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Working Committee 6

"Utilization of Gases for Domestic, Commercial and Transportation Sectors"

Study Group 6.1: Gas appliances for the 21st century

Part 1 - Appliances

Comité de Travail 6

« Utilisation des gaz pour les secteurs domestique, commercial et du transport »

Groupe d'Etude 6.1 : Appareil à gaz pour le 21 siècle

Partie 1 - Appareils

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ABSTRACT

This report gives a review of the worldwide status on appliances with respect to gas utilisation for the domestic and commercial markets. This use represents about 10% of the total gross energy worldwide, and the share is growing. The development of the gas market is today one of the most effective solutions for saving energy and reducing the CO_2 emission.
Today's general trend is an increase of the domestic and commercial gas markets, even if some appliances are declining (e.g. water heaters are increasingly replaced by combi-boilers).

Heating is indeed the largest energy consumer in the domestic and commercial sectors for most of the countries in this survey and, therefore, there will be a strong focus on boilers and furnaces as a means to fulfil the Kyoto agreements.

The report points out a number of technical challenges for the development of the gas market. In some situations there is a huge potential for energy savings and CO_2 reduction simply by having the technology available in the emerging markets, as for example in China.

In the future, the gas market will expand in the sector of domestic and commercial use. The magnitude of this expansion will greatly depend on the capability of the gas industry to bring an answer to the identified technical challenges.

RÉSUMÉ

Ce rapport fait la synthèse de la situation mondiale actuelle en matière d'utilisation du gaz dans le secteur domestique et commercial (qui représente à l'heure actuelle 10% du total de la consommation énergétique de la planète). Ce chiffre est par ailleurs en augmentation. Le développement du marché du gaz est actuellement l'un des moyens les plus efficaces en faveur des économies d'énergie et pour lutter contre les émissions de CO_2.

La tendance actuelle va dans le sens d'un développement du marché même si par ailleurs la vente de certains appareils sont en régression (par exemple les chauffe-eau remplacés par des chaudières à double service.)

Le chauffage est de loin l'activité la plus consommatrice d'énergie (pour ce qui est du secteur ici concerné) pour la plus part des pays. Pour cette raison les appareils de chauffage sont l'objet d'un intérêt grandissant et sont considérés comme un moyen efficace pour le respect des accords de Kyoto.

Les challenges techniques nécessaires au développement du marché du gaz sont identifiés dans ce rapport. Dans certaines situations, il existe un potentiel énorme d'économie d'énergie et de réduction de CO_2 simplement par l'intégration des technologies existantes sur les marchés émergeants comme par exemple la Chine.

Dans le futur les parts de marché du gaz dans le secteur domestique commercial vont augmenter. La magnitude de cette expansion dépend en grande partie de la capacité de l'industrie du gaz a trouver des réponses aux challenges techniques identifiés.

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STUDY GROUP 6.1: GAS APPLIANCES FOR THE 21ST CENTURY

PART 1: APPLIANCES

Prepared by Jean Schweitzer, DGC with the input of all members of the SG6.1 (see the details of the contribution in section 8 and in the introduction document of SG6.1 work).

The report was mainly prepared on the basis of data given by the IGU members. The accuracy of the conclusion is depending on the accuracy of the data provided by the members.

1. SUMMARY

The use of gas for domestic and commercial applications represents about 10% of the total gross energy worldwide, and this share is growing as gas tends to gain a foothold in the markets of electricity in developed countries or traditional energy sources (e.g. coal) in developing countries.

There is no doubt that gas technology has a significant impact on tomorrow’s world environment. Not only sophisticated technologies are needed, but also simple and cheap ones that the new consumers from countries in transition or development can afford.

Up to now, there was one specific gas appliance for each specific gas application. In the future, the same gas appliance will provide several services. Already heating and hot water production tend to be integrated in one single appliance (combi-boiler). Tomorrow, heat pumps will provide heat and cooling, micro CHP heat and electricity.

The gas technologies shall also open to combination with renewables. Not only has the consumer more and more environmental concern, also the future energy policies of the countries may make the renewables technology economically feasible, and the combination of gas with solar will develop.

Hydrogen and natural gas with fuel cells might bring about a strong revolution in the application and appliances we know from today's world (see the "Technology" report).

For utilisations like central heating boilers, the technology has reached maturity. Still, there are possibilities to realise savings by optimising the installation of the boilers. So efforts need to be made, not in the direction of technology improvement, but in the education of installers and the development of design tools. Furthermore, there are large savings potentials in the replacement of older technologies with the newest available. For some of the markets, the replacement of low-efficient boilers would also offer the opportunity of having safer appliances installed.

Today, gas is mostly used for heating purposes (90%). One characteristic of the future market will be the development in air conditioning. The boiler technology of today is not necessarily adapted to compete against cheap electricity heat pumps that can produce both heat and cooling. The gas heat pump is, therefore, an appliance that can have a great importance.

In general, emissions are not an issue for the consumers, but emissions are important for the image of the gas industry, especially considering the competition with other energy sources. The consumer will see the benefit of high-efficiency boilers, but the advantages of low emission appliances are more for the overall society than for the individual consumer, who, therefore, would not be prepared to pay the extra cost of low-emission burners.

Indoor Air Quality (IAQ) will be an increasingly important issue when it comes to cooking with gas. It is a challenge for the gas industry to improve the IAQ in order to keep gas cooking in the houses.

For the development of NGV, today, consumers hesitate to purchase natural gas vehicles due to the lack of a viable fuelling infrastructure. Similarly, auto manufacturers hesitate to produce natural gas vehicles due to the lack of demand.

Overall, the future of gas for the domestic and commercial sector looks good. But there are a few challenges to get the technological development needed to have on the market the appliance able to compete with other energy forms.

The calculations carried out show that substantial energy savings can be obtained by accelerating the process of replacement of older boilers. This will also result in large reductions in CO_2 emission.

2. INTRODUCTION

2.1 Scope

The report deals with the situation of the market for domestic and commercial appliances for heating and hot water production, cooking, cooling and lighting. Home fuelling appliances have been added, as well.

The work carried out is aimed at evaluating the present situation of development of natural gas (NG) technologies both on the technical aspects and on marketing aspects. Efficiency and emissions are studied particularly with regard to environmental impact and energy savings that can be obtained by gas technologies. The gas technologies are also compared to the main competitors (fuel oil and electricity). The objective of the work was also to study the coming gas technology and report on the development and possible field test. The task also includes analysis of the present situation and conclusion on the action needed to strengthen the present share of NG in domestic and commercial applications.

The selection of the issues to be incorporated in this report have been discussed and decided in the SG6.1. Some application as drying have been removed from the list because the lack of expertise in the group of experts.

"Horizontal" topics as gas quality and gas distribution systems in the house have been incorporated in this report as they are related to all applications dealt with in this document.

Note that the survey is dedicated to appliances and not to functions. Therefore, district heating does not fall under the scope of the present study. However, as it is a large part of some of the markets, the information sent (e.g. Russia) has been integrated in this report as well (see Annexes).

2.2 The method used, data gathered and their exploitation

Most of the data used for this survey is from IGU members who have answered a detailed questionnaire (see below and also Annex 3). The detailed tables of answers can be seen on the IGU web site (link to the work of SG6.1 for the triennium 2000-2003).

As we were missing the data from countries such as Canada, Australia and partly for China, we have been looking for more data in order to get an overall realistic idea of the situation worldwide. As the first results showed that the heating function is the largest gas consuming function for the domestic and commercial sector, we have decided to make additional research to cover the missing data from the countries above - but mainly for the heating - so as to get a complete view of the situation worldwide. The results of those investigations are given in Annex 4.

The following information was requested from the questionnaire.

Part 1. Evaluation of the existing market. Data

- Estimated natural gas units in operation, net increase and replacement per year
- Estimated average gas consumption for the application
- Efficiency and emissions
- Replacement flows

Part 2. Evaluation of the existing market. Comments

Marketing aspects

- The main competing energies
- The costs (Appliance costs, energy costs and maintenance costs)

Technical aspects
- The efficiency
- The emissions
- The comfort level
- The safety
- The noise
- The electric consumption
- The reliability
- The ease of use

Part 3. New technologies (appliances and components)
- New technology or development of new technology

Part 4. Field-tests

Part 5. Conclusions
- Actions that would be needed to solve the problems and develop the market
- Most promising technologies in this field
- Main hurdles for the development of the products

Another source of data was the bibliographic work based on various sources including Internet research. See also the detailed copy of the questionnaire in Annex 3.

Units used in the report and main conversion factors [12]

Energy
Unit used: **kWh**
Main conversion factors

1 kWh = 3600 kJ = 860,11 kcal
1 TWh = 10^{12} Wh = 10^9 kWh
1 BTU = 1.055056. 10^3 J
1 toe is a **ton of oil equivalent**. This is 10 million kcal or 41.86 Gjoule
Note that 1 m^3n of natural gas is about 10 kWh
1 tef = (ton equivalent fuel) is the same as toe (ton of oil equivalent). Depending on the authors one or the other is used.

Power
Unit used: **kW**

Main abbreviations used in this report

CH	Central heating
CHP	Combined heat and power
EU	European Union
IAQ	Indoor air quality
IH	Induction heat (electrical cookers)
LPG	Liquefied Petroleum Gas
NG	Natural gas
NGV	Natural gas vehicle
PV	PhotoVoltaic
VRA	Vehicle refuelling appliance

Natural Gas - or Gas

Note that sometimes we have not been able to distinguish if the information that was given was applying to natural gas only (NG) or to LPG as well. In this case we have used “gas” and not “natural gas”. However, we consider that worldwide natural gas has a much larger market share. Therefore, in most cases “gas” can more or less be understood as NG.

Questionnaire data and additional research

The following countries have provided data (answers to the questionnaires): *Great Britain, Portugal, Poland, Japan, Switzerland, Croatia, Denmark, France, Spain, Slovakia, The Netherlands, Czech Republic, Germany, USA, Thailand, Russia, China*

We have made our own data research in order to find data on countries that did not answer or to get more complete information on the following countries: *Belgium, Canada, Australia, Ukraine*
Finally, we have made additional research of data to get more complete information on the following countries: *USA, China.*

2.3 The share of gas in the domestic and commercial sector in the overall energy consumption in the world - WHAT IS GAS USED FOR AND WHERE?

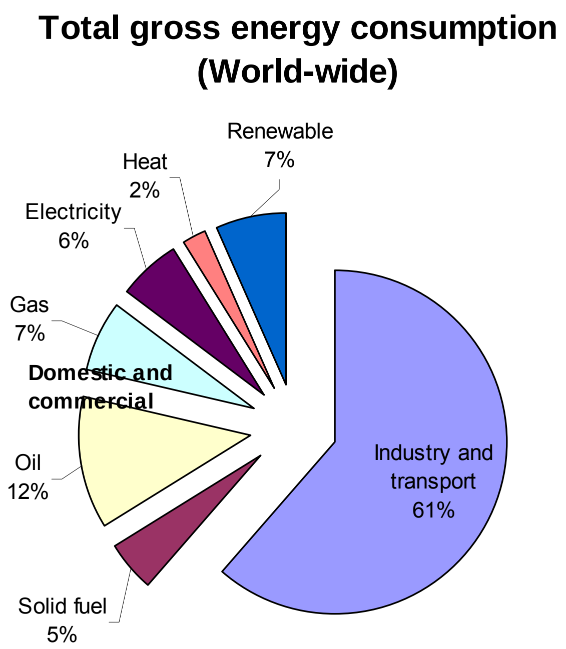

Figure 1: Share of gas in the domestic and commercial sector in the world energy consumption

Before going into details, it is relevant to investigate what is the share of gas in the world so as to gain a better idea of the impact of the gas domestic and commercial technology improvement worldwide. Note that the overall objective of the report is not to give an accurate picture of the world - wide energy situation so we have taken the data that was available and made a rough estimate.

According to [11] the total gross energy consumption in the world is 9403 Mtoe (see conversion factors under 2.2).

About 40% of the total energy consumption is used for domestic and commercial purposes, and 7% of the total is gas. The exact proportion of gas is, in fact, larger, because some of the energy forms that count in the statistics used are heat (e.g. district heating), which is partly produced with gas. From the data given, it is not possible to differentiate natural gas from LPG.

The overall trend worldwide is an increase of the gas share in replacement of solid fuel, electricity and fuel oil. We may assume that the overall contribution of gas for domestic and commercial in the overall energy balance worldwide is today probably about 10% and increasing (considering that the figure of 7% is from 1997 and that part of the "heat" is produced by NG).

Therefore, the impact of the improvement of the gas technology is of major importance for energy savings and CO_2 reduction worldwide.

Can the conclusions of this report be extended worldwide?

We have been gathering data from the main countries that are using natural gas. We have made some bibliographic work on the countries we had no data for.
Interpreting the data given in [12], we can estimate the percentage of the world market that is covered by this study.

