat and clean water vapour from high moisture content natural gas exhaust heat streams. Typically, condensing natural gas exhaust gases results in a corrosive condensate that should be treated before disposal. Gas Technology Institute (GTI) has developed a new technology based on a nanoporous ceramic membrane that selectively extracts water vapour and its latent heat from natural gas exhaust gases. This is achieved through the patented Transport Membrane Condenser (TMC). Water vapour passes through a low-pressure-drop membrane and then condenses in direct contact with a low-temperature water stream. Contaminants such as CO2, CO, O2, $NO_x$, and SO2 are inhibited from passing through the membrane by its high selectivity. The recovered water is of high quality and mineral free, therefore can be used as supplemental makeup water for industrial processes and other uses. The TMC is commercially available for industrial boiler flue gas heat and water recovery. A wider range of applications are in development, including: industrial drying, commercial laundry heat and water recovery, a high-efficiency residential furnace humidifier that requires no external water supply, and other novel uses. The TMC provides an opportunity for substantial energy and water savings. For example, energy savings as high as 14,000 GJ/year are possible on a 2945 kW (300 boiler horsepower) boiler operating at high firing rates for 8000 hours per year. In addition, annual water savings of 1.6 million litres/year can be realized, providing added economic savings through avoided fresh water purchase, water treatment costs, and disposal.

### Background
An extensive amount of energy consumed today comes in the from fuel combustion—which results in substantial water vapour in the flue gas stream. In natural gas-fired equipment, water vapour often exits in the flue gases at a volume percentage up to 18%. Typically the water vapour along with its substantial latent heat is exhausted into the atmosphere, limiting thermal efficiency of these processes. Exhaust gas temperature can be reduced to its condensation temperature (dew point), but large heat transfer surfaces are required. In addition, conventional condensing equipment results in a problematic corrosive condensate with a pH level of 3-5. If 40 to 60% of this water vapour and its latent heat could be recovered, thermal efficiency would increase by approximately 10% or more for most of natural gas processes – a truly transformational technology. The TMC technology was developed by GTI as a component for high-efficiency boiler program that was sponsored by the United States Department of Energy (DOE), Utilization Technology Development (UTD), and other partners.

**TMC Concept**

Gas separation membranes generally can be categorized as porous and non-porous. Porous membranes, depending on pore size, can achieve higher transport fluxes than nonporous membranes but the separation ratio (or selectivity) is often lower. However, the vapour separation characteristics of porous membrane can be greatly improved under a condition wherein the vapour condenses within the membrane pore structure to such an extent that it completely fills the pores and prevents the transport of the non-condensable gas components. Under such a *capillary condensation* mode, one observes high flux rates and dramatic increases in the membrane selectivity towards the condensable component (i.e., water in this case).

GTI's experimental study found that a nanoporous ceramic membrane with a six nanometre mean pore size, when working in the Knudsen diffusion transport mode had insufficient water vapour transport flux and poor separation characteristics, as expected. But when the gas stream is adequately cooled by heat transfer from the permeate side, a higher performance capillary transport mode is evidenced. Water vapour transport flux then increases by a factor of more than 5 from the value measured in the Knudsen diffusion mode (Figure 1) and the separation ratio is vastly improved by a factor of more than 100.
Consequently, the onset of the membrane capillary condensation is a critical point for porous membrane vapour separation switching from a low performance mode to a high performance mode.

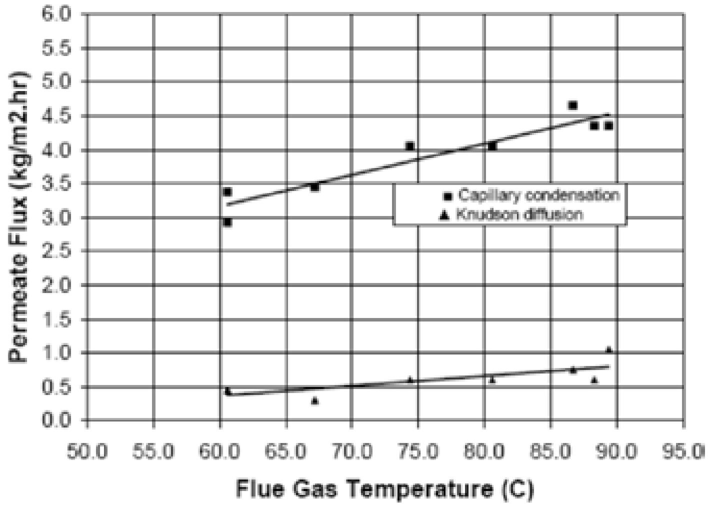



Figure 1: Membrane Transport Mode Effect

Figure 2 depicts the TMC concept for boiler applications with exhaust gas flowing on one side of a nanoporous ceramic membrane tube and cooler boiler feed water flowing on the opposing side. Flue gas water vapour is transported through the membrane structure by first condensing inside the inner separation membrane layer (60A to 80A pore size), then moving through the intermediate layer (500A pore size) and finally through the substrate (0.4 µm pore size). Other gas components in the flue gas are blocked from passing through the membrane by the condensed liquid. The net result is an important three-part benefit: sensible waste heat recovery, latent heat recovery from water condensation, and recovery of clean water (derived from natural gas combustion) that can be added to the steam generation process (without a concern over non-condensable gases such as CO2 that would otherwise cause a corrosive condensate).

Importantly, the TMC's capillary condensation mechanism operates with very low pressure drop—making it suitable for exhaust gas recovery systems.

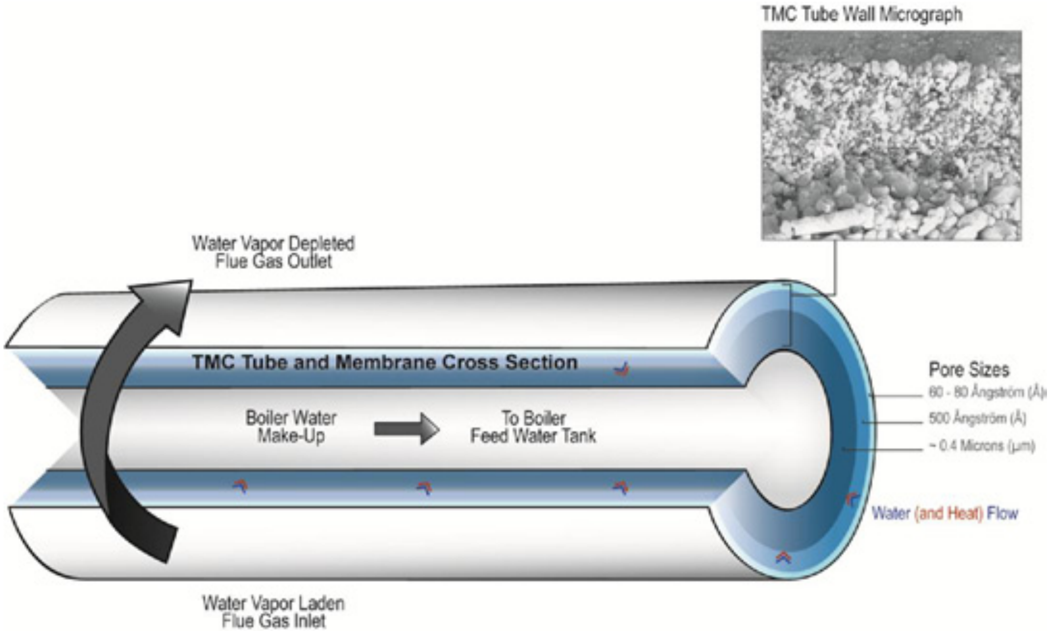



Figure 2: TMC Concept Schematic (Single Tube Cutaway)

**Field Demonstrations for Industrial Boilers**

Four TMC systems have been installed and operated in industrial boiler applications prior to commercial release by Cannon Boiler Works

- Specification Rubber in Alabama has operated for over 15,000 hours with a 94% fuel-to-steam efficiency (HHV), 19% reduction in fuel consumption, 19% reduction in greenhouse gas emissions, and a 20% reduction in boiler feed water. The TMC alone contributes over 40% of the boiler efficiency increase and is responsible for all the water savings.
- Clement Pappas & Company in California has operated for over 10,000 hours with a 93% fuel-to steam efficiency (HHV), 12% reduction in fuel consumption, 12% reduction in greenhouse gas emissions, and a 20% reduction in boiler feed water.
- Baxter Healthcare in California has operated for over 4,000 hours with a 93% fuel-to-steam efficiency (HHV), 12% reduction in fuel consumption, 12% reduction in greenhouse gas emissions, and a 20% reduction in boiler feed water. This was the first demonstration of the pre-commercial (beta) TMC modules (Figures 3 and 4).
- Richardson Brands Company in New York – A recent installation that is expected to achieve 94% fuel-to-steam efficiency (HHV) and recover 40% of the exhaust gas water vapour.

Figure 3: Baxter Healthcare Installation Figure 4: 2nd Generation TMC Module

**Energy and Economic Benefits**

The TMC technology, when used in combination with heat recovery economizers, provides energy efficiency, water savings, and energy cost saving benefits for consumers. Figure 3 shows the potential annual energy savings as a function of firing rate and annual operating hours. Energy savings as high as 14,000 GJ/year are possible on a 2945 kW (300 boiler hp) boiler operating at high firing rates for 8000 hours per year.