Some of the markets are quite well known, either because we have got a good feedback from the questionnaires or because we have been able to gather reliable data from the literature.
The markets that we consider to be rather well known are indicated with cells in white background in Table 1. (See the column "Gas").

Some other markets are only partially covered by the study and are indicated with dark grey cells in Table 1. We estimate that we have got information to cover about 50% of the market from the partially covered areas (for Asia we only have data from China. But China has about half of all energy consumption in Asia).

Finally, there are markets for which no data was given or found (principally because the markets are small and they would not change the overall conclusion of this report). (Cells with **this kind of shading**, in column "Gas").

As a result, we estimate that this report covers 70 to 80% of the domestic and commercial gas markets.

Final energy consumption, domestic and commercial (in mtoe)							
	Solid	**Oil**	**Gas**	**El.**	**Heat**	**Renewables**	**Total**
EU	10.1	108.1	141.4	98.0	16.2	22.2	**396**
EFTA	0.4	8.4	0.9	6.0	0.4	0.9	**17**
NAFTA	10.4	259.4	134.8	107.8	2.7	14.8	**530**
OECD Pacific	8.5	67.0	10.1	30.6	0.3	2.6	**119**
Central Europe	18.5	17.9	16.9	11.8	12.3	3.6	**81**
CIS	31.6	60.4	106.9	44.3	107.4	9.4	**360**
Africa	8.6	45.6	5.5	16.0	0.0	115.2	**191**
Middle East	0.4	56.6	20.2	10.8	0.0	0.9	**89**
Asia	233.0	195.4	20.0	74.2	10.5	271.0	**804**
Latin America	3.9	44.4	9.0	13.5	0.0	23.1	**94**
TOTAL	**325**	**863**	**466**	**413**	**150**	**464**	**2681**

Table 1: Final energy consumption, domestic and commercial

Explanations to Table 1:

- EU is the European Union (UK, Germany, France, Spain, Italy, etc.)
  EFTA is Switzerland, Norway and Iceland
  OECD Pacific is Japan, Australia and New Zealand
  CENTRAL EUROPE is Poland, former Yugoslavia etc.
  CIS is the former Russian federation, including Ukraine and Russia etc. (in the statistics above it also includes the three Baltic states)
  Middle East includes Iraq, Iran, Israel etc.
  Asia includes India and China
  Latin America includes Brazil, Venezuela etc.

2.4 The overall gas market today. What applications?

The questionnaire asked for both the number of appliances on the market and their average consumption. We can, therefore, combine those data to see how much each application is consuming and compare the different applications to each other.

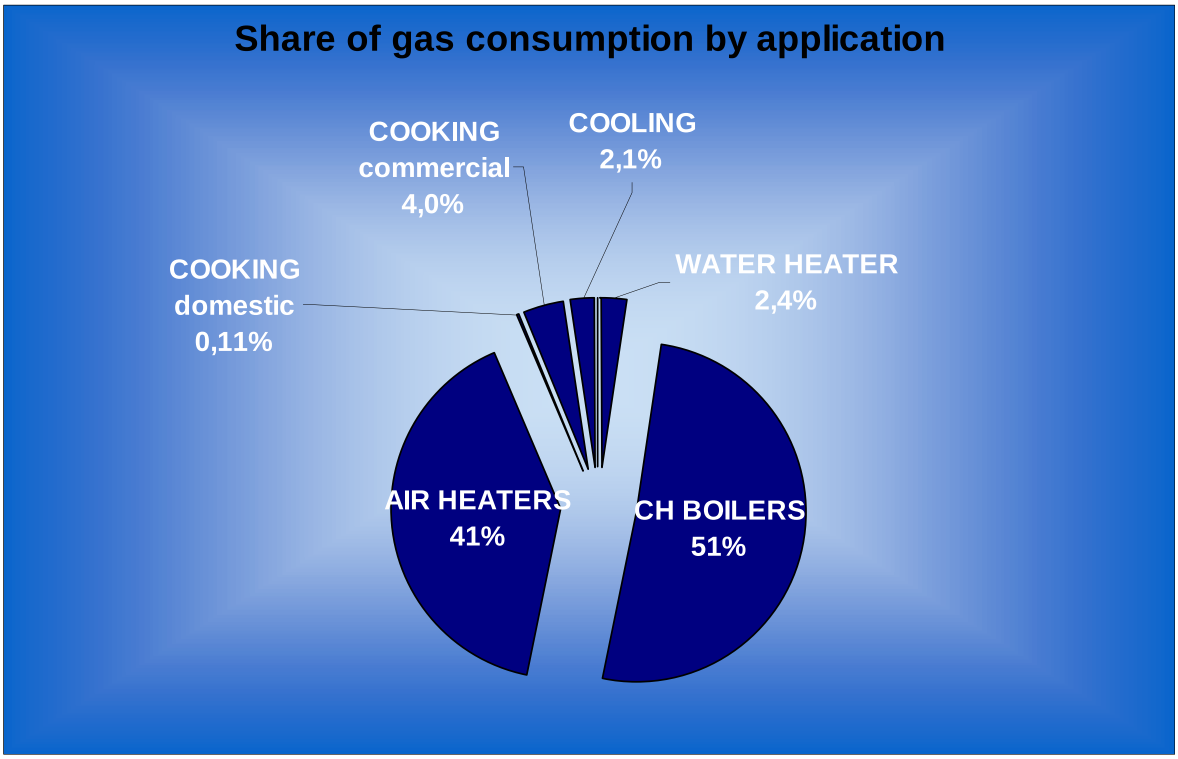

Figure 2: Share of gas consumption by appliance

Heating is the main gas application in the domestic and commercial sector. Therefore, heating plays a main role in the image the customer has of the energy "natural gas". If the customer is satisfied with his heating system he will have a positive image of gas and possibly consider other applications as cooking, drying etc. Heating is increasingly combined with **hot water production**. **Cooking** might not have a large share in the total consumption of household, but plays a more important role for the commercial sector. More and more customers want and can afford more comfort and it in this respect **cooling** will develop in the future.

The **decorative gas light** is not a large market but it is used for the prestige and image of gas.

Finally, **home fuelling** with NGV enters in the family of gas appliances despite being quite different from other: it does not burn gas.

2.5 The share of each application

Heating with CH boiler and air heating accounts for more than 90% of the total gas consumption. In number of appliances heating might not be the strongest market, but for a single appliance, the gas consumption for heating is 10 times as much as for hot water and 20 times as much as for cooking (see section 3.3).

The market is stable, and gas has a good competitive position over electricity (considering the price of gas and the performance of the appliances). However, in the future, the customer demand for cooling makes electricity a more competitive energy on the market due to the availability of the technology of heat pumps. Air heating is almost entirely an American market.

2.6 What is the share of each country in the overall gas consumption for the applications considered?

USA is the largest market in the panel of the countries covered by this study. In the world, about 40% of the gas used for domestic and commercial applications is in the USA. Germany and UK also have a strong position with about 15 and 10%. The rest of the market is shared between the other countries.

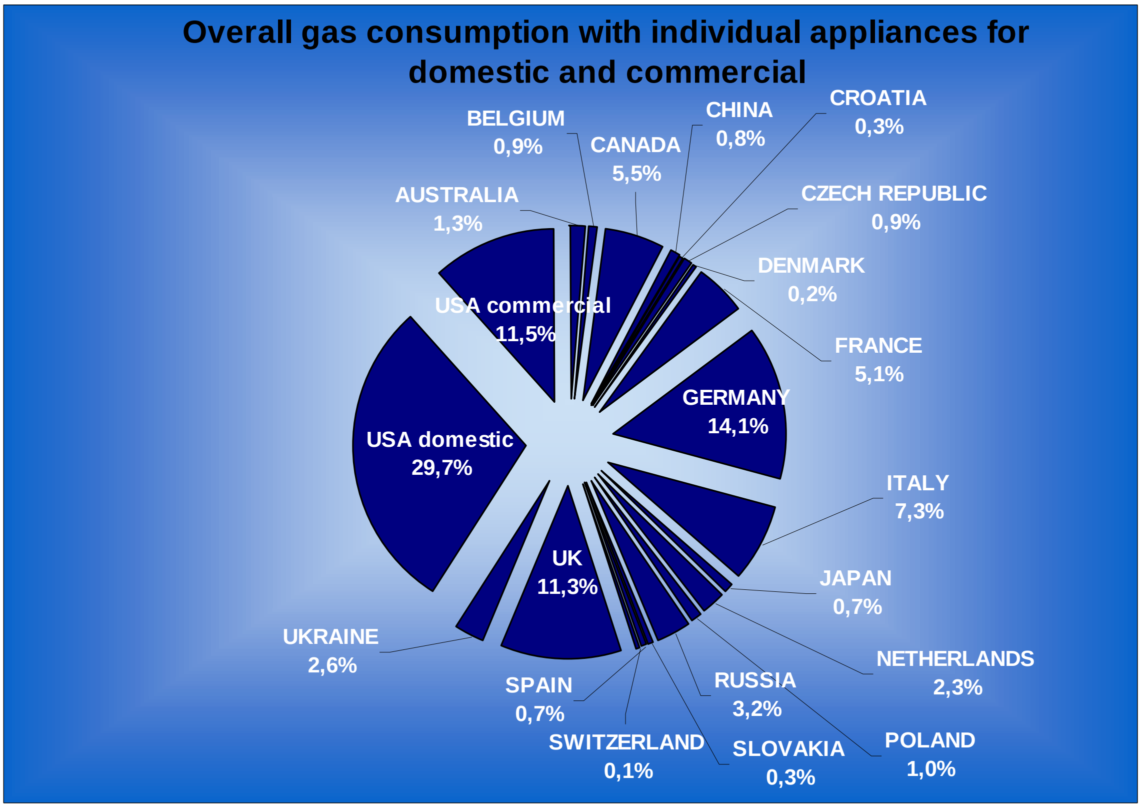

Figure 3: Overall gas consumption with individual appliances, domestic and commercial

2.7 China - the future market?

One main result of the study is the very large market emerging in China. The potential market is considerable, and the appliances for the new market are perhaps not exactly up-to-date. Therefore, there is a huge potential for energy savings and CO_2 reduction simply by having the newest technology available in this market.

The use of gas for heating purposes in China is for the time being unclear to the authors of this report, but it is certain that the day the gas will be used for that purpose in China it will have an enormous impact on the energy savings and the CO_2 emissions, because it will replace coal.

If the gas has a huge theoretical potential in China, it is still unclear if there is a possibility for this market to expand considering the energy policy of China, but the first data gathered seems to indicate that there are ambitions plans for an increasing use of NG in China.

However, we do not know if the market for gas is towards individual appliances or larger plants (e.g. district heating).

3. TECHNICAL ASPECTS

3.1. Short explanation of the technologies covered by this report

3.1.1. Heating & Hot Water

For **heating**, the study concentrates on central heating boilers and air heaters. Central heating units (also called hydronic central heating) are connected to radiator systems. The heat produced by the combustion of the gas is transmitted (by a heat exchanger) to water that circulates in the radiators. In some countries (typically USA, Canada, Australia) the heat is transferred directly to air through an air distribution system instead of radiators (furnaces).

For the **condensing boiler technology**, some of the latent heat in the flue gas is transformed in useful heat during a process of condensation of water vapour of the flue gas. The design of the heat exchanger and flue gas exhaust makes this possible.

The **hot water** is basically produced either with a central heating boiler producing both heating and hot water (so called "combination boiler" or "combi-boiler") or with dedicated appliances (so called "water heater"). They can both either heat water in a storage tank or directly heat the water when the user opens the tap. In the last case the heater is called "instantaneous" water heater.

3.1.2. Cooking

The cooker technology design is widely known. It generally consists of two parts: the **hob** and the **oven** that can be either sold separately as independent units or together in a combination. Note that often the cookers are mixing gas and electricity. A typical mixing is a gas hob with electrical oven.

The hob has typically two or four burners that burn gas directly and with direct contact of the flame under the pan. The combustion products are going into the room where the appliance is installed. In some countries, however, there is a tradition for using ventilation systems to evacuate the combustion products from the room. Ceramic plates are offering an easy-to-use and clean solution. The burners in this last case are either similar to the traditional cookers or can be radiant burners.

3.1.3. Cooling

Cooling production consists of removing heat from the place to be cooled (hot source) and transferring it to a heat rejection area (cold source). The energy transfer is allowed by a refrigerant fluid that follows a thermodynamic cycle made of four phases: compression, condensation, pressure loss and evaporation. The compression phase that drives the refrigerant may be realised by using a mechanical or a thermo-chemical process. These two different systems lead to the two main technologies on the market today:

- Engine heat pumps driven by electricity (EHP) or natural gas (GHP) use a mechanical compressor
- Absorption technologies use a thermo-chemical process, in which an absorbent absorbs and desorbs the refrigerant during the compression phase

Regarding absorption technology, the desorption process can be done once (single-effect machines) or twice (double-effect machines). A two-time process, when possible, improves the efficiency of the machine defined as the cooling capacity on the natural gas consumption ratio.