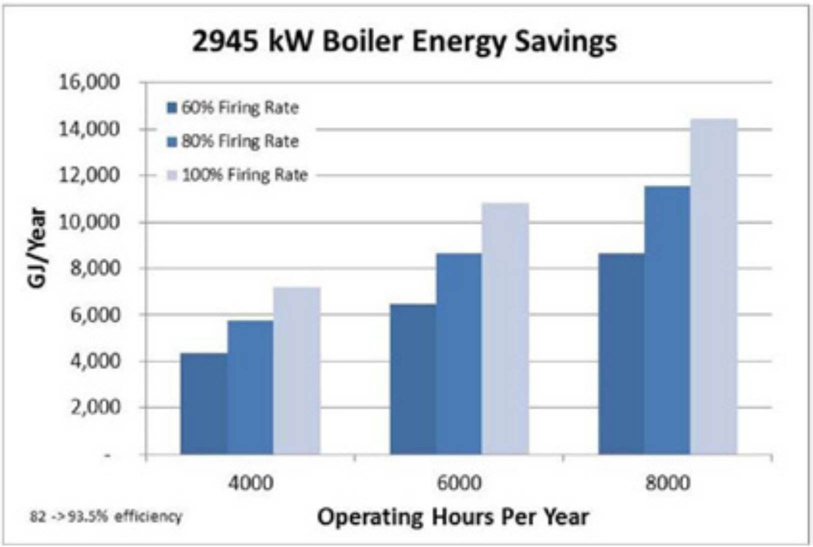



Figure 3. AHRS Energy Savings Benefits

The TMC provides the added benefit of recovering water from the exhaust gas that can be used for steam generation. Figure 4 shows the potential water recovery rates at different firing rates and operating hours for a 2945 kW (assuming a 40% exhaust water recovery rate). Annual water savings of 1.6 million litres/year are possible at higher firing rates and operating hours. This water provides economic savings through avoided fresh water purchase, water treatment costs, and disposal.

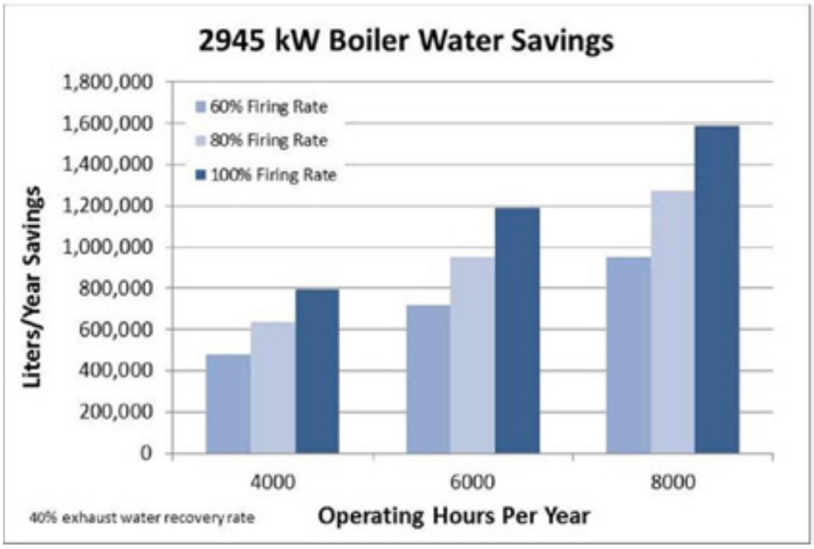



Figure 4. AHRS Annual Water Recovery Rates

Payback periods of 1.5-3 years are possible with this new product (depending on size, operating hours, firing rate, and natural gas prices). The payback period is somewhat higher in the United States due to a sharp reduction in natural gas prices in recent years. The TMC technology provides a unique value proposition for the gas industry in numerous low-temperate heat and water recovery applications. The recovery of clean water from natural gas combustion products represents a unique differentiating feature of this technology.

**Commercialization**

GTI licensed the TMC technology to Cannon Boiler Works (CBW). CBW is an established supplier of boiler heat recovery devices including economizers, vent condensers, air coolers, after coolers and other energy efficient devices. They are currently marketing the TMC under the trade name Ultramizer® for both new and existing boiler systems. (http://www.cannonboilerworks.com/home.html). For boiler rooms with sufficient space above the boiler, the Ultramizer is stacked directly on top of the boiler to reduce equipment footprint (Figure 5). CBW celebrated the first Ultramizer ceremonial start on September 9, 2010 at a brewery in Pennsylvania on an existing fire tube boiler system.

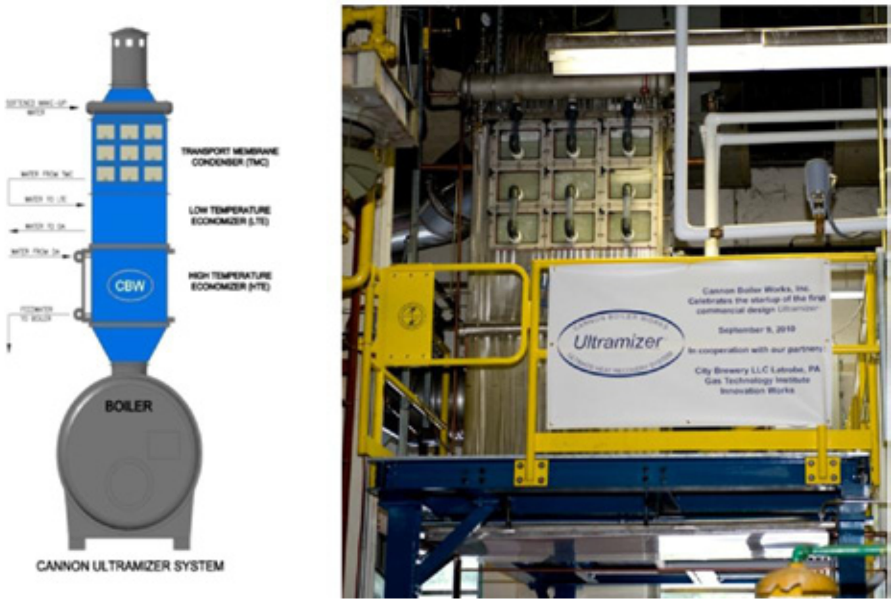



Figure 5: Ultramizer Design and Deployment at First Commercial Site

**Expanded TMC Applications**

The TMC waste heat recovery technology was developed initially for industrial boiler applications. However, this low temperature waste heat and water recovery concept can be applied to any gas steam with water vapour content >15% and temperature >60°C. Applications include wet scrubber heat and water recovery, drying operations, humidification processes, kilns, furnaces, ovens, and other uses.

GTI is currently conducting research and demonstration of the TMC technology for specialty flue gas/water recovery markets including:

- Commercial laundries: A demonstration was installed in October 2010 for recovery of heat and water vapour associated with direct contact steam use.
- Add-on device for home furnaces to increase efficiency and provide a space humidifier that requires no external water supply. Three test units are in operation (two in residential use).
- Design for a vent condenser product.
- Coal fired power plants: A slip stream demonstration will be installed in late 2011.

The TMC's ability to cost effectively conserve energy and recovery water from natural gas combustion products represents an important new technology for the natural gas industry. This concept represents a foundation technology that can be built up for use in a broad spectrum of applications.

## PAPER 2

# INNOVATIVE, FLAMELESS REGENERATIVE BURNERS FOR DIRECT FIRED FURNACES OF HOT DIP GALVANIZING LINES UP TO 15% LINES PRODUCTIVITY INCREASE

Clotilde Villermaux, Nicholas Richard, Thierry Bellin-Croyat, Guillaume Daill, Philippe Buchet (all from GDF SUEZ)
Karen Beaujard, Armand Danda, Bertrand Louis, Hubert Saint-Raymond (all from Arcelor Mittal Maizieres Research)

**ABSTRACT**
On some hot dip galvanizing lines, the heating furnace entry is equipped by direct fired burners managed with sub-stoechiometric gas combustion conditions. Indeed, the production of high added value steel grades and the respect of the high product coating quality requirements lead to continuously control the interaction between the furnace atmosphere and the strip surface: a key point consists on mastering the strip surface oxidation / heating kinetics to be able to reduce the oxides during the soaking time. The air deficiency into the preheating atmosphere is used to control the oxides nature and its thickness depending on the steel grad and the process conditions. A perfect wettability of the strip during the galvanizing process is thus ensured.

ArcelorMittal and GDF Suez worked together on an innovative technology dedicated to the pre-heating sections equipped with direct fired burners Hot Dip Galvanizing lines.

The innovative burning technology dedicated to non-oxidizing heating atmospheres consists on a combination of an integrated post-combustion system, a regenerative system and a flameless combustion technology. The association of those three principles is a European innovation by itself. It had to allow to:

- guarantee a complete combustion at the furnace exit
- lead to high energy efficiency
- achieve a cleaner process (NOx& CO)
- obtain a homogeneous heating temperature

The main issues to solve before implementing the innovation on one industrial line were:

- How to design the regenerative burners' technology to reach a healthy behaviour in flameless combustion? What optimization of the working parameters to achieve maximal performances?
- What feasibility to implement flameless regenerative burners into heating section firing under sub-stoechiometric combustion conditions? What impact on the steel surfaces?

We demonstrated the particular interest of the technology for continuous annealing lines as the R&D program led to evaluate the expected energy savings, pollutant emissions and productivity gains in the case of a line retrofit:

- A saving up to 15% on gas consumption and associated CO2 emission,
- A decrease of 10% on CO emission
- A low level of NOx emission: 200 mg/Nm3 Qa 3% O2
- No impact on product quality

These encouraging results allow us to predict a productivity increase up to 15% on the studied bottlenecks of HDG lines, especially dedicated to high added value steel grades. Complementary measurements and tests will be conducted in real production conditions on the industrial line where the first implementation of developed flameless regenerative solution will be done to assess the performances measured in the semi-industrial conditions.

ArcelorMittal lines are especially interested in increasing the productivity of high added value steel grades like the hot stamping “Usibor” grade dedicated to automotive and industry applications. The markets perspectives show a high demand of those grades so that the identified lines require corresponding productivity increase.

The key processes of galvanising lines are the annealing treatment occurring into the annealing furnace, the galvanising section and the finishing section (Figure 1).

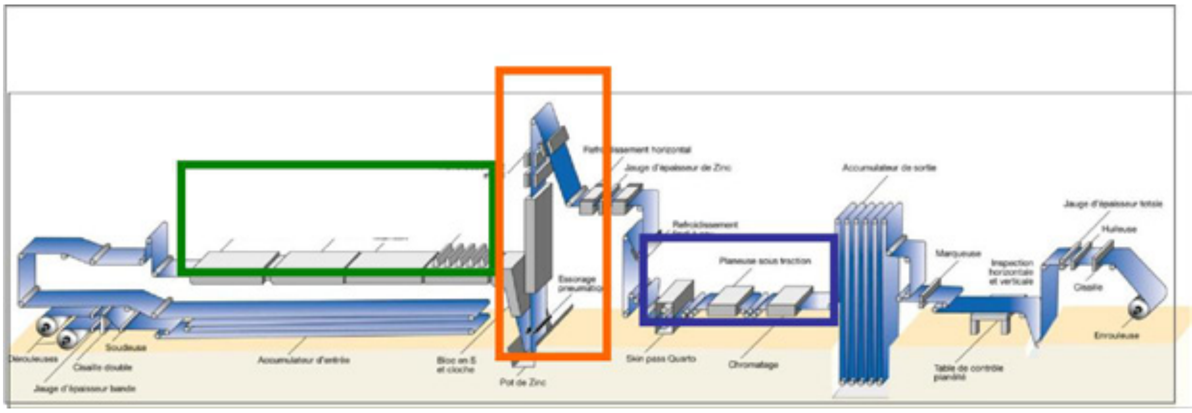


*Figure 1: Diagram of a galvanizing line*

The metallurgical characteristics and the mechanical properties are obtained during the heating treatment and by mastering the cooling profiles. The coating aspect and the corrosion properties of the galvanised strip are obtained during the coating deposition on the strip surfaces at the exit of the galvanizing bath (liquid metallic coating).

The preheating section, the heating section, the soaking zone and the rapid cooling section make up the annealing furnace. Most of the strip heating occurs into the preheating section.
Many hot dip galvanizing lines are equipped with a preheating section divided in 2 zones (figure 2): a post-combustion section and a heating zone equipped with direct flame burners managed with substoechiometric gas combustion conditions.

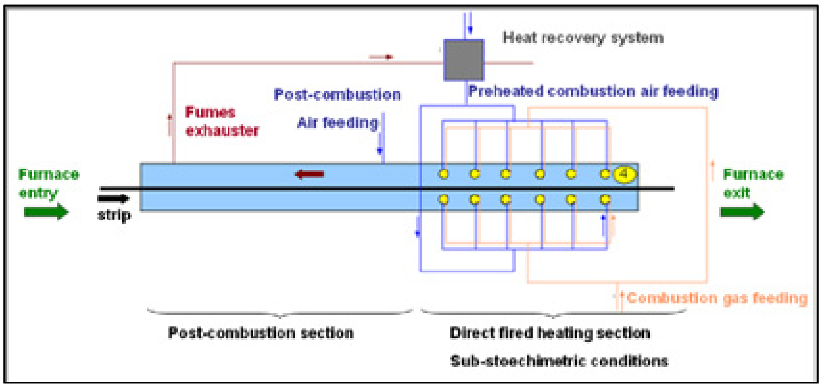



*Figure 2: Diagram of a preheating section equipped with direct fired burners*

The production of high added value steel grades and the respect of the high product coating quality requirements lead to continuously control the interaction between the strip surface and the gas furnace atmosphere, especially in the direct fired section: a key point to take care during the galvanizing process consists on mastering the strip surface oxidation/heating kinetics to be able to reduce the oxides during the soaking time. A perfect wettability of the steel strip during the galvanizing process is thus ensured. The air deficiency into the furnace is used to control the oxides nature and thickness on the steel surface depending on the strip chemical components and process conditions

Many continuous annealing lines and more especially hot dip galvanizing lines equipped with direct fired furnace preheating section encountered bottlenecks issues to increase their productivity thanks classical heating power boosting.

The principle of regenerative burners with the fumes aspirations cycling particularly arouses the industrial lines interest. In addition, the reduction of energy consumption that allows the flameless regenerative technology is relevant to respect the European environmental standards and to reduce the production costs. For both productivity and energy savings objectives, an innovative technology based on flameless regenerative burners matches the industrial needs.

<u>Principle</u>

GDF-Suez and ArcelorMittal identified the potential interest to apply flameless regenerative burners to the specific conditions of preheating section on galvanizing lines. The innovative burning technology dedicated to non-oxidizing heating atmospheres consists on a combination of an integrated post- combustion system, a regenerative system and a flameless combustion technology. The association of those three principles should allow meeting the following requirements:

- to guarantee a complete combustion at the furnace exit
- to lead to high energy efficiency
- to achieve a cleaner process (NOx& CO)
- to obtain an homogeneous heating temperature

GDF-Suez and ArcelorMittal decided to join their complementary competencies within a collaboration (2007-2010) to test and to characterize in semi-industrial conditions the performances of this innovative solution, and finally to prepare the first industrial implementation.

The working principle of these industrial burner prototypes is presented in Figure 3:

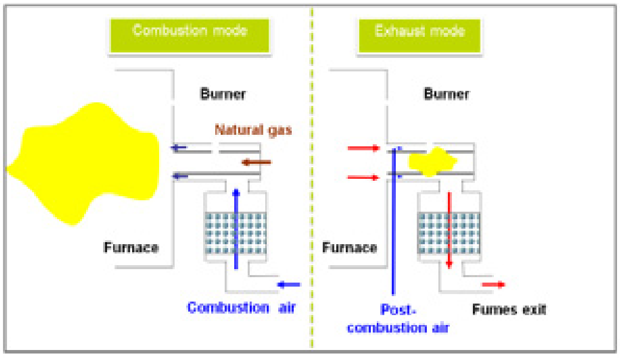



*Figure 3: Working principle of innovative technology*

During the exhausting mode, the fumes of the furnace (~1300°C), that still contains combustible (air deficiency combustion) are sucked through the burner chamber. Then the combustion of the not burnt elements occurs thanks a second air injection to obtain a complete combustion (post-combustion in over stoechiometric conditions). Finally the fumes (~1400°C) go through the regenerator to transfer its heat to the ceramic spheres of the regenerative store so that the fumes are quite cold at the exit of the regenerator (< 300°C).

When the cycle switches from exhausting phase to combustion mode, the ambient air (~25°C) is injected through the regenerator store to be preheated (~1000°C) before entering into the burner's chamber. The preheated air is then sent into the furnace chamber at high velocity and separately from combustion natural gas so that the combustion occurs into the furnace with the flameless principle.

The adaptation of the flameless regenerative burners to sub-stoechiometric conditions of the preheating section of galvanizing lines is a European innovation by itself and raises issues like:

- How to design the regenerative burners' technology to reach a healthy behaviour in flameless combustion? What optimization of the working parameters to achieve maximal performances?
- What feasibility to implement flameless regenerative burners into heating section under sub-stoechiometric conditions? What impact on the steel surfaces?

Results: Benefits / savings of gas estimated

The pair of burner prototypes that have been tested are based on a commercial regenerative flameless burner design (300kW gas power). The regenerative storage and the post-combustion chamber between the nozzle and the regenerative tank have been adapted to investigate several technical options (size, injection...) in the perspective of this particular application.

The project was set-up following three work axes:

1- Experimental characterization of the combustion efficiency and the gas atmosphere generated by these prototypes within an semi-industrial scale furnace, optimization of operating conditions;
2- Based on previous results, impact of the generated gas atmosphere to the steel surface.

3- Evaluation of the energy savings, the environmental impact and costs savings for specific ArcelorMittal hot dip galvanizing lines with dedicated numerical tools.