A three-phase desorption (triple-effect machines) further improves the efficiency of the machines. For the triple-effect technology, the absorption chillers use lithium bromide/water ($LiBr/H_2O$) fluids. Only gas combustion energy is used for generation of H_2O gas from $LiBr/H_2O$ in single-effect absorption chillers. Gas combustion and condensing energy of H_2O is used for generation of H_2O gas from $LiBr/H_2O$ in double-effect absorption chillers. So, there are two generators in a double-effect absorption chiller, which are called higher-temperature generator (HGE) and lower-temperature generator (LGE). A triple-effect absorption chiller has three generators, which are called HGE, middle-temperature generator (MGE) and LGE.)

3.1.4. Home fuelling

The technology referred to in this report is Vehicle Refuelling Appliance (VRA). A VRA is a natural gas compressor (no storage) intended for unattended refuelling of vehicles. Classified as an appliance, the VRA has automatic shut-down and relief of hose and system pressure. The report refers to products from FuelMaker and Sanyo. The models are designed to refuel fleets, forklifts and ice swobbers in commercial applications, but can be and have been used in residential applications. FuelMaker has developed a new VRA specifically designed for the consumer market. "Phill", a VRA and certified appliance, is intended for indoor installation and is available at the date of this report.

3.1.5. Decorative gas light

Historically, the initial use of gas was for lighting. Gas street-lighting, which at the time represented a total change in public lighting and influenced the night-time life of cities, gradually gave up its position to electric lighting.

Figure 4: Example of decorative gas lighting (Disney park)

At the beginning of the 21st century, a huge number of gas lamps are still in use worldwide, with the largest number of street lights undoubtedly being in Berlin (in excess of 50,000). In the USA, probably more people are familiar with gas lamps that anywhere else in the world. Interestingly, however, this is largely because the manufacturers have adapted their products to modern production techniques and produce a cheap pastiche gas lamp right down to the open flame. Disney do their bit, even utilising gas lighting in Eurodisney. Cities like Boston have added hundreds of gas lamps over the last decade or two. More than 300 gas lamps are in Japan, where they have been installed over the last 15 to 20 years in major streets and parks as symbol of their past. Owing to the development of colour mantles, customers may choose four types of gas lights – white, orange, green or pink.

Throughout the world, gas lighting is used mainly in historic parts of cities and at castles and chateaux in gas lamps, lanterns, etc. These are mostly replicas of historic gas lighting devices. Natural gas is also used for decorative purposes for open flames and gas torches (for statues, eternal flames, etc).

In contrast to electric lighting, however, gas has significant disadvantages - higher initial costs, more frequent maintenance (replacement of hoses) and lower luminous intensity. It is not, therefore, realistic to expect the wider use of natural gas for lighting purposes. For the gas industry it is not a typical gas market, but it is promotion of natural gas.

Please note that in the next sections of the report, we will not deal anymore with this technology as the following points do not apply to gas decorative light.

3.2. State of the art (efficiency, emissions, etc.)

The data collected (section 2.2) are the main basis for this survey on efficiency and emissions. In addition to the data collected, the respondents were also asked to give their opinion about technical aspects such as comfort, safety, noise, electric consumption, reliability and ease of use.

As usual when proceeding with questionnaires, the differences in the answers are partly due to the difficulty of appreciating the market correctly, partly because there are real differences due to the market depending on the technologies used. In some cases, we had to correct the data for the interpretation: some countries with similar market must have similar products and thus similar performances for the appliances.

Therefore, when data are used for calculation projection of what would be the future of NG, we have been adjusting the data according our best knowledge.

3.2.1. Heating & Hot Water

Heating with CH boilers

The efficiency of the gas appliance

The technology is in its maturity and we are close to the maximum theoretical efficiency that can be obtained on boilers. For that reason, the efficiency is NOT considered a problem, except in Japan (see below). For some countries the high cost of efficient appliances (as the condensing ones) is considered a problem (e.g. France).

The example of the situation in Japan (source: TOKYO GAS)

The heating demand is relatively small compared with hot water demand in Japan. Hot water is used for bath and/or shower, washing dishes, whereas central heating in the entire house by a radiator system is not widespread due to the Japanese climate, "high" gas price and not having enough space for the system. However, the share of so-called "combi-boilers" is increasing. In some circumstances, the "combi-boiler" can have a power up to 50 kW for hot water supply and 17 kW for floor heating The floor heating system is not installed in all rooms, but in limited places such as living rooms and bedrooms.

There are two reasons for the relatively low efficiency of Japanese boilers compared with the other countries:

a) One reason being the above-mentioned situation. The demand for hot water supply is much larger than the heating demand. Furthermore, the hot water supply load variations are large (can be from 5 to 50 kW for instance).

b) Another reason being the lifetime (reliability) of the boiler. The heat exchanger is usually installed above the burner unit. The burner might be damaged by condensation water; therefore, the design prioritizes the reliability and not the efficiency.

Please note that the METI (Ministry for Economy Trade and Industry) subsidizes high-efficiency boilers (mainly condensing ones).

The "laboratory" measured efficiency might differ pretty much from the real efficiency of the installed appliances considering the sometimes high standby losses of older boilers. Therefore, the values given shall be considered maximum values that are not necessarily achieved in practice (the respondents were asked to give the full-load efficiency 60/80).

The existence of strong markets in some countries for low-efficient (e.g. cheap technology) boilers further explains the differences in the answers.

Efficiency and emissions. Average values calculated from the answers to the questionnaires.		**Water heaters**	**CH boilers**	**Air heaters**
Net efficiency (*) of units older than 15 years				
Range from	Net %	63	79	72
Range to	Net %	75	88	82
Average	Net %	72	84	76
Net efficiency (*) of new units NON-CONDENSING				
Range from	Net %	72	87	77
Range to	Net %	83	95	87
Average	Net %	80	90	82
Net efficiency (*) of new units CONDENSING (given for water temperature set of 30/40)				
Range from	Net %		94	87
Range to	Net %		106	93
Average	Net %		100	90
NOx emission for units older than 15 years				
Range from	mg/kWh	207	156	250
Range to	mg/kWh	293	256	400
Average	mg/kWh	238	204	300
NOx emission for new units				
Range from	mg/kWh	167	46	60
Range to	mg/kWh	250	123	120
Average	mg/kWh	166	89	78

(*) efficiency under standard test conditions (eg. 60/80 for CH boilers)

Table 2: Efficiency and emissions for boilers, air heaters and water heaters

According to the answers from the questionnaires, the efficiency of the older units is about 85%. This seems to be a bit optimistic considering the still large markets for pilot flame boilers and atmospheric burner technology. According to the questionnaires answers, the new traditional boilers have an average efficiency of about 90% (net). This is probably a bit too optimistic. For condensing boilers the average is about 100%.

To figure out the annual efficiency that reflects the efficiency of installed appliances, more accurate figures would probably be obtained when subtracting 5% at each of the figure above given.

The existence and availability of the technology is one thing - in some cases the best technology (e.g. condensing) is not sufficiently present in the market for marketing, price, or other non-identified (in this study) reasons. Another problem is the overall efficiency of the whole heating system (annual-seasonal efficiency). Energy efficiency is rarely considered at the installation stage of the boiler. Therefore, there are large efforts to be made in order to achieve a better matching boiler installation in order to optimise the efficiency of the installed appliances. The investigations carried out in Europe (BOILSIM SAVE projects [3]) have demonstrated that a given boiler may be adapted to one type of installation while not to another. Today, tools are available for the correct design of the installation, but there is a need for **installer education**.

The **information to the consumer** is also a crucial issue. In most of the countries, the consumers are not involved at all in the process of choosing their boiler. The attention given to the choice of the boiler is much lower than that given to any other kitchen hardware that costs much less! Therefore, labelling and other simple information systems shall be developed also using the Internet. In Europe, a number of initiatives, such as SEDBUCK (UK) /4/ and a database on the BOILERINFO (EU) /5/ web site are both initiatives on the web that are aimed at informing the consumer. BOILER INFO is a prototype of an interactive tool that offers a database with more than 600 boilers.

The objective is not to make the consumer an expert, but to involve him more in the choice of the right boiler for his own installation and to create a fruitful discussion between the consumer and the installer. The consumer side demand should also stimulate the need of the installer education. As a result, we should find better products on the market and also more satisfied consumers.

The promotion of the best appliance is a positive action, but it shall be kept in mind that there are cases where the installation of cheap (and perhaps less efficient) boiler would be the most suitable solution (e.g. in case of low heat demand) Therefore, we should take care not to eliminate this type of appliance from the market: otherwise, electric heating would easily take over this market share.

Moreover, in countries where gas is cheap, but boiler and installation expensive, low cost and simple technology would be more adapted to fulfil the market demand.

The emissions of the gas appliance

The difference given in the questionnaires for the NO_x emission of new units is once again (to some extent) due to the appreciation of the respondents. In some cases, the differences of technology used might explain some of the large differences seen when comparing some countries.

Emission is quite a controversial question: about half of the countries consider the emissions (NO_x) to be too high, whereas the other half does not see emissions as a problem. This may depend on the regulations in force (and the severity of those) in the individual countries. There are still large differences in the emissions of the appliances available on the market, but many low NO_x emission burners are available. The technology is there, but is not yet widely spread. The emission of methane from boilers is sometimes used as an argument against gas (e.g. argument of district heating companies in The Czech Republic).

To summarise the situation, as answered by one respondent: "The NO_x emissions have to be decreased without any cost". Low emission is a requirement, for which the consumers are probably not prepared to pay, as there is no financial consequence for themselves. Therefore, they might request clean appliances, but they do not think that they are to pay an extra price for getting those. As a result, emission is more an issue for the gas utilities and gas industry. For keeping the advantage of NG in the competition with other forms of energy we need to keep emissions at the lowest possible level.

The comfort level offered by the gas appliances

The comfort is never considered a problem. As most of the appliances are oversized, they are able to produce enough heat in all situations. In general, the control systems are able to keep the temperature at a reasonably comfortable level. Only overheating during sunny winter days might possibly be considered a comfort problem.

The oversizing has been studied in Denmark /8/. But while it was a real problem for the overall efficiency (because of high standby loss) a few years ago, it is not a problem any longer with today‘s light wall-hung boilers that have low losses.

The safety of the gas appliances

Only France and Spain consider safety an issue. Safety is a general concern, but different countries have different approaches, and different respondents have different perceptions of the question. Fatal accidents occur in all countries, so we may conclude that there are problems in all countries. A level of zero accidents, however, is almost impossible to reach.

Relatively new markets have fewer problems, since the appliances are also new. There are two kinds of problems: gas explosions and flue gas poisoning. The first category is linked to voluntary action (suicide or sabotage) that will always be difficult to prevent. The second category (poisoning) is in general linked to a poor combustion resulting from chimney obstruction or hardware problems of the installation. CO detectors could prevent a number of casualties, but there are still a number of problems with the reliability and placing of these detectors. Furthermore, a number of gas companies are for a safety philosophy based on the boiler technology and, therefore, stipulate that the gas appliance itself (and not an external component) must shut down the burner as soon as it produces CO. This philosophy makes the use of detectors unnecessary and also avoid difficult marketing of the appliance ("you need to use a CO detector" is a recognition that the appliance itself is not safe). Therefore, the solution of appliances with “built-in” safety is probably the best approach for **new installations.** But for **existing ones,** the safety remains a problem to be treated via detectors or inspection.

The noise from the gas appliances

Only France mentions the noise as an issue. The reason being a regulation that limits the boiler noise and the fact that not all boilers on the market are able to respect that regulation. New EU labelling plans might make the noise problems extend to other countries, as well. However, the noise depends very much on the individual installation, and the many countries that have boilers installed in non-heated rooms (e.g. outside the living space) are probably not concerned by noise.

Noise was also regarded as a problem in Denmark in the case of replacement of fuel oil boilers with light wall-hung gas boilers. The ensuing higher start/stop frequency resulted in dilation in the water pipes, which in turn caused a lot of complaints. The problems have been resolved with adapted control settings.

In Japan, appliances are usually installed on the outer wall of the house. From the competition with electrical appliances, manufactures have been reducing the noise level to 48 dB(A) or less. Moreover, a label is attesting "Low Noise" to the appliances of 45 dB(A) or less.

The electric consumption of the gas appliances

Not that many countries mention electricity as a problem, but as above the problem might be there without being identified as such, as only a few countries are actually measuring electricity from gas appliances. An annual electricity consumption of up to 1000 kWh/year can be measured for some of the boilers on the market (this includes the pump consumption). This could be up to 15% in the energy balance of a CH boiler. For many countries this means up to 30% in the financial balance of the heating costs when the electricity cost is twice the cost of gas.

The EU Commission has recently accepted a project [6] that deals with the reduction of the electric consumption of gas appliances. The first action would be to **inform** consumers about the electric consumption of this appliance. Too many users and even gas companies have not realised that the consumption of the pump and other components is not at all negligible in regard to the overall gas consumption. We shall take care that the gas appliances are not slowly becoming electric appliances.

The reliability of the gas appliances

Only France and Switzerland indicated reliability as a problem. The cause of the reliability problem is not necessarily connected to the appliance; it can also be due to the installation or hydraulic system. It is difficult not to speak about maintenance and repair costs when discussing reliability. The respondents and the gas industry might also overlook the real problem of reliability. It is, however, a reality that the new boilers with a lot of electronics and components have a higher risk of failure than boilers of simple design. In a replacement situation, some users would rather buy a cheap but reliable boiler than a high-efficient one that might have more reliability problems. A failure will in most cases cost more than the annual savings and will also cause some inconvenience (no heat or hot water until the boiler is repaired). The problem of reliability is that it cannot be measured in advance. Only statistics can show the problems afterwards. In the countries where the gas companies organise servicing of the appliances, they can have an influence on the market by publishing the failure statistics by appliance trademark and model. Doing this will encourage the manufacturers to improve the reliability of the boilers, especially of the models implicated.

This said, most of the manufacturers are also interested in having reliable appliances on the market and in most of the cases there is a good collaboration between the gas industry and the manufacturers. There have, however, been a limited number of cases in the past where some manufacturers considered the boiler maintenance a business and gave for this reason only low priority to the robustness of their appliances.

The ease of use of the gas appliances

Only France indicated the ease of use as a problem. For average consumers, the technicality of some boilers might be too developed. Mostly, users do not interact with their boiler-control system and let the installer do the adjusting job. Therefore, it is not considered a problem in general, but in most cases the user is unable to enter the sophisticated functions of the boilers (especially the control functions). In general, most of the important functions to the user (thermostat) are designed in a simple enough way. New designed boilers are also having functions that indicate the nature of the failures in a simple way (when they happen). The trend is certainly to go away from the complicated control panels that were trendy in the 90's.

Design aspects

The design is rarely a problem, as in general the appliance is installed in parts of the house where the design does not matter much. However, this is not always true and in more and more instances the boiler is seen beside other kitchen hardware. In Japan, the design has another importance, i.e. the size of the appliance. This aspect is considered as very important for the competition with other energies.

Heating with air heater

The **efficiency** data we have got is from countries where the technology is not very widespread. (Unfortunately, we have not got detailed data from the USA). According to the answers given in the questionnaires, 76% is the efficiency of the appliances installed. 82% is the efficiency of the new appliances and it is up to 90% when it comes to condensing appliances.

A lot of progress seems to be achieved on the **emissions** of those appliances (from 300 mg/kWh NO_x to less than 100 mg/kWh NO_x within 15 years.

The efficiency is considered as a problem by most of the respondents. Here are the other points mentioned:

- Improve the installation quality (ambience control, modulating power of burners, etc.)
- Promote condensing type for energy saving and for environment
- Warm air units are expensive and not favoured by the public (this is of course not true for USA/Canadian and Australian markets)

Research was also done on the Internet and has led to the identification of the following problems:

- Temperature distribution in the room (comfort problems)
- Indoor air quality
- Noise
- Practical aspects (a radiator uses less room than a furnace)
- Maintenance

Hot water production

The efficiency of the gas appliance

The **efficiency** of hot water heaters depends on the tapping programme. Therefore, the appreciation of the efficiency is difficult. We do not know if the differences given by the respondents are due to the appreciation of the data or to real differences because of the technology used. This explains why the gap between new/old technology can vary from a few percent to about 25%! (Depending on the country).

According to the answers from the questionnaires, the efficiency has on average improved from 72% to 80% (net) when comparing the data older than 15 years with the data on new appliances.

However, the efficiency is NOT considered a problem, except in China and the Netherlands. Note that we do not have the efficiency data for China. Because of the market size in this country, the impact of even a few percent on the efficiency of the appliances will have considerable effect on the energy savings and CO_2 emissions.

In most of the countries, the traditional (non-condensing) technology has reached maturity and we are close to the maximum theoretical **nominal** efficiency that can be obtained on heaters. However, as for heating, the **annual** efficiency of water heaters is another question. The interaction with the heating function, the start/stop loss and standby loss can really change the initial figure by a factor two or more. Therefore, as for the heating, there is a need to make a correct evaluation of the real efficiency of the installed appliance. The efficiency was not really an issue up to recently, as the hot water demand is in general smaller than the heating demand. As a result, the focus has always been on heating. However, as the insulation requirements in houses are becoming more severe, the heat demand diminishes and the hot water demand is, therefore, becoming relatively larger. Japan might be a good example to illustrate this trend.

When savings on heat for water production might not be an issue, saving water might be the main problem in the future. Already in some countries, the cost of the water used for sanitary hot water is larger than the cost of the gas to heat up this water. As water will be a general problem for the environment, we expect the price of water to grow faster than the price of the gas, and the technology should focus on saving water.

The emissions of the gas appliance

As an average the NO_x **emission** has decreased from 240 mg/kWh to 170 mg/kWh when comparing the data older than 15 years with the data on new appliances.

As for boilers, the emission is considered a problem for some countries and not for some other countries. In POLAND and SLOVAKIA, the low limits fixed by the authorities are causing problems for the certification of the appliances.

The comfort level offered by the gas appliances

The comfort is considered a problem for instantaneous appliances producing hot water (see definition in 3.1.1). Variation of water temperature during the tapping is a known problem and is in the process of being solved by some of the manufacturers on the market (use of capacity and control). This is probably the main issue for the hot water function (at least for instantaneous appliances).

The safety of the gas appliances

Only China and Spain consider safety an issue. Again, we have no details about the problems encountered in China so it is difficult to conclude which action to undertake for this particular case.

As for the boilers, solution of appliances with “built-in” safety system is probably the best approach for **new installations.** But for **existing installations,** the safety problem shall be treated via detectors or inspection.

Another issue that is not related directly to gas safety is the **legionella problem**. This could be a potential problem, especially with storage water heater. Not very much data is available about the casualties/accidents of this nature, but during the last years a number of accidents have brought focus on this problem. The most effective technical solution consists in heating the water tank to a high temperature. This is, of course, more energy consuming, but it is not clear how wide-ranging the problem is and it is therefore difficult to identify the real size of the legionella problem.

The noise from the gas appliances

Only China and Denmark mention the noise as an issue. In Japan the noise from heaters is about 50 dB (A) and some appliances’ noise is even below 45 dB (A) (silent appliances).

The reliability of the gas appliances

Only France and China indicated the reliability as a problem. (Cf. the previous Section on heating).

3.2.2 Cooking

Domestic

Efficiency and emissions of gas appliances are not generally considered to be a problem. This is not a surprise, considering the low level of annual consumption of the domestic cookers. It is about 20 times less than the gas consumption used for the heating so it has a relative small impact in the budget of the consumers in most countries. **The average net efficiency of units older than 15 years** is 60%, and it is the same for every country, for which a survey has been made. Note that China gives an average net efficiency of 45%, but this is probably a question of interpretation of the questionnaire. The efficiency of the cookers depends greatly on the measurement method used (quantity of water heated).

The average net efficiency of new units is also around 60%. This means that no improvements regarding efficiency of natural gas cooking appliances have really been made. The technology of the burners is more or less the same.

The average NO_x emission of new units in The Netherlands is 65 mg/kWh, which is obviously in the lower end of NO_x emission levels. For Czech Republic and Slovakia, average NO_x emission of new units is 105 mg/kWh

Recently, gas cooking was suspected of producing **micro particles** in the air and studies are ongoing to clarify this. Furthermore, there have been debates lately, especially in the UK, about the potential danger of gas cooking. Investigation is presently ongoing on those subjects. IAQ is certainly an issue for the gas industry. In Denmark, investigations have concluded that gas cooking does not bring about any problems in the houses. However, this shall be considered with respect to the technology used, the ventilation rules and other factors that may vary from country to country.

As regards the **comfort level offered by the gas appliances**, two aspects (trends) should be stressed. First, some countries have a problem with the public acceptance of natural gas cooking appliances. They are considered to be out of date (not modern, which is the case in the Czech Republic). Also, there is a need to reduce heat radiation from cooking stoves to increase the comfort (and safety) level. An adequate answer would be to launch a new generation of gas cookers, with better design and comfort for users.

Safety of gas appliances for cooking is related to valid legislation in that field. Generally, it is not considered to be a problem, except in Croatia (in case there is no thermal shut-off valve), in Japan (where installation of flame failure devices is also mandatory, while fire prevention devices for fryer and flame arrest for fish grill are not mandatory) and in Switzerland.

The **noise from gas appliances, their electric consumption and reliability** are not considered to be a problem in any case.

A majority of responses to the questionnaire indicated that the emphasis should be put on the **cleaning** of gas cooking appliances. There is a necessity to improve the design of appliances to make the cleaning easier and to improve the appearance. What is needed is the elimination of unevenness in the burner section and adaptation of fluorocarbon film coating or glass plate for easy cleaning. On the other hand, state-of-the-art gas cookers with ceramic plate and radiant burners are demanded, but unfortunately still not widely available on the market. They are also fairly high-priced.

Commercial

The net efficiency of new and 15 years old units is (according to replies to the questionnaire obtained from France) the same (between 70 and 80%) as for the domestic sector.

Note again that the efficiency of cookers is greatly depending on the test conditions. When CEN standards are based on heating of a given quantity of water, we do not have the information about how this efficiency is measured elsewhere. The quantity of water is a very determining parameter for the efficiency.

NO_x emission from older units is around 160 mg/kWh, while emission from new units varies between 95 and 160 mg/kWh.

Emissions from gas cooking appliances in the commercial sector are considered a problem in 65% of the answers received. Emissions from gas cookers are generally a problem when comparing gas with electric appliances. But, there are, in general, no problems with NO_x, whereas CO is likely to be a problem under poor ventilation conditions.

The comfort level offered by the gas appliances is satisfactory according to 65% of the answers received. The main request seems to be a lower heat radiation from the appliance.

According to results of a survey, the noise from gas appliances and their reliability are considered no problem at all. The same applies for the ease of use, with the remark, however, that improvements of operation ability and the introduction of microcomputer control are necessary due to increase of part-time workers in franchise restaurants.

In one half of the answers received, cleaning of gas cooking appliances was pointed out as a problem, and in the remaining half it is no problem at all). Therefore, this problem seems to be of a subjective nature. This is, of course, more important in public restaurants than in households, due to strict sanitary and hygiene rules and legislation.

3.2.3. Cooling

The cooling market is today not very developed, and USA, Japan and France are probably the three most important countries that are using cooling with gas. It is mostly a market concentrated in the commercial sector.

First, regarding absorption units, currently sold products in France have a cooling net efficiency of 0.65 on the [17kW; 100kW] power range and an average cooling net efficiency (based on gross calorific value) of 1 on the power range of more than 100kW (double-effect products - see Section 3.1 for the definition). In Japan, the latest absorption products (2002) have a net efficiency of 1.35 (the COP 1.35 of gas absorption chillers is only cooling COP, and heating efficiency of those is 85%). The efficiency for cooling, the so-called Coefficient Of Performance (COP), is defined the ratio of output energy for cooling and input energy. Cooling cycle is heat pump cycle, so COP is more than 1 (Average heating/cooling) on the large power range (more than 100kW). A few products are commercialised, in Japan only, on the residential market: a 5kW cooling power lithium bromide absorption chiller by RINNAI and an 8kW cooling power gas heat pump by SANYO. The cooling efficiency of these products is 0.8 and 0.96, respectively, while there heating efficiency is 0.8 and 1.2.

Regarding gas engine heat pump units, the data from Japan indicates that the net efficiency is 1.3 (average heating/cooling) for machines in the [14 kW; 50 kW] power range.

New projects are under development to increase the net efficiency of absorption machines thanks to triple-effect technology

Also, the next generation of gas engine heat pumps is seen to have a net efficiency as high as 1.5.

As far as NO_x emission is concerned, absorption machines for premixed burners and burners with fans have emissions between 100 and 140 mg/kWh.

The rate depends on the burner chosen, as countries often adapt their own burners to the machines.

Croatia, France and Spain do not consider the efficiency of gas appliances an issue for the development of the market today. Nevertheless, France adds that improvement of efficiency is considered (ongoing research) by the manufacturers as already mentioned (triple-effect, improvement of internal exchanges, absorption gas heat pumps, etc.).

In Japan, Germany and The Netherlands efficiency is seen as an issue. Japan says this is the main reason for current development of high-efficient gas engine heat pumps. The different points of view can be explained by different market maturity and long- or middle-term views.

The emissions and noise of gas appliances are not considered an issue for the development of gas air-conditioning in any of the countries, except for Spain. Japan adds that emission is not a problem because lean combustion or catalyst technology is applied and will give emissions that are lower than the ones given above.

The comfort level offered by gas appliances as well as the safety of gas appliances are not considered issues for the development of gas air-conditioning in any of the countries.