Complementary experimental means, complex measurements and numerical tools have been displayed, based on GDF Suez and ArcelorMittalexpertises.
Resulting from characterization campaigns, the performances of the tested burners are already encouraging and already suitable for industrial use:

- No operating problem has been detected. The burners and its associated post combustion systems run under safe conditions, during ignition and operation.
- Performances in terms of $NO_x$ and CO emissions need a set of optimised values of the operating parameters, but have already satisfactory levels for an industrial use.
- Combustion efficiency of this innovative technology is very high and promises to reach a more energy efficient furnace compared to actual technology.
- Temperature field within the furnace, and particularly near the strip, seems to be quite homogeneous, leading to a better heating quality.
- There is no impact of the generated atmosphere on the quality of the surface of the strip

Two different real cases of ArcelorMittal industrial issues have been investigated for a demonstration operation on an industrial site. The estimation of the gains on these industrial lines have been obtained thanks to the numerical tool that have been validated as representative of existing lines and as able to model the innovative regenerative burners implemented on the line.

Energy savings stakes for line A: for that case, a full conversion from standard burners to the innovative burners has been analysed. Provided the innovative burners are located at an optimised place on the line, not simply replaced at the location of the existing burners: we can then have significant energy savings (up to 14% of thick strip) while respecting the constraints of the furnace such as the maximum temperature of the roof.

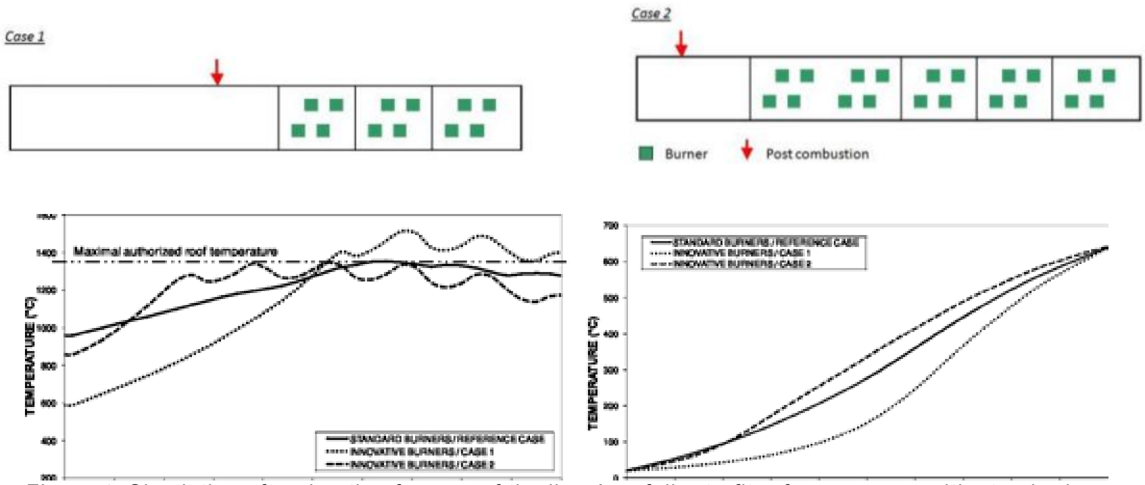


Figure 4: Simulation of preheating furnace of the line A— full retrofit reference case with standard burners and different options of the innovative technology implementation

A productivity increase issue for line B: for that case, a retrofit of one combustion zone has been studied. Indeed, the preheating furnace of this line is equipped with a classical recovery system and 3 burning zones. The first burning zone could not be used because of extraction flow rate and temperature limitations of the recovery system. This power limitation implies a bottleneck in term of production. No existing technology meets the issue except the full retrofit of the recovery system.

The computations performed to dimension the heating power repartition and the burners location show that the implementation of regenerative burners into the first burning zone, can lead to a maximum productivity increase of 15 % for the considered product order book whereas additional energy savings can reach 5% (specific gas consumption)

The strip thermal profile and target temperature at the exit of the preheating furnace are respected as well the acceptable roof temperature and fumes temperature at the exhauster.

In that second industrial case, this technology is the optimal candidate to solve the furnace bottleneck in order to increase productivity at lower investment's costs.

<u>Conclusion</u>

Thanks to experimental campaigns on the behaviour and performances of the burner prototype, to an original survey on its impact on the product quality, and to complementary calculations with a dedicated numerical tool, we demonstrated the particular interest of the technology for continuous annealing lines.

The Research and Development program led to validate the feasibility to implement flameless regenerative burners into heating section under sub-stoechiometric conditions and to evaluate the expected energy savings, pollutant emissions and productivity gains in the case of a line retrofit:

- A saving up to 15% on gas consumption and associated CO2 emission,
- A decrease of 10% on CO emission
- A low level of NOx emission: 200 mg/Nm3 Qa 3% O2
- No impact on product quality

These encouraging results allow us to predict a productivity increase up to 15% on some bottlenecks Hot Dip Galvanizing lines, especially dedicated to high added value steel grades.

Complementary measurements and tests will be conducted in real production conditions on the industrial line where the first implementation of developed flameless regenerative solution will be done to assess the performances measured in the semi-industrial conditions and the estimated associated gains.

## PAPER 3

# DEVELOPMENT OF HCCI NATURAL GAS ENGINES

Kazunobo Kobayashi[1], Takahiro Sako[1], Yoshima Sakaguchi[1], Satoshi Morimoto[2], Sumihiro Kanematsu[3], Kiyoshi Suzuki[4], Tohru Nakazono[5], Hiroyuki Ohtsubo[5]
[1] Osaka Gas, [2] Tokyo Gas, [3]Toho Gas, [4] Saibu Gas, [5] Yanmar – Japan

**Abstract**
The possibility of turbo charging a natural gas-fuelled homogeneous charge compression ignition (HCCI) engine was experimentally investigated. The performance of the engine fitted with a newly developed turbocharger was demonstrated. As a result, 43.3% brake thermal efficiency, 0.98 MPa brake mean effective pressure, and 13.8 ppmNOx emission have been realized. This value shows the possibility that a power generating efficiency of 40% at a power output of 50 kW can be achieved when applied to combined heat and power (CHP), even allowing for the energy losses in the generator and the power inverter. For practical use, ignition timing control, operation control, including how to start or input load and ensuring durability, remain to be investigated. To clarify these, we carried out an endurance test of a newly developed 25 kW HCCI package without supercharging.

**Background**
Figure 1 shows the current gas engine CHP line-up. The range of power output is from 1 kilowatt for residential use to several megawatts for industrial use. The power generation efficiency of 40% is the average at the receiving end by thermal power generation in Japan. The electric power generation efficiency of large-scale CHP is over 40%, higher than the average receiving-end efficiency of thermal power generation. However , the efficiency of small-scale CHP (100 kW or less) is not so high. Therefore, small gas engines with high efficiency are highly expected. Against this background, we have focused on HCCI combustion as an innovative technology.

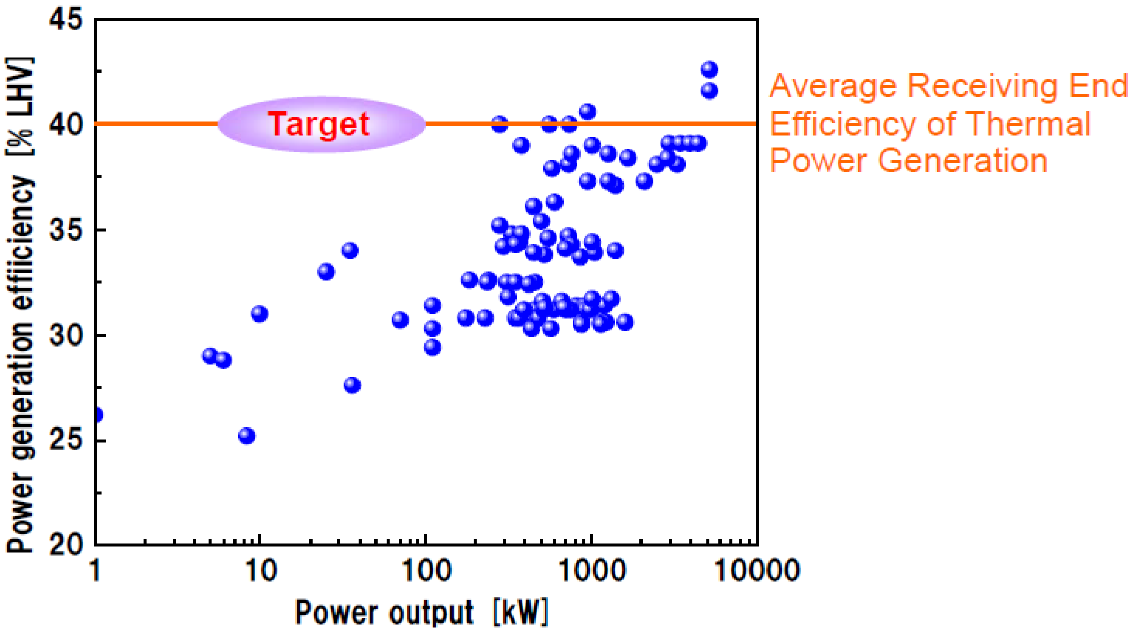



Fig. 1 Current gas-engine CHP line-up

**New Engine Combustion System: Homogeneous Charge Compression Ignition (HCCI)**

HCCI engines have the potential to be lower in NOx emissions than diesel engines and higher in thermal efficiency than gasoline engines under low partial load[1][2]. In the HCCI engine, ultra-lean air-fuel mixture is highly compressed by the piston and ignited at the self-ignition temperature. Then, combustion occurs in the entire combustion chamber, and the combustion rate is very high. As a result of ultra-lean combustion under a high compression ratio, high thermal efficiency and extremely low NOxemission have been achieved. Previous studies have revealed that the load range where HCCI engine operation is possible is limited, regardless of the fuel, by the risk of misfire and combustion instability[3]. Studies have also revealed a difficulty in ensuring stable combustion over a wide range of operation, including full load. Stationaryengines for combined heat and power (CHP) are required to have high combustion efficiency as well as clean emissions. On the other hand, stationary engines for CHP tend to be operated within a relatively narrow load range around the rated load. Considering these circumstances, HCCI gas engines may be a more fuel- and environmentally efficient option compared with conventional diesel or spark ignition (SI) engines for application to CHP. Natural gas has a higher self-ignition temperature than other fuels, so that the use of natural gas in HCCI engines makes it possible to operate them under higher compression ratios.