Only Japan sees the electric consumption of gas appliances is as a problem; efforts are made to decrease the electric consumptions of cooling fan and refrigerant pump. Typical electric consumption of natural gas cooling appliances is 5%, and 1% of the cooling output for compact-range machines (<150kW) and large-range machines, respectively.

The reliability of gas appliances is taken into account by Japanese manufacturers, whose goal is to extend life duration of gas engine heat pumps from 10 to 13 years. In other countries, gas appliances are said to have a good reliability (mainly absorption units with life duration between 15 and 20 years).

The ease of use of gas appliances is not considered an issue for the development of gas air-conditioning in any of the countries, except for Germany.

We can synthesise the answers about the main issues as follows: Efficiency is a concern for half of the respondents. There is unanimity as regards considering comfort and safety to be no issue. Finally, emissions, noise, electric consumption, reliability and ease of use are considered a problem in only 15% of the answers.

3.2.4. Home fuelling

Efficiency, noise, reliability

For the latest models of Vehicle Refuelling Appliances (VRA) the service interval is about 4000 hours (e.g. FuelMaker). Previously, discontinued models had shorter service intervals (2000 and 2300 hours, respectively). The improved performance reflected by an extended service interval results in a 50% reduction in maintenance costs compared to earlier models. As an example, FuelMaker models C3, FM4, FMQ-2.5 have a power consumption of 0.33-0.4 kWh/m^3 compressed.

Noise and electric consumption are not considered issues for the development of the natural gas home refuelling market. France added that the electric consumption is rather low (1.1 kW).

Emissions

Comments on NO_x emissions are not applicable, since a VRA does not burn natural gas. This question was not addressed in the questionnaire.

Comfort level and safety

Overall, the main opinion among VRA users is positive. All countries stated that the units are safe and simple to operate, easy to install and convenient. Again, the costs, both appliance and maintenance, are the main negative opinion. VRAs are mainly used in commercial applications where the comfort level is slightly different from what it would be at home. Except for Germany, all countries stated that they would appreciate the convenience of home fuelling. As long as the unit is certified as an appliance, users will be comfortable with this product. In the Czech Republic, France and the United Kingdom, there are no regulations for designing, building and operating VRAs. In Japan, installation and maintenance are regulated by the bylaw of gas utility law. Indoor refuelling has a unique set of safety precautions in France and the Netherlands (indoor refuelling is allowed by regulation. The device should, however, stay outside), but that appears to be the only restriction.

3.3. The estimated average gas consumption for the application

This data is used later on for making the projection of energy savings etc. (See further below in the section **Scenario for the implementation in the long term**).

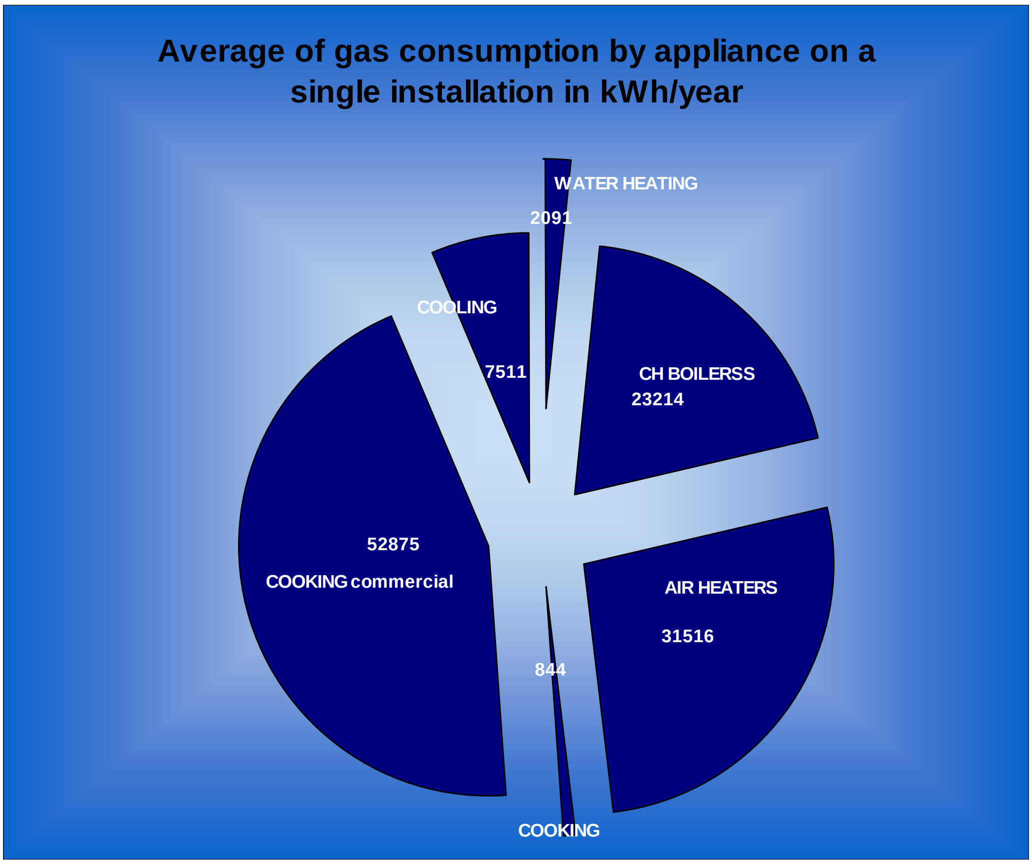

Figure 5: Average of gas consumption by appliance

The figure indicates the energy that is used in an average installation for the different applications considered. It shows the potential impact of commercial cooking. A commercial cooker will use twice as much gas as a domestic boiler. Domestic fuelling appliances also have a very high potential, but the number of respondents was too low to allow for a reasonable assumption. Also, the values given varied very much, and the differences between commercial and domestic can be very large. (See also section 4.5) If this application develops in the future it can have quite important consequences for the gas market in terms of gas consumption.

The average annual consumption for **heating** varies from country to country. Note first that it is difficult to get precise values and that there are large uncertainties on the result given. Even in a single country there will be very large variation in the consumption. The main factors are the climate, the heat conservation regulations, the size and insulation of the houses and the cost of the gas for the consumer (the very low Japanese average - less than 5000 kWh - is probably due to a combination of low average housing surface, good insulation, and relatively high gas price).

Because of the energy conservation legislation and due to the Kyoto agreement, there is a trend in most countries to reduce the energy consumption. The trend started already in 1973 after the energy crisis and e.g. US data [2] shows that between 1973 and 1988 the gas consumption in the residential sector has decreased by about 30%. The same applies for the commercial sector. This situation changes the market requirements and there is an increasing need for low-power units. In many cases when the building is renovated (insulated), the heating appliance is not changed and becomes oversized. However, most of the studies show that oversizing is not necessarily harming the efficiency. [8]

For **hot water production,** the average annual consumption by units is also very depending on the country. Note first that as for heating, it is difficult to get precise values and there are large uncertainties on the result given. The values given vary from 1000 to 4000 kWh/year for a family.

There have been a number of studies about the question of hot water demand and there are clearly some cultural aspects that play a strong role. The family composition and the habits as well as the price of the water are among the factors that are to be considered. The most recent trends for Denmark show that the average is now about 2000 kWh/year.

Also for **cooking**, there is a wide difference in estimated average gas consumption between various countries. Cultural differences between countries explain part of those differences.
The average gas consumption is about 800 kWh, but it may vary from the double or the half depending on the country.

For **cooling,** the estimated average gas consumption for commercial applications in France (1.84GWh/year) is about ten times lower than that in Japan (17.5GWh/year). This differences is due to the differences in climate and operation hours.

3.4. The most promising technologies and field-test results (when available)

3.4.1. Heating & Hot Water

Heating

Condensing appliances are given as "new" technology in a number of countries. However, for a number of other countries, condensation is already an existing technology that has been implemented in the market for several years. The respondents have mentioned the development of new burners either to lower the emissions or to improve the efficiency, as for example the new generation of burners (ceramic, catalytic).

The control of the combustion is a problem in the countries where the gas quality is subject to variations. A new self-adapting system (SCOT) was developed in Germany. It is already integrated in commercially available boilers on the market.

To an increasing extent the combination of gas with renewables is allowing energy saving and flexibility, and at the same time it makes the image of gas "greener". The storms in 2000 that left a number or areas in Europe without electricity - and as a consequence without heating - gave birth to the idea of self-powered boiler in some countries. There is a prototype of boiler using PV (Photo voltaic) cells to produce electricity in Switzerland. Finally, micro CHP (< 5 kW_e) is developing fast and is expected to be on the market in 2005/2006.

Micro CHP, fuel cell boilers and combined hybrid systems (gas and solar) are the probably the technologies of the future. Those technologies are covered by the "Technology" report. Appliances able to burn **hydrogen** would probably also soon be a challenge.

Among the new technologies for **air heaters** are catalytic radiant panel for ambience heating and condensing heaters.

Here are few web sites of a gas companies and manufactures for air heaters in **Japan**. They illustrate the technology used in this country.
http://www.tokyo-gas.co.jp
http://www.osakagas.co.jp
http://www.tohogas.co.jp
http://www.saibugas.co.jp
http://www.rinnai.co.jp
http://www.gas.or.jp
http://www.meti.go.jp

A few **field tests** were mentioned in the survey:

- The PV cells to produce electricity in Switzerland are part of a proposal of a European project that includes field test (same technology as described above).
- Field tests are all combinations with new technology development in the Netherlands (CHP, heat pump, solar). The test is described under the corresponding items (see below in the "Technologies" section.
- A large demonstration project of various gas technologies (DEO). The programme is funded by the EU [7]

For **air heaters** the following field tests have been mentioned:

France

Tests have been carried out in five buildings with air renewal for creation of a standard dimensioning method for radiant gas appliances. The measurements of the air renewal rate are made using a tracer gas. The thermal reactions of buildings, the consumption and the comfort are also analysed.

The Netherlands

The main issue for the application of air heaters is the control for the appliances in large halls. A lot of work has been done to facilitate the design, and further work is planned to improve the controls (model based control)

Hot water

The condensing technology seems to be the next generation, but might pose a problem considering the legionella risk. A new system of heating water to minimise the legionella risk has been developed (France), and instantaneous heating water systems with little storage to reduce waiting time are now also on the market.

No field test has been mentioned in the survey.

3.4.2 Cooking

Domestic cooking

One of the **most interesting new technologies** is 3D glass ceramic cook top for gas applications. The convenience of glass ceramic cook tops is no longer limited to electric appliances In **France**, Eurokera and Gaz de France have examined and developed a new cook top, on which **the grates** can be completely or partially replaced by glass ceramic support. (The grate is the metal grid that separates the burner from the cooking plates). It is integrated into the cook top in order to ensure support of the pan. Benefits are superior aesthetic appeal, easy to clean, no grates etc. In **Japan**, emphasis has been put on efficiency improvements of cooking stoves; elimination of water from fish grills; intelligent fish grills and IT (Information Technology) for gas ovens.

Among the developments we can mention:

- Efficiency improvements of cooking stoves: A solution adapted in a new technology is to curb the protrusion of the flame (this is the part of the flame that is in contact with the pot or pan)
- IT for gas ovens: A coded number that stands for the required oven temperature, heating hours, etc. is presented in the recipe on a web site. Customers can cook easily by simply inputting the coded number.

The new gas appliances/technologies listed above are in a way the answer of the gas industry to the competition with electric Induction Heat (IH) cookers. IH works by indirect heating of the pan or frying pan by electromagnetic radiation.)

The share of IH cookers is increasing in Japan - and in all countries in general, because of the ease of cleaning, superior aesthetic appeal and safety (the consumer does not use "open flame").
An example of such technology can be seen at http://www.suzumokikou.com/subpages/ihms2000.html.

The advantage of gas cooking stoves against IH cooking stoves is that customers can use all burners at the same time because there is no limitation for the input (input for the IH cooking stove is limited to less than 4.8 kW).

To conclude, the most promising technologies in this field are:
- Gas cookers with ceramic plate and radiant burners
- Introduction of electronic parts for control of the gas cooking appliances
- Development of more aesthetic high-efficiency burners
- Moving towards easy-to-use gas appliances by information network
- Flue gas evacuation systems

Commercial cooking

Although the conclusions are restricted by the small number of responses, they still show general trends.

In France, new technologies that are reported, are aiming at improving efficiency and reliability:
- A new inside flame burner to increase efficiency (This is a burner that does not have a centrifugal flame like traditional burners, but a centripetal flame. This allows decreasing the surface of the burner without changing its capacity; it also increases its efficiency by optimising the heat exchange)
- Infrared burner using metallic fibre to increase reliability
- PID regulation to increase regulation efficiency

In Japan, several projects are aimed at increasing efficiency. The most promising new technologies in this field are connected with improving the comfort level in the kitchen and the operation ability (by introducing micro-computer control).

3.4.3. Cooling

Several developments are currently conducted around the world. For absorption machines we can mention the following:
- High-efficiency absorption machines (new exchangers, new internal design, etc.) for the commercial sector
- Competitive absorption machines for residential and light commercial markets (cooling power less that 10 kW)
- Absorption heat pumps (a 10 kW machine is under development by Gas Natural, BG and FAGOR (ROTEX project))
- Triple-effect absorption machines (by HITACHI, KAWASAKI, YAZAKI, and DAIKIN under a government sponsored project)

For gas engine heat pumps the following developments are reported:
- High-efficiency gas engine heat pumps for the commercial sector
- Gas engine heat pumps with hot water supply function for the residential market

Depending on the country, the results expected from the development of these new products are to develop a market and/or to strengthen the competitiveness against electric appliances, keeping in mind that the main issue, on the residential market, is the high cost of gas appliances and, on the commercial market, the development of new refrigerant cycles.

No field-tests have been reported.

3.4.4. Home fuelling

A new device is being developed by FuelMaker (Phill) and it will be available in 2002 at a price of USD 999. The United Kingdom indicated that the British Gas group is developing a new hydraulic compressor for home based refuelling. Since the time of this study, British Gas has terminated the development of a home based unit. Japan mentioned the Sanyo unit, which is the most common appliance currently available in the country. It was developed in a government sponsored project from 1992 to 1994.

The convenience associated with home fuelling might provide a very promising avenue for gas utilities to increase market share.

Field tests

Japan stated that the Sanyo VRA is currently in its commercial stage.

The United Kingdom indicated that 10 units of British Gas' new appliance were installed for field tests. The trial was successful in terms of VRA performance; however, they encountered some noise problems with the vehicle refuelling nozzle. Since the time of this study, British Gas has terminated the development of a home based refuelling unit.

4. MARKETING ASPECTS

In this section the data presented are those from the questionnaires received and the countries, from which we have been able to gather data. See the opening remark in the beginning of this report.

For the figures given in this section, the value "zero" is either a sign that a market is not identified, or that we have not got any data.

4.1 Heating & Hot Water

Heating with CH boilers and air heaters

Estimated natural gas units in operation

CH boilers are widely used and especially the EU is a large market. In the EU, the market is dominated by Germany and the UK. In the EU, the total park of CH boilers installed is probably between 60 million and 80 million units. In the USA alone, almost 50 million air heaters are installed.

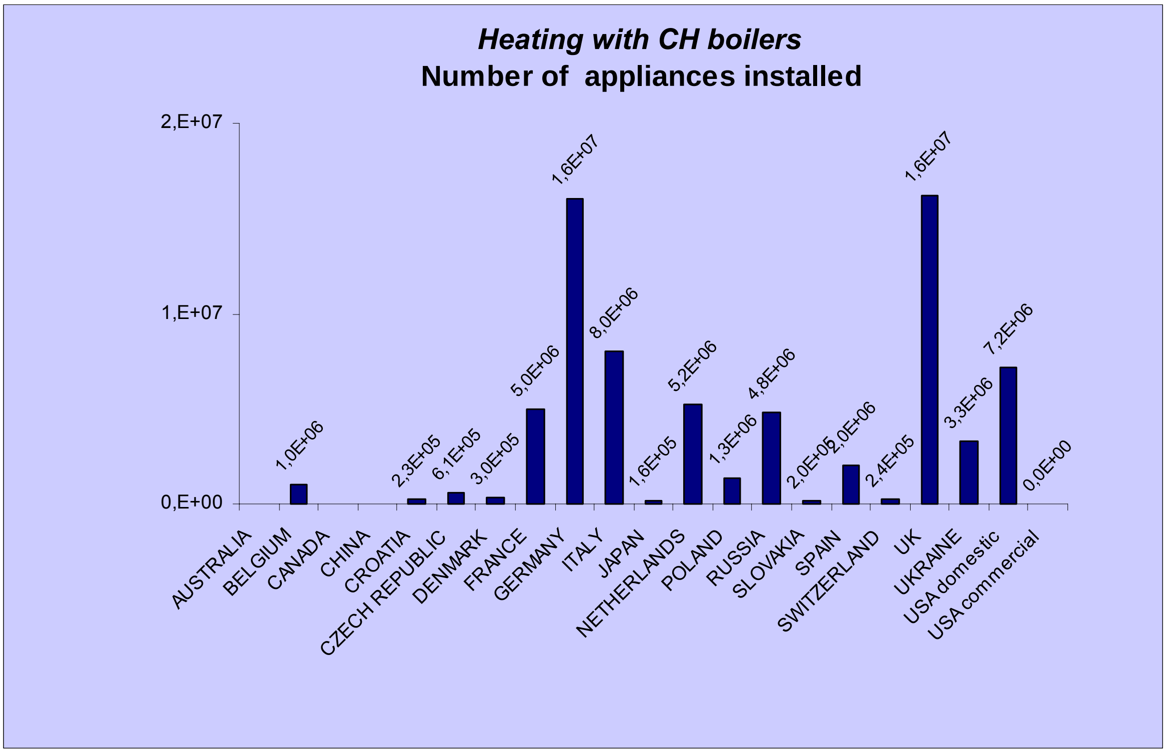

Figure 6: Number of appliances installed (CH)

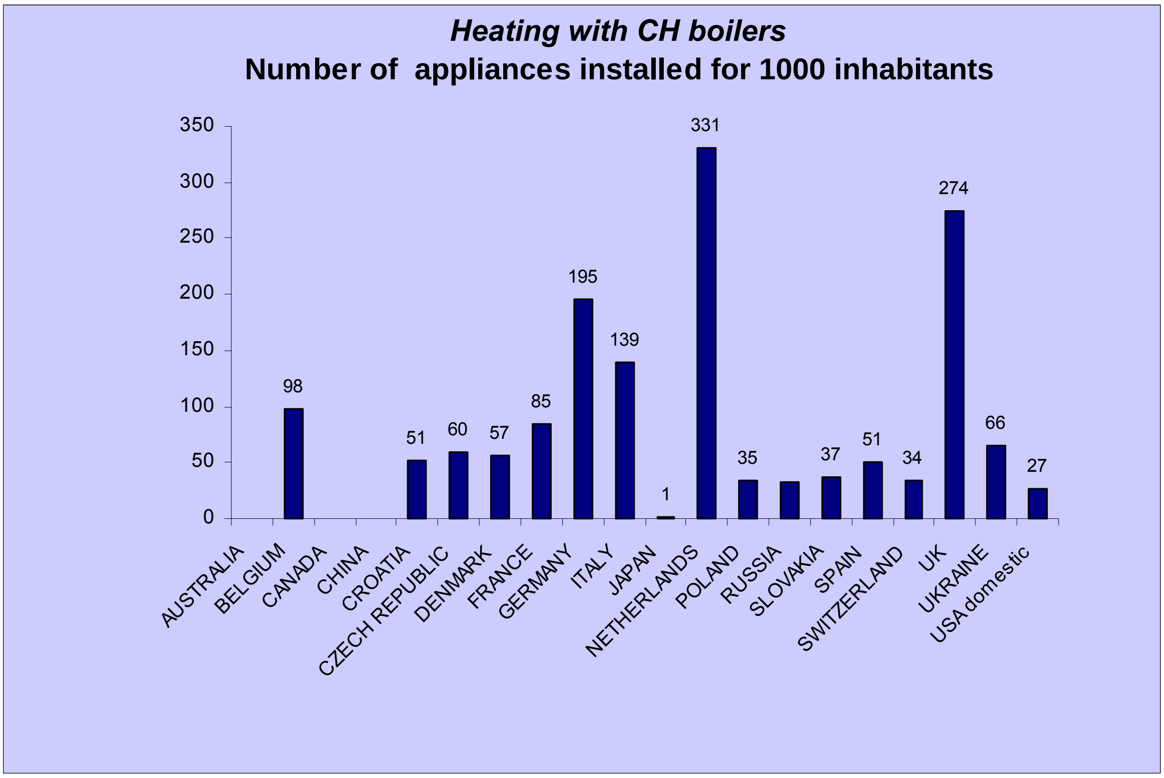

Figure 7: Number of appliances installed for 1000 inhabitants (CH)

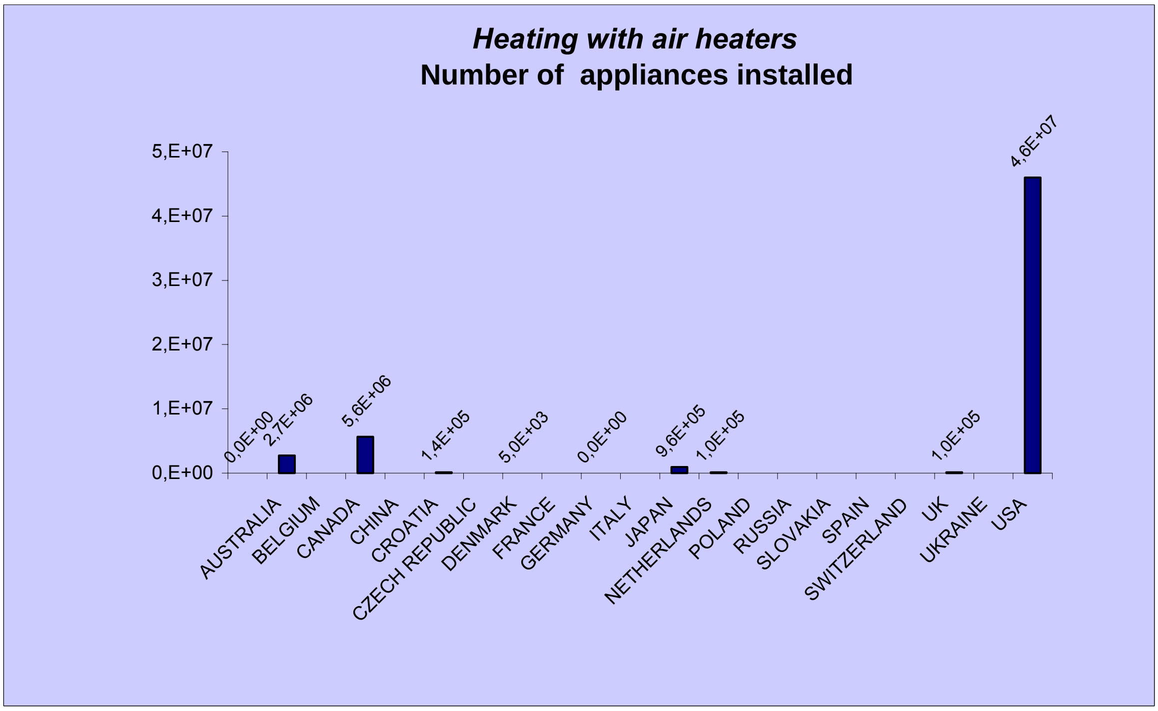

Figure 8: Number of appliances installed (air heaters)

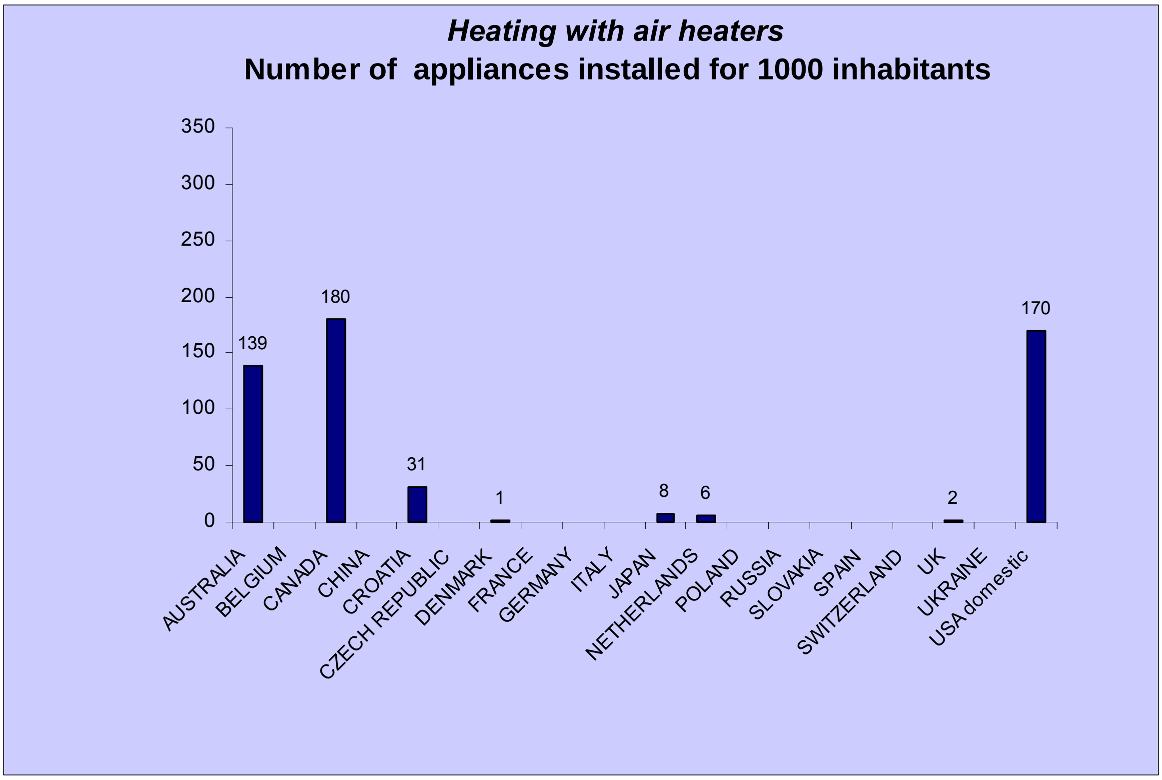

Figure 9: Number of appliances installed for 1000 inhabitants (air heaters)

Replacement data was not given for all countries, but it is generally recognized that the lifetime of a gas appliance is approx. 10-15 years. Therefore, the replacement market - for the group of countries covered by this survey alone - is between 3 and 5 million. To that we shall add the new market (market for new gas consumers) that is estimated to about 1 million units. The data we have from other sources tend to show that the values above are probably much underestimated. Therefore, they are only given as an indication.