Most studies have been made to expand the operating range of natural gas HCCI engines[3]. While it has been shown that both the ignition timing and combustion duration are controllable, there remains much room for further improvement in terms of mean effective pressure.

**Considerable Potential of HCCI Engine**

The base engine used for this test was a natural-aspiration, water-cooled, 4-cycle natural gas engine. Experiments were carried out, using a naturally aspirated engine fitted with an external supercharger and a butterfly valve for back pressure control to simulate a turbocharger. Figure 2 shows the performance of a turbocharged HCCI engine compared with a conventional SI engine and a natural-aspiration HCCI engine. The conversion efficiency of the generator and that of the power inverter were assumed as 95%. The power generation efficiency of the natural-aspiration HCCI engine was about 5% higher than that of the conventional SI engine. On the other hand, the brake mean effective pressure (BMEP) and power generation efficiency of the turbocharged HCCI engine were both much higher than those of the conventional SI engine. In particular, the BMEP was about twice higher than for the conventional SI engine and the power generation efficiency was about 40%. This means that the turbocharged natural gas-fuelled HCCI engine has a considerable potential.

Due to the characteristics of natural gas as a fuel, a high intake air temperature is necessary to achieve self-ignition, but with the turbocharger, intake air heating becomes unnecessary, which is another advantage.

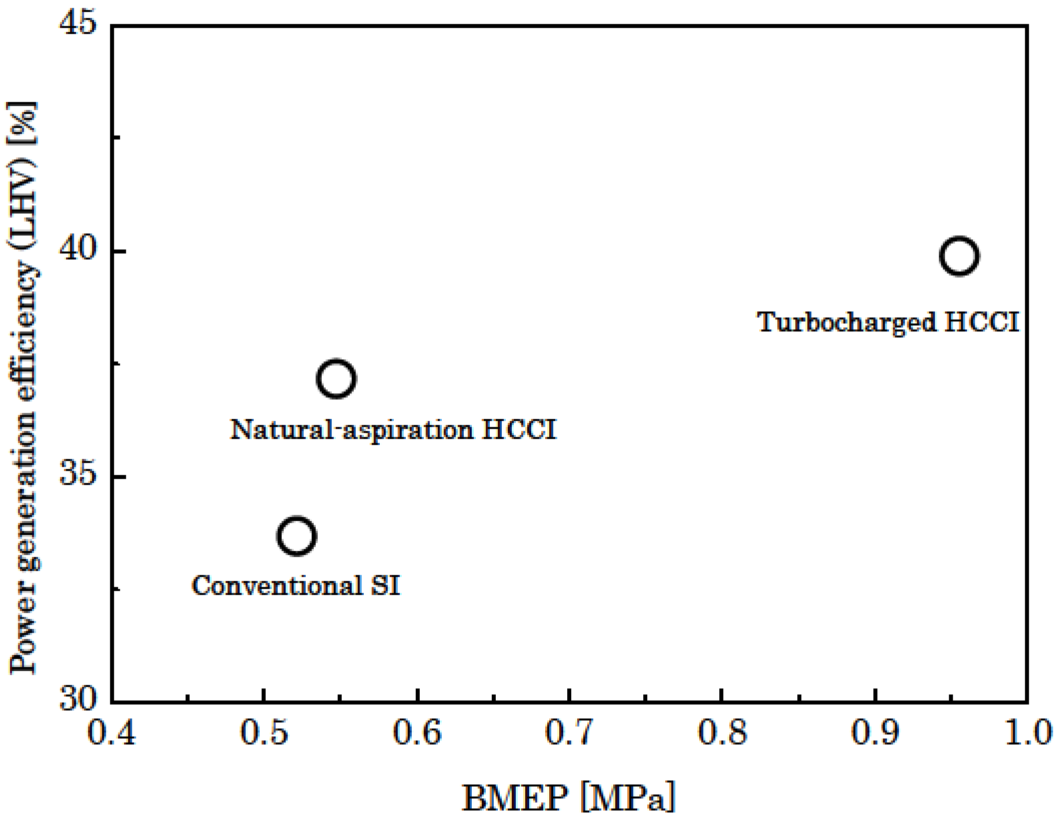



Fig.2 Comparison of turbocharged HCCI engine and natural- aspiration HCCI engine.

**Demonstration of High Efficiency and Extremely Low NOx Emission Using a Newly Developed Turbocharger**

There has been no small gas engine with a turbocharger. In this study, a specialized turbocharger was newly developed. Compared with a conventional turbocharger, the size of the turbine scroll and diffuser was increased. Figure 3 shows the test engine on which the newly developed turbocharger is mounted.

Fig.3 Turbocharger mounted on HCCI engine

As a result, 43.3% brake thermal efficiency, 0.98 MPa brake mean effective pressure, and 13.8 ppm NOx emission have been realized. These values show the possibility that a power generating efficiency of 40% at a power output of 50 kW can be achieved when applied to CHP, even allowing for energy losses in the generator and the power inverter.

**Approach for practical use of the HCCI engine**

The HCCI engine has a very high potential for a CHP power source. However, for practical use, ignition timing control, operation control, including how to start or load input, and ensuring durability, remain to be investigated. To clarify these, we carried out an endurance test of a newly developed 25 kW HCCI package without supercharging. Figure 4 shows this newly developed 25 kW HCCI package. The engine was evaluated as to its durability, including the engine control unit.

In the future, we intend to refine the product specifications; power output, power generating efficiency, cost, and so on.

Fig.4 Newly developed 25 kW HCCI package

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## PAPER 4

# COMMERCIALISATION OF A RESIDENTIAL PEM FUEL CELL CHP “ENE FARM”

Kunihiro Nishizaki, Tokyo Gas Co.Ltd.; Kazuhiro Hirai, Osaka Gas Co. Ltd.

**Abstract**
Proton Exchange Membrane fuel cell (PEMFC) based residential CHP fuelled by natural gas has been developed by Japanese Gas Utilities from around 2000. And from JFY 2005 to JFY 2008, over 1,300 natural gas residential PEMFC CHP systems were demonstrated in the Large Scale Stationary Fuel Cell Demonstration Project conducted by NEDO[*1] subsidized by METI[*2]. In the project superior performances of the systems, such as 23% reduction in primary energy use and 38% reduction in CO2 emission, were demonstrated in actual use at real households.*1: New Energy and Industrial Technology Development Organization, *2: Ministry of Economy, Trade and Industry

Encouraged by the satisfactory result, Tokyo Gas and Osaka Gas stepped for commercialization of respective residential PEMFC CHP system with their joint development partners such as Panasonic, Toshiba Fuel Cell Power Systems (Toshiba FCP) and so on. Intensive development activities were conducted aiming higher reliability, longer lifetime, easier installation and maintenance, improved remote control device and lower cost without sacrificing the superior performance demonstrated in the Large Scale Demonstration Project.

As a result of the development, the both companies successfully released their respective commercial model of residential PEMFC CHP systems with a trade name “ENE FARM” in the spring of 2009. And the ENE FARMs were released from the other Japanese natural gas utilities too.

Each model of ENE FARM, whose rated power is from 0.7 to 1 kW, generates power and hot water for domestic use efficiently with electrical efficiency of over 35 % and overall efficiency of over 80 %. With the high performance, large reduction in primary energy consumption is expected. Counting their superior performance, METI has started subsidization for the customers who install the system in order to promote the market penetration of the residential PEMFC CHP systems from JFY 2009.

Over 7,700 natural gas ENE FARMs were sold in about two years from their launch to the end of March 2011. And the number of sales contract of ENE FARM in three months from April to June 2011 is approaching 5,000.

## 1. Basic technology development

PEMFC, a kind of fuel cell, is a technology that can generate power efficiently with very low environmental impact (clean exhaust, low noise and vibration etc.) in very small scale such as sub-kW class using hydrogen as its fuel. Although PEMFC is operated at relatively low temperature or 60 to 80 deg C, its waste heat can be recovered as hot water useful in households.

Counting these features, Tokyo Gas and Osaka Gas proposed a concept of highly efficient residential CHP system using PEMFC combined with natural gas fuel processor, and the Japanese Gas Utilities including both companies started development program respectively from around 2000. Schematic of a residential PEMFC CHP is shown in Fig. 1.

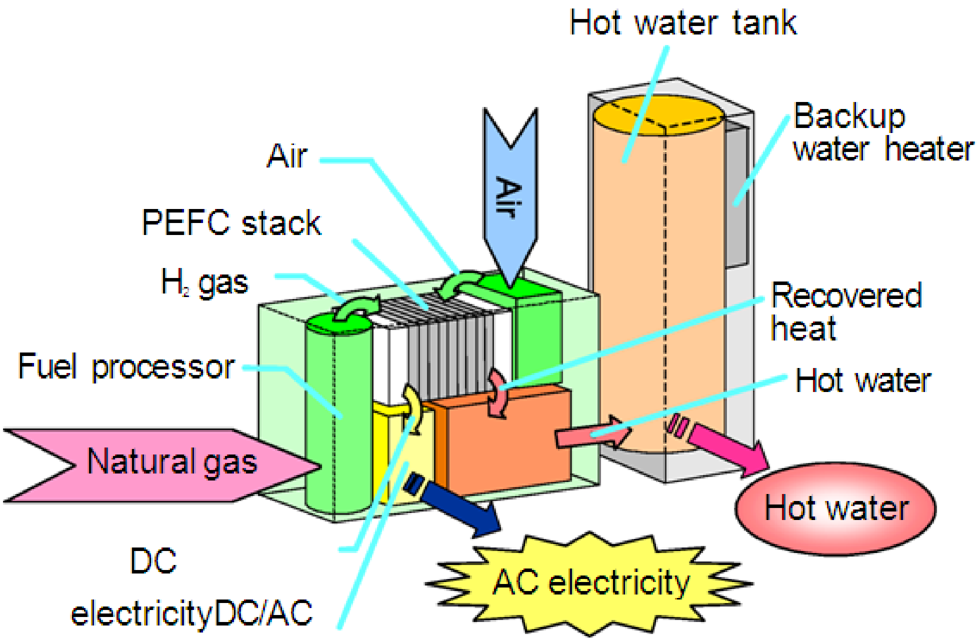



Fig.1 Schematic of a residential PEMFC CHP

Many basic technical barriers, including highly efficient and compact natural gas fuel processor, durability of the PEMFC stack and the fuel processor against frequent start and shutdown without nitrogen as protective inert gas, intelligent operation control to achieve maximum energy efficiency in real household, were overcome in the early stage of their development program with PEMFC manufacturers.

And in parallel many barriers related to regulation were also overcome by cooperation of Japan Gas Association, PEMFC manufacturers and other energy industries such as oil and LPG. Tokyo Gas and Osaka Gas played a main role in these activities.

As a result, PEMFC CHP systems 23% reduction in primary energy use and 38% reduction in CO2 emission as an averaged data of the best performance model in the Large Scale Stationary Fuel Cell Demonstration Project. The project was a program conducted by NEDO subsidized by METI to test a large number of PEMFC CHP systems at real households from 2005 to 2008.

2. Commercial product development

Encouraged by the satisfactory result from the Large Scale Stationary Fuel Cell Demonstration Project, Tokyo Gas and Osaka Gas stepped for commercialization of respective residential PEMFC CHP system. Tokyo Gas teamed with Panasonic and Osaka Gas teamed with Toshiba FCP and ENEOS Celltech respectively.

Performance of PEMFC CHP systems at the project was superior, but many issues, such as higher reliability (Reduction of troubles), longer lifetime, easier installation, easier maintenance, improved remote control device and lower cost, still remained and intensive development activities were conducted for each issue.

1) Reliability

In order to reduce troubles, design was improved based on the analysis of troubles of the past models and prototypes.

2) Lifetime

Durability of PEMFC stack and fuel processor those decide lifetime of the system was greatly improved by intensive R&D in the academia and the fuel cell industry. But for commercial release, methods to confirm their lifetime in shorter time were necessary too. Both companies established the methods with their joint development partners as a result of intensive R&D. As a result, targeted lifetime was established.

3) Installation and maintenance

Shortening the time and reducing the hands for installation and maintenance is also very important. Workers engaged in installation or maintenance of usual domestic gas appliance checked prototypes. Design was improved by their advices.

4) Remote control device

In order to improve users' satisfaction, the information displayed at the remote control device was enriched in terms of power generation, recovered heat usage, $CO_2$ reduction and so on.

5) Cost

In addition to the cost reduction of major components such as PEMFC stack and fuel processor, simplification of system configuration contributed to reducing cost. Some BOP (balance of plants) components from NEDO project that developed BOP components based on the unified specification by Japanese residential PEMFC manufacturers were adopted.

As a result of these efforts, Tokyo Gas and Osaka Gas have successfully developed and released respective commercial products of PEMFC CHP system keeping superior performance. Their specifications and appearance was shown in Table 1.

Table 1 Specifications and appearance of PEMFC CHP released in 2009

| | | Tokyo Gas /Panasonic | Osaka Gas / Toshiba FCP (TSB)<br>Osaka Gas / ENEOS Celltech(EC) |
|---|---|---|---|
| Fuel type | | LNG based natural gas (category 13A) | |
| | Max. output | 1 kW | 0.7 kW |
| | Min. output | 0.3 kW | 0.25 kW |
| | Electrical efficiency | 37 % LHV | 35 % LHV |
| | Heat recovery efficiency | 52 % LHV | 45 % LHV |
| | Dimensions | W780 D 400 H 860 mm | W890 D300 H 895 mm (TSB)<br>W900 D350 H 900 mm (EC) |
| | Dry weight | 125 kg | 105kg |
| | Dimensions | W 750 D 480 H 1883 mm | W 750 D 440 H 1900 mm |
| | Dry weight | 125 kg | 105kg |
| | Tank capacity | 200 L | 200 L |
| List Price | | 3.465 million yen | 3.255 million yen |
| Appearance | |  |   |

## 3. Market development

The Japanese residential PEMFC industry determined a common brand name called “ENE FARM” prior to its commercial launch by a proposal of Tokyo Gas and Osaka Gas. It contributes to improvement of public recognition of residential PEMFC CHP.

Besides, both companies established their own system for installation and maintenance in order to penetrate ENE FARM smoothly.

And ENE FARMs developed by both companies were released by the other Japanese natural gas utilities too.

Counting the superior efficiency of ENE FARM, METI has started subsidization for customers who install the system in order to promote the market penetration of the residential PEMFC CHP systems from JFY 2009. Amount of subsidy was 1.4 million yen in JFY 2009 and 1.3 million yen in JFY 2010 for a system at the maximum.

As a result, Over 7,700 natural gas ENE FARMs developed by both companies were sold in about two years from their launch to the end of March 2011.

Although METI's subsidy has been decreased to 1.05 million yen from April 2011, the sales of ENE FARM are favorable. The number of sales contract of ENE FARM is approaching 5,000 in only three months from April to June 2011.

Tokyo Gas and Osaka Gas will continue to make efforts to improve and promote ENE FARM. For example, in April 2011 Tokyo Gas and Panasonic released improved model with higher efficiency (40 % in electrical efficiency), lower price (ca. 2.76 million yen) and smaller installation space requirement (2 $m^2$, about half of the previous model).

The residential PEMFC CHP, ENE FARM, is expected to improve primary energy consumption, reduce $CO_2$ emission and expand the natural gas sales in residential area by its market penetration because of its high efficiency in Japan and in all over the world by adjusting to the foreign market in the future. And this will greatly contribute to the growth of world gas industry.

Note: This paper was adjudged the winner of IGU Gas Efficiency Award 2012. The full paper is available in the CD attached to this document.

# ABSTRACTS OF THE FINALISTS OF IGU'S SOCIAL GAS AWARD

## PAPER 1

### VEHICLE CONVERSION TO DUAL GASOLINE/CNG FROM 150 TO 100,000 IN 5 YEARS IN PERU

Luis Felipe Fernández Perez, former Commercial Natural Gas Manager of Pluspetrol Peru Corporation

#### Background

One of the main challenges when a natural gas (NG) reservoir is discovered in a country where there is no demand for the product is deciding between a project with a Natural Gas processing plant, and transporting the gas to another main NG pipeline to export the product; or developing an integrated project including an energy matrix change.

Peru decided on the second option. The project was ambitious, consisting of building a cryogenic plant in the jungle of Cusco and transporting the gas to Lima through a pipeline over the Andes, climbing as high as 4,000 meters above sea level and covering over 500 km from start to finish. Additionally, the distribution project in Lima was put out to a tender to select an experienced company who could not only physically build the system, but also build a market starting with 10 initial contracts signed with the Government to ensure a minimum volume to start operations.

One of the major issues in the market to be developed was to achieve the transformation of the motor vehicle pool, especially taxis, to a dual gasoline/CNG system, not only to save money but to reduce gas emissions, since most taxis in Lima ran on diesel.

#### Aims

To create a CNG motor vehicle pool focused on taxis.

#### Methods

Operations at Camisea began in August 2004. The first clients were the 10 industries indicated above, from which the market slowly grew based on the real savings made by possible by the use of NG.

After five year of increased conversion of vehicles from gasoline to a dual Gasoline/LPG system, the question was how to explain the advantages and differences between this trend and the conversion to dual Gasoline/NG.

In order to plan effective actions to develop the motor vehicle CNG market, it was necessary to answer the following questions:

What companies will convert the cars to a dual Gasoline/NG system?