The condensing technology has either overtaken a very large part of the market in a few countries (e.g. the Netherlands and Switzerland, where it is more than 90%), but it is quasi nil for most of the other countries.

Estimated net increase in natural gas units per year

Some markets are in strong expansion (Japan and Spain), but for most countries, the sales of boilers is in the replacement market, where the expansion is quite limited. However, globally gas is taking shares of the fuel oil and/or electricity. Nowhere in the world is the market decreasing. The central heating market has a solid position and is an expanding market.

Estimated replacement per year

The replacement of boilers varies much from country to country. Most of the countries have a replacement rate of a few percent. The principal factor for replacement is the market age, replacement financial incitements and other parameters that are not identified in this study, as this point is too detailled for this survey.

Example of three successful markets for condensing boilers

In general, the fraction of condensing boilers of the sales is very low, but in three countries the percentage is quite high:

1. In Denmark, due to an incentive campaign in 2000-2001 where consumers received a rebate of about 10% on the total price. It is not yet known if the market share will remain so high, but the first estimates seem to indicate that the campaign has been successful in eliminating one of the barriers: the installers are now less reluctant to offer condensing boilers to their clients.
2. In the Netherlands there has been an intensive campaign to promote the use of condensing boilers, both by advertisements and by financial incentives. As a result, the cost of the boilers has dramatically decreased and is not far from the cost of modern non-condensing boilers. Newly built houses (70.000 a year) are almost all equipped with condensing boilers since the building regulations (E.P.N Energie Prestatie Norm, Energy Performance Standard) require energy efficient solutions.
3. In Switzerland. Since the beginning of market introduction in the late 80's, no special campaign was launched to promote the condensing technology. The following points might explain the success obtained by the condensing boiler in this country:
   a. The price difference between condensing and conventional boilers is not that large.
   b. The Swiss people are concerned about the environment and are willing to pay a little more for advanced technology with a high efficiency.
   c. There are no special installation requirements for condensing boilers (P<70 kW).
   d. Considering the running cost over the life cycle there is a clear benefit using the condensing technology.
   e. Some cantons in Switzerland prompted the introduction of this technology by legislation.

What are the main competing energies?

Electricity and fuel oil are the main competitors. In some countries, **district heating** is also limiting the development of the CH heating with gas. But as the power and heat generation units for district heating are increasingly based on NG, district heating is only partly a competitor (NL: District heating also uses waste heat from electricity generation). In a few countries (e.g. Czech Republic - TCH) electricity is taking increasing parts from the gas market share. Also renewables (e.g. TCH) is becoming a stronger competitor. In 1996, AGA considered the US market as stable, despite electricity gaining market shares (over fuel oil) [1]. One characteristic of the US market is the development or air conditioning and there the electric heat pumps have a strong position for providing both heat and cooling. Also in the Netherlands, electricity driven heat pumps are a serious competitor. Electricity has the advantage of cheaper installation costs, but in most countries the kWh price of electricity is much larger than the price of the kWh of gas. In this context, the trend of lowering the heat demand is clearly an advantage for the electricity. The payback time of a gas installation for very low heat demand is too long.

In the EU, **renewable** energy might play an important role in the near future. The EU Commission has launched a number of programmes that are aimed at increasing the share of renewables in the energy market. Therefore, financial incentives and a general development for green energy will make the development of solar possible, as for example in Germany manufacturers have already some technology that is combining solar and gas. Renewables alone cannot cover the average heating/hot water demand. Therefore, a marriage between renewables and gas seems to be a good solution for both the gas industry and the solar industry.

Fuel oil is another competitor, but not as strong as electricity. Fuel oil is generally well implemented in areas not covered by the gas net and in some countries (as DK) it is not really a direct competitor, as the technologies are covering different geographical areas (fuel oil taking the areas where the gas grid is not developed).

The competing energies are also depending on the national situation: **coal** is still a competitor in Poland as the price of coal is low.

When looking at the competitors to the gas technology, we shall not necessarily focus on type of energy, but also on the service. More and more, the market might develop toward the combined production of heating and cooling and the energy that will provide this double function at reasonable installation and running cost might take over the existing market in the long run.

In that respect, electricity is becoming competitive on the market of heat pumps for the production of heat and cooling. The technology might be attractive for a customer ho also wants to have cooling and who may switch from gas to electricity. The menace is not yet spread over all the markets, but if this is confirmed, the boiler technology of today is not adapted to compete against such technology.

The costs related to gas appliance (appliance costs, energy costs and maintenance costs)

The costs related to gas appliances may cause problems in some countries. The **appliance costs** compared to electric heaters can be a real problem. Especially when the building designer is not the user he often chooses an electric system that is cheaper to install than a gas CH system.

Energy costs are always a positive point for NG in comparison with electricity, but other energies can sometimes beat natural gas in price, as coal does in Poland.

The installation costs and the **maintenance costs** are also considered a problem in some countries. For example in Germany, the chimneysweeper has to check the flue gas duct and the correct combustion periodically, which means recurrent payments. As the heat demand is decreasing due to the overall implementation of building insulation regulations, the maintenance or **repair costs** of gas appliances will increasingly be considered a problem in the future.

Potential market changes

In many countries, gas is in a favourable position for further development (e.g. the USA). For some of the countries (e.g. D; NL) the markets are close to saturation and the challenge is not to develop the market, but to keep the customers. The development of the gas grid in such saturated market is too expensive in regard to the potential number of new consumers connected, and district heating offers much more favourable prices (NL). Also some countries (e.g. Russia) have a tradition for district heating. Gas has a favourable position also on the district heating market with for e.g. the production of heat combined with the production of electricity with turbines.

Hot water

Independent water heaters are appliances that are designed to produce only hot water. Combination boilers are not included here (treated under boilers for the heating).

Estimated natural gas units in operation

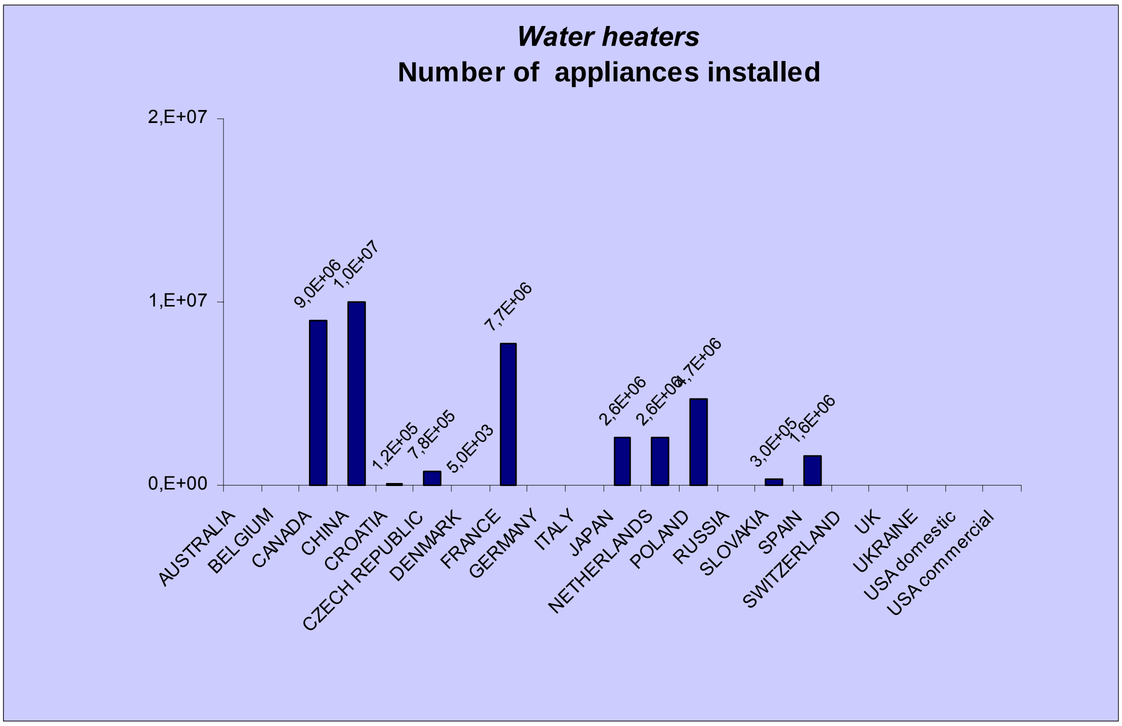

Figure 10: Number of appliances installed, water heaters

Water heaters are widely used. The total market size in the countries that have replied (CZECH REPUBLIC, CHINA, CROATIA, DENMARK, FRANCE, GERMANY) is about 30 million units. In China, 10 million units are installed!

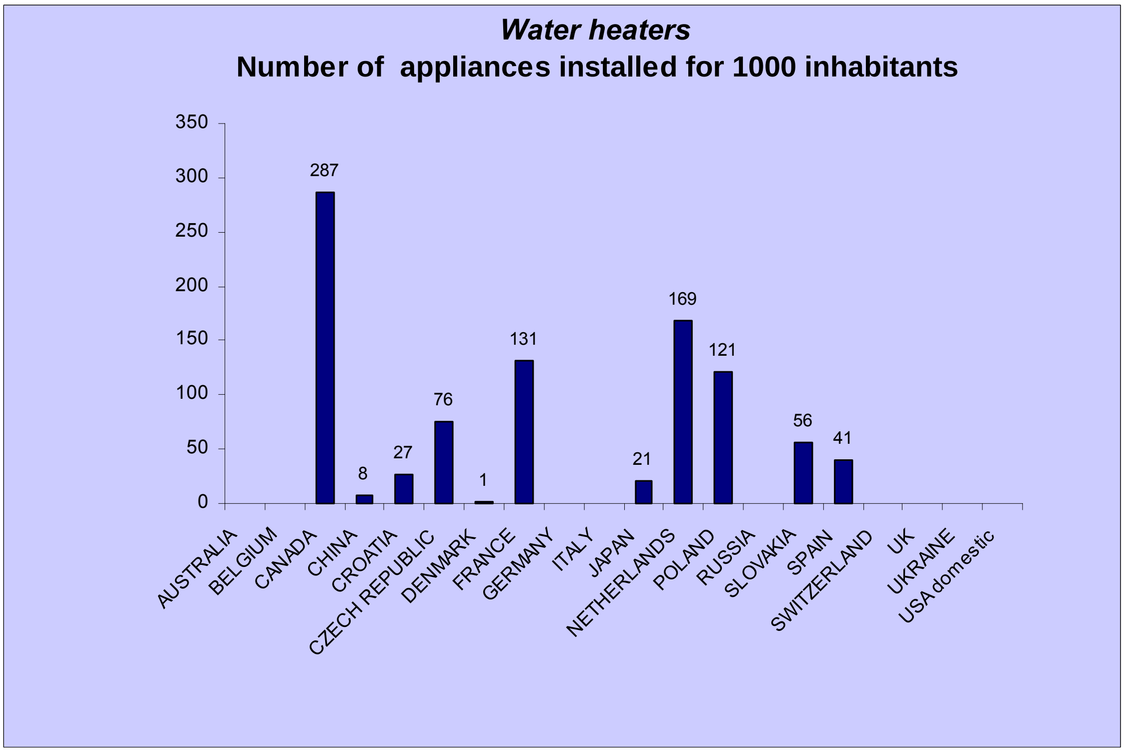

Figure 11: Number of appliances installed for 1000 inhabitants, water heaters

Estimated net increase in natural gas units per year

Some markets are in strong expansion (China 2 million = 20%), but for most of the countries, the sales of water heaters is either limited (France, Spain, etc.) or even strongly decreasing. The total replacement market is slightly over 2 million, which is corresponding well with a lifetime of 10 to 15 years.

Estimated replacement per year

For water heaters, the market is really a replacement market and not a new market.