What would the prices be for converting a car or buying a new CNG vehicle?

How could a taxi driver afford to pay for conversion to this dual system?

How would cars fill their tanks with NG?

How can a dual system automobile be bought while maintaining the manufacturer's warranty?

The answers showed us that we were starting from square one, and the only alternative was to work on different fronts, not only simultaneously, but in an integrated manner, seeking out:

1. Investors willing to go into dual system CNG conversion repair shops

2. Investors interested in going into the CNG service station business

3. Car dealerships interested in going into the CNG or dual system car business

4. Financing programs for taxi drivers to convert or buy CNG cars

5. Reduction of the risk involved in credits for conversion, in order to obtain real warranties and a low default rate on payments

To achieve these goals, a multi-task team worked on the design of a "Gas-Up Control System" that not only combined all market needs, but also helped to create the CNG market and enabled it to grow formally.

The contributors to the project were:

1. Consejo Supervisor del Sistema de Gas Natural (Supervising Council of Natural Gas System).- Government Institution created to integrate all facts to be part of the project. This Council is integrated by Hydrocarbons Director from the Energy Secretary responsible of supervise CNG Service stations, Traffic Director from the Communications Secretary responsible of supervise conversion repair shops, and Production Director from Industry Secretary responsible to supervise all the equipments involve.

2. CorporaciónFinanciera de Desarrollo COFIDE ( www.cofide.com.pe ) - The Supervising Council named COFIDE as responsible to implement and operate the project.

3. Gas Natural de Lima y Callao.- This is the NG distributor in Lima. They sponsored the project and proposed the system based on the Colombian experience.

4. Pluspetrol Peru Corporation.- As Natural Gas Producers, acted as sponsor of the project interested in develop a controlled growth of CNG market, and to avoid informality existing in all other hydrocarbon products markets.

### Gas-Up Control System

To integrate all the variables involved in creating a CNG market, a centralized database system was developed, connected by a microchip installed in the tank of each converted car. This database gives us real information on the credit granted for the conversion, and calculates a repayment amount with each time a CNG automobile gasses up at a service station.

This microchip transmits the following information:

- Vehicle data.
- Data on the dual system equipment installed.
- Repair shop that performed the conversion. Each repair shop must be certified by the NG Supervisory Authority.
- Annual checkup of all conversion equipment.
- Five-year checkup of the CNG tank.

After a car has been converted to dual Gasoline-CNG system, the Supervisory Authority appoints a Certifier to verify:

- That the Repair Shop is certified.
- That the equipment installed, including the tank, has been registered with the Authority.
- That the installation was made in accordance with Peruvian technical laws on NG.

Once the Authorized Certifier completes the previous steps, the microchip is installed in the CNG pump hole, the car's data is entered in the chip, and it is then registered in the centralized system database.

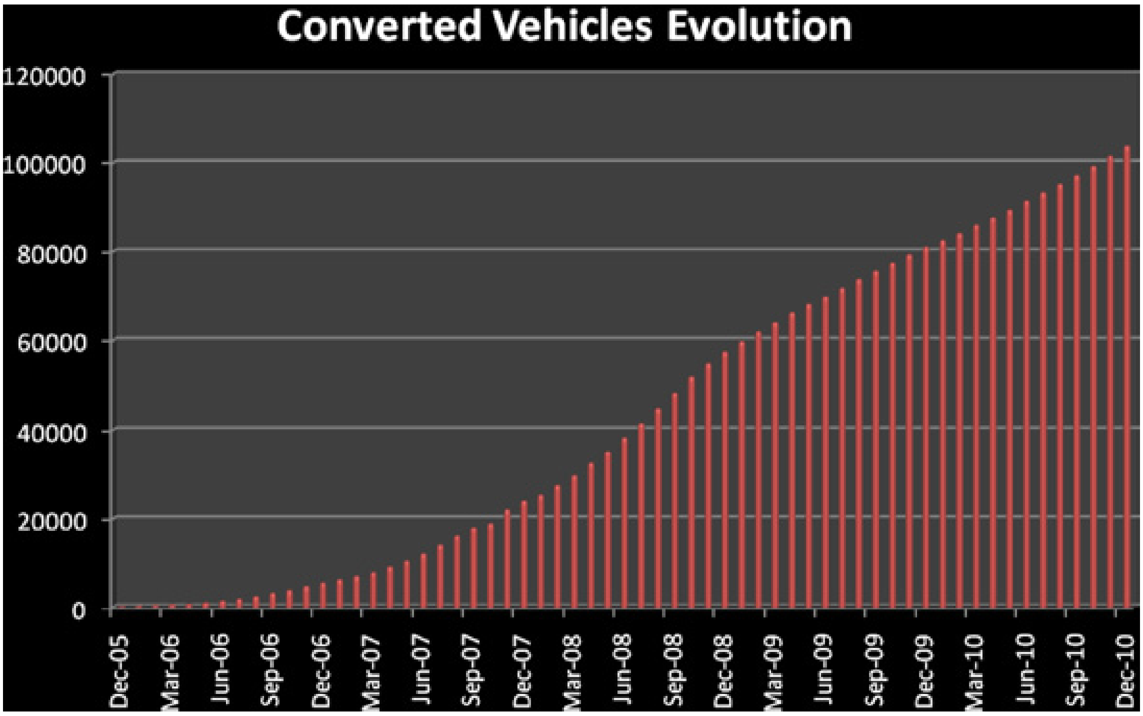
Likewise, all service stations have installed hardware and software that allow the CNG pump to read the microchip data and communicate with the main computer and the centralized system database simultaneously. When a car comes in to fill up on CNG and the hose is connected to the tank, the information from the microchip installed in the car identifies the vehicle and the computer searches for it in the database of the centralized system. The car will receive authorization to pump CNG only if it is registered the database. To the contrary, authorization will be denied.

Additionally, the loan paid out to the taxi driver may be input to the centralized system and an additional amount of money may be calculated that the taxi driver must pay with each CNG gas-up to pay installments on the loan. This facility not only enables taxi drivers to finance conversion costs, but it also lets car dealers sell new cars that can be paid off with each CNG gas-up.

Other benefits of this system include:

- Enables traceability of all components of the CNG conversion equipment
- Prepares statistical information
- Provides commercial information
- Any other information the authority may require

## Results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Jun-07
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Jun-08
Sep-08
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Mar-09
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Dec-10


Conversion Repair Shops
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140
180
210
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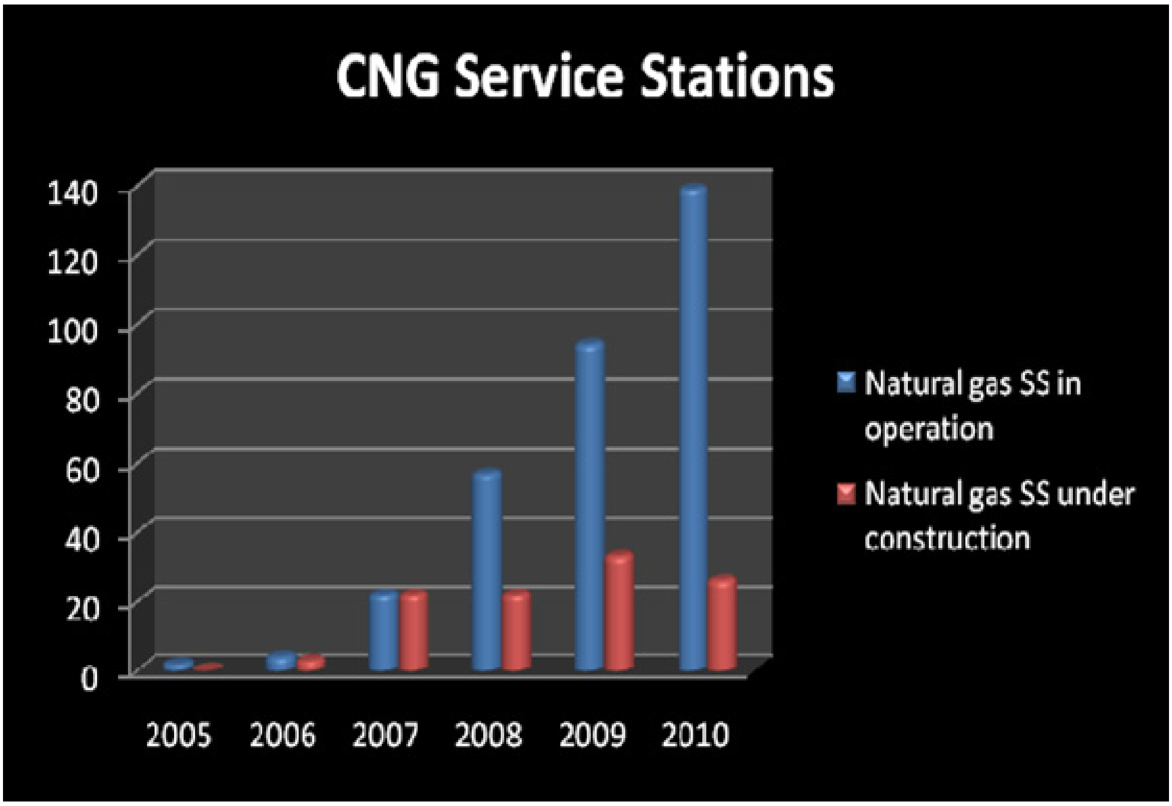
2006
2007
2008
2009
2010




**Conclusions**

- This system helps maintain control over the CNG market, avoiding informal facilities that may be made in violation of safety standards, since the entire conversion chain and CNG gas-up system is online.

- This system enables an extraordinary rate of growth for the car conversion market.

- Needless to say, countless problems were encountered along the way, basically because the growth rate of each actor in the market was different. However, we have already achieved the stability the market needs to continue growing in an orderly and sustainable manner.

Note: This paper was adjudged the winner of IGU Social Gas Award 2012. The full paper is available in the CD attached to this document.

## PAPER 2

## TOWNGAS "LOW CARBON ACTION!" CAMPAIGN

James YC Kwan, Executive Director & Chief Operating Officer, The Hong Kong and China Gas Co. Ltd.

**Abstract**

According to the Hong Kong Environmental Protection Department, every Hong Kong resident emits an average of 6.7 tonnes of carbon dioxide annually, further aggravating the global warming problem. The Hong Kong and China Gas Company Limited, namely, Towngas, has always sought to be a responsible company through its vision to be Asia's leading clean energy supplier. The Company strives to identify opportunities to invest financial and intellectual capital to make town gas greener and ever green for the low carbon future of Hong Kong.

Gas production, transportation and utilization are the three key focuses of green engineering initiatives. The Company reduced the emission of carbon dioxide substantially with the introduction of natural gas and the use of landfill gas, together accounting for over 50% of our total production fuel, which also meant a 17% reduction in carbon emissions i.e. equivalent to **134,500 tonnes**. Comprehensive gas network asset O&M programmes minimize GHG impact to the environment. High efficiency gas utilization technologies developed locally and from aboard provide green choices to the market for wise use of energy.

Within the community, Towngas encourages the people of Hong Kong to lead a greener life under its "Low Carbon Action!" campaign. The campaign was kicked off in October 2009 with the launch of "Low Carbon Action!" on Facebook and the official website of "Low Carbon Action!" at www.towngas.com/lowcarbonaction. The site offers energy saving lifestyle tips to enhance awareness and promotes the aim of reducing carbon emissions by **one million tonnes** together with the public. A series of green initiatives have also been rolled out to different stakeholders in the community, with the emphasis on the younger generation. A year since its launch, the campaign has generated promising public awareness of environmental protection in the community.

## PAPER 3

### BUILDING STRATEGIC HUMAN CAPITAL – BEST PRACTICES IN THE NETHERLANDS

Mrs G.Dam, Mr A. Buijs; Students Media BV; GasTerra BV; Energy Valley

**The International NRG Battle**
Shortage of talent in the competitive gas and oil industry has become a critical business issue. In the Netherlands, the company StudentsMedia started in 2009 the International NRG Battle as an groundbreaking event for attracting and retaining talent in order to innovate the energy business. The International NRG Battle started as a pilot project in 2009 and has become the most successful annual returning event in the Netherlands for attracting talent. StudentsMedia has expanded the NRG Battle with their own NRG magazine and is broadcasted on National Geographic.

**Online selection in the Energy Talent pool**
StudentsMedia has got a online Energy Talent pool (StudentStock) where international bachelor and master graduates (for example: finance, technique, commercial, energy) sign up if they are interested in working in the energy sector. These students are online tested on their personality and four types of IQ. With the test results, in combination with their resume, we know exactly what the students' full potential is (for example: leadership-, management-, innovator-, strategic-, entrepreneurial potential and excellent talent).

The Energy pool of students is unlocked online for all the companies that participate in the NRG Battle. Companies select and contact the talents they need for their cases/companies directly and online.

During the NRG Battle the companies meet, compete and innovate with student teams whom they have selected themselves. Each company sends a case instructor and young professional to present an actual energy issue and to assist the student teams in solving the case. The stude nt teams battle for the best ideas and solutions.

At the end of the day, all the student teams pitch their idea to an expert jury. The jury selects the most innovative ideas based on three criteria of the American patent; novelty, utility and non-obvious of character. The winning teams will go to the finals at the end of the year.

Once a preliminary round has finished, the teams and experts of the companies meet to improve and implement their ideas. Some companies choose strategic issues and ask the students to work out a part of the solution with the help of experts and innovation is boosted. Some students are wanted by more companies due to their exceptional talent. These *most wanted students* are free to pick their own company or project of interest. In addition they will be rewarded with an honorable reference and rise in ranking in the Energy pool.

**International Ambitions NRG Battle**
The Energy Talent pool and the NRG Battle have he potential to become a worldwide application in the field of energy. Moreover, it could assist in online attracting and retaining talent worldwide.

The aim for 2011 is to allow students form abroad to participate in the NRG Battle via Skype. We plan to start an online skype pilot in Australia, Denmark and Germany.
StudentsMedia ‘s ambition is to become a worldwide online Talent hub for the Energy sector.

**Personality structure winning teams**
We discovered that innovative (winning) teams have a certain type of personality structure. In 2011 StudentsMedia will research the personality structure of winning teams. With the results of this research, we expect to predict which teams will come up with winning solutions and boost innovation, based on their personality type and structure in teams.

This will be interesting for recruiting top teams for innovation and projects in the worldwide energy sector.

**Building strong Human Capital**
StudentsMedia also assists companies in discovering the personality structure of their most excellent people. When you know who your best people are and who are the scarce talent you can recruit in a more strategic way. We discovered there is a strong correlation between excellence and accomplishing strategic goals. We use the Corporate Identity Model for this analysis and do an internal benchmark in the company.

## PAPER 4

# A SUSTAINABLE AND CLEAN ISTANBUL: IGDAS' TRANSFORMATIVE ECOLOGIC STRATEGY AND ITS ENVIRONMENTALLY EFFICIENT TRAINING PROJECT

Kuddusi Atalay, IGDAS, Turkey

**Abstract**

Istanbul is considered as one of the center of civilizations, hosted Byzantine and Ottoman Empires. It is essential to protect archaic architecture of city and to introduce high standard of clean environment for the people's of Istanbul. In tandem with, IGDAS took its 'social responsibility' to create environmentally natural gas projects and made great investment to provide how to use energy efficiently and environmentally friendly. IGDAS's target for Istanbul is to realize natural gas projects that would address not only today but also tomorrow and future generations by adopting a visionary point of view that would broaden horizons. Hence, having environmental safety, fresh air, clear atmosphere and a blue sky, Istanbul has in great depth to the IGDAS' twenty years works and public services. IGDAS started providing natural gas to the public service in 1992. Almost 7,5 million people's of Istanbul learnt how to use natural gas and left behind the conventional energy consumption habit in their home, offices and factories. Hence, this social awareness about the use of environmentally friendly, natural gas has been one of the great transformations for 13 million people of Istanbul who live in safe and comfortable clean environment.

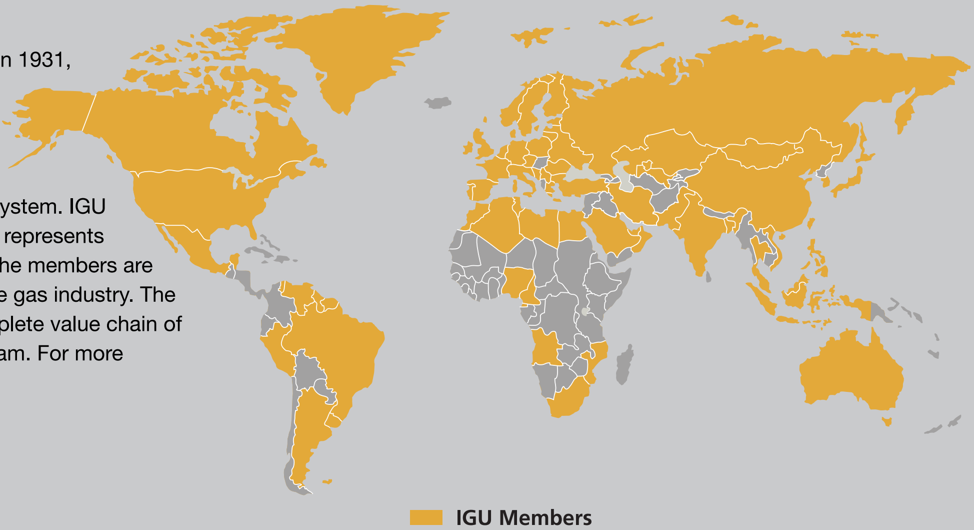
Natural gas stories of metropolitan cities have similar experience and questions in the world. In a sense that we ask an important question; what if Istanbul did not have any chance to use natural gas?

In order to answer such simple question, we need to look at financial cost of pollution and measurement of negative effect of traditional fuel consumption when the natural gas could not use in Istanbul. This paper evaluates the role of natural use in metropolitan cities from different perspectives. The awareness about clean environment and the use of low rate pollution, noticeable low $SO_2$ and $CO_2$ energy sources changed the costumer behavior that effectively increased economic power and sustainability in the society.

IGDAS is aimed at providing unconditional customer satisfaction in use of natural gas service for the public 24 hours in whole year. This paper does explain first Istanbul's natural gas maintenance cycle and its series of effect on pollution, health and energy efficiency.

## IGU

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

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