Comments on the replacement process and flow

There are clearly two types of markets:

1. The markets that are decreasing (e.g. DK, NL, D). In Denmark, the appliances are mainly found in the city of Copenhagen and are replaced by district heating or electricity. There is no more interest for those in Switzerland either.
2. The markets that are increasing. In a few markets, gas is taking some shares from electricity or other energies (Croatia and Spain- about 4 to 5%) and the huge market of China in full expansion. Beside this, few markets are slightly expending (e.g. CZECH REPUBLIC).

Costs (appliance costs, energy costs and maintenance costs)

As for the boilers, the **appliance costs** compared to electric heaters can be a real problem. **Energy costs** are always a positive point for NG when comparing with electricity.

Potential market changes

The situation is rather different from one country to another. When China is strongly developing its market, a lot of European countries are replacing the water heaters with combi-boilers.

Action needed to develop the market

The strategy of many countries is the introduction of combi-boilers. Therefore, we shall probably promote this solution and even promote the combination with solar energy to make more savings possible and make gas a more attractive product.

For many countries, the water heater is already considered as an appliance from the past. The combi-boilers are supposed to replace the water heater in those countries. However, considering the very important market in China, there is a clear interest in solving a number of the problems that have been mentioned by this country (mainly too low efficiency). But we are missing details about the characteristics of the appliances available and of the Chinese market. This point could also be added to the list of the important points for the next triennium.

The answers received from the questionnaire have also been mentioning the following points:

- Improve the comfort level with better control systems, preheating buffers to reduce waiting time etc.
- Promote the condensing type for energy saving
- Certification of personnel in charge of installation and maintenance of the appliances (Spain)
- Improve the regulations concerning exhaust ducts and chimney in new buildings (Spain)

Please note that the two last points apply in general for the other gas appliances.

Recommendations

Considering the above, it is difficult to give recommendations that cover the need of all countries. There are some countries that have already made the choice of eliminating the appliances (water heaters) that will in time be replaced by the combi-boiler technology. For those countries, research is inappropriate, but perhaps the marketing of combi boilers shall be stronger to avoid the challenge of the electrical water heaters.

For the countries with a clear interest in maintaining and improving the technology, there seem to be a number of technical challenges:

- Improve the water heater efficiency (especially for the Chinese market), perhaps with condensing technology when possible?
- Solve the comfort problems. The progress achieved in this field will also benefit the combi-boiler (instantaneous combi-boilers also have comfort problems).

4.2 Cooking

More than 100 million domestic cookers are installed throughout the world.

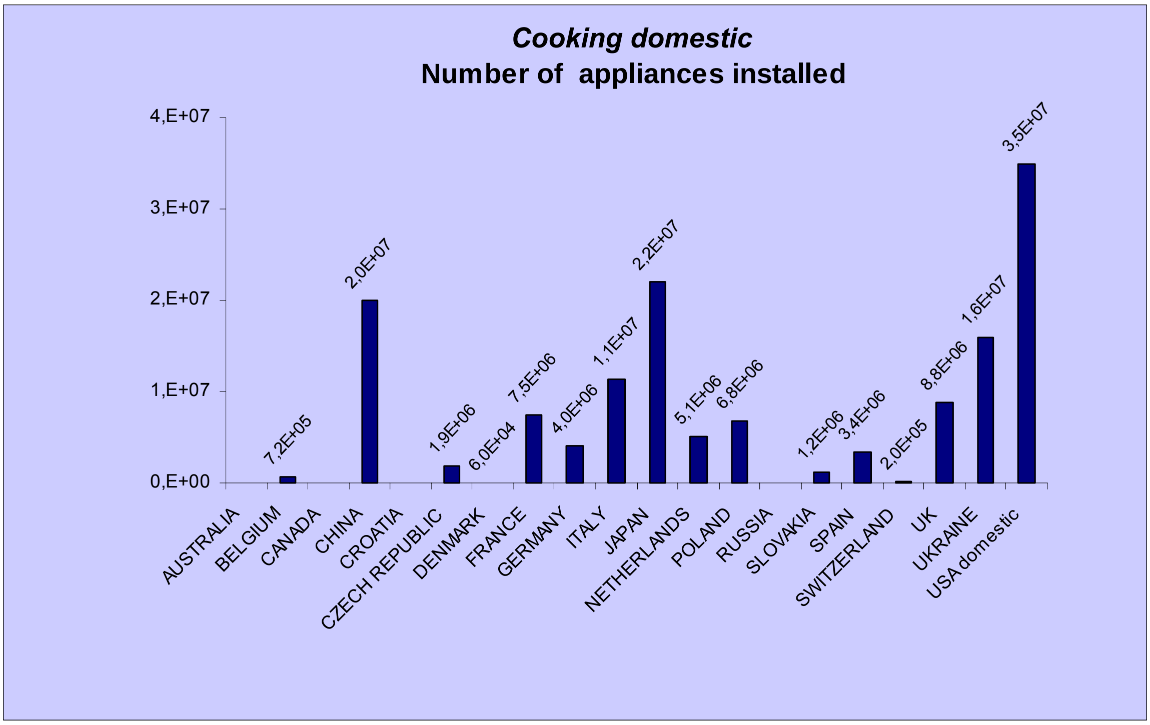

Figure 12: Number of appliances installed, cooking domestic

The total number of natural gas cooking units in operation in the household sector is partly depending on the size of the country (population). Therefore, number of units per 1000 inhabitants has been calculated to show general trends. *Note that for all the data collected for this report, the figures presented on the graphs are sometimes only rough estimates. For example in this case, other sources (Tokyo Gas) have mentioned a rate of 400 appliances per 1000 inhabitant in Japan (the initial figure was 173). This illustrates the difficulty of obtaining accurate data in general when organising such surveys*.

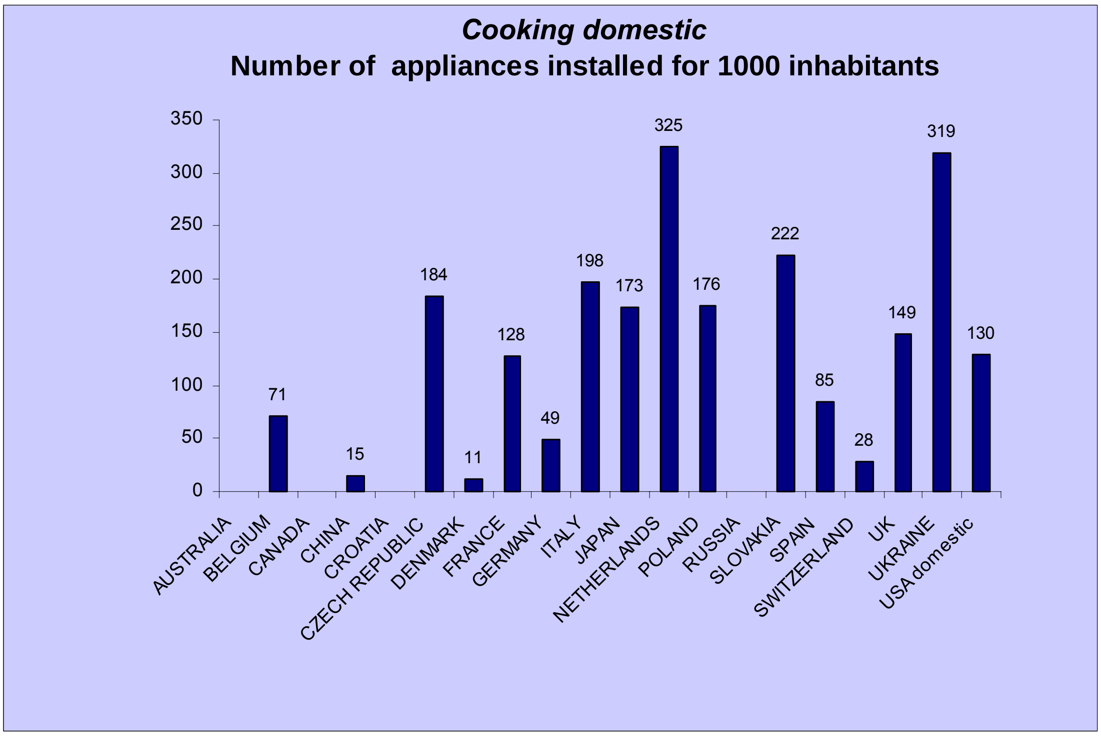

Figure 13: Number of appliances installed for 1000 inhabitants, cooking domestic

As data from the important gas countries were missing, an analysis of the correlation between number of natural gas users in the household sector and the number of gas cooking appliances has been made to obtain an estimate of the market.

The share of gas customers having a cooking appliance is shown below to illustrate the difference in the penetration depending on the country (only countries for which we had data on the number of gas customers are presented on the graph).

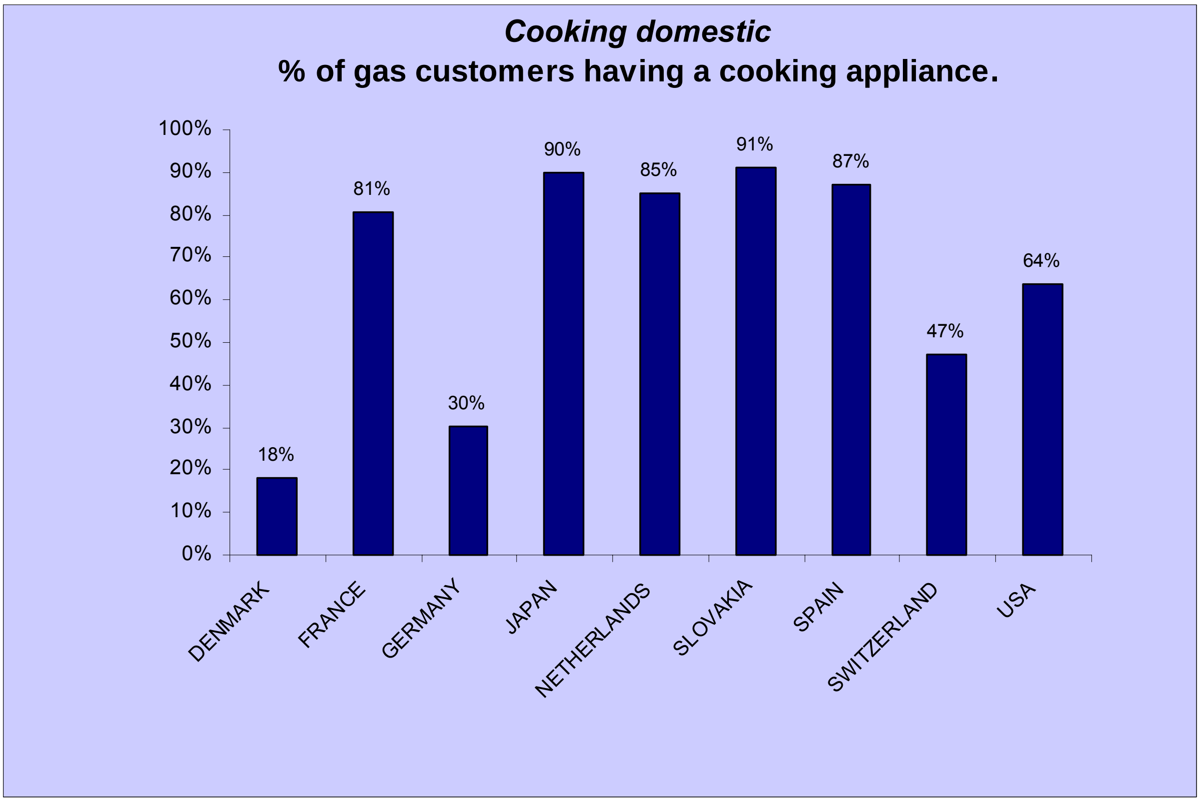

Figure 14: Share of gas customers having a cooking appliance

Germany and Denmark have a relatively low share of natural gas cooking appliances in total number of residential natural gas users. This is probably due to the developed market of state-of-the-art electric cooking appliances and customers habits. Other countries, such as Slovakia, have a very large share (above 90%).

Getting data from countries for which no data have been sent

A regression formula between estimated number of natural gas cooking appliances in operation and total number of natural gas units has been calculated according to available data, but only for European countries (Japan and US markets have been excluded from calculation, as the models might not be adapted to these countries).

According to the formula developed, Italy for example will have (with the total number of 14 million residential consumers) around 8 million natural gas cooking appliances. This is, of course, only a mathematical exercise (although, theoretically it might be possible that this curve explains the European market well).

Each gas market has its own history (from recently developed markets where networks were originally developed for natural gas to mature markets with a long history and tradition, from town gas and LPG to natural gas) and its own moving forces such as availability of appliances, rebates, loans, etc. All this has a huge influence on every specific market.

A different curve is used to explain the correlation between estimated number of natural gas cooking appliances in operation and number of residential natural gas users, taking into account markets in US and Japan. Although the correlation is very high (almost 96%), this formula is strongly influenced by the size of these markets. Therefore, it will probably not be precise enough to estimate number of natural gas cooking appliances if the total gas market of the analysed country is small (like in case of almost every European country compared to US).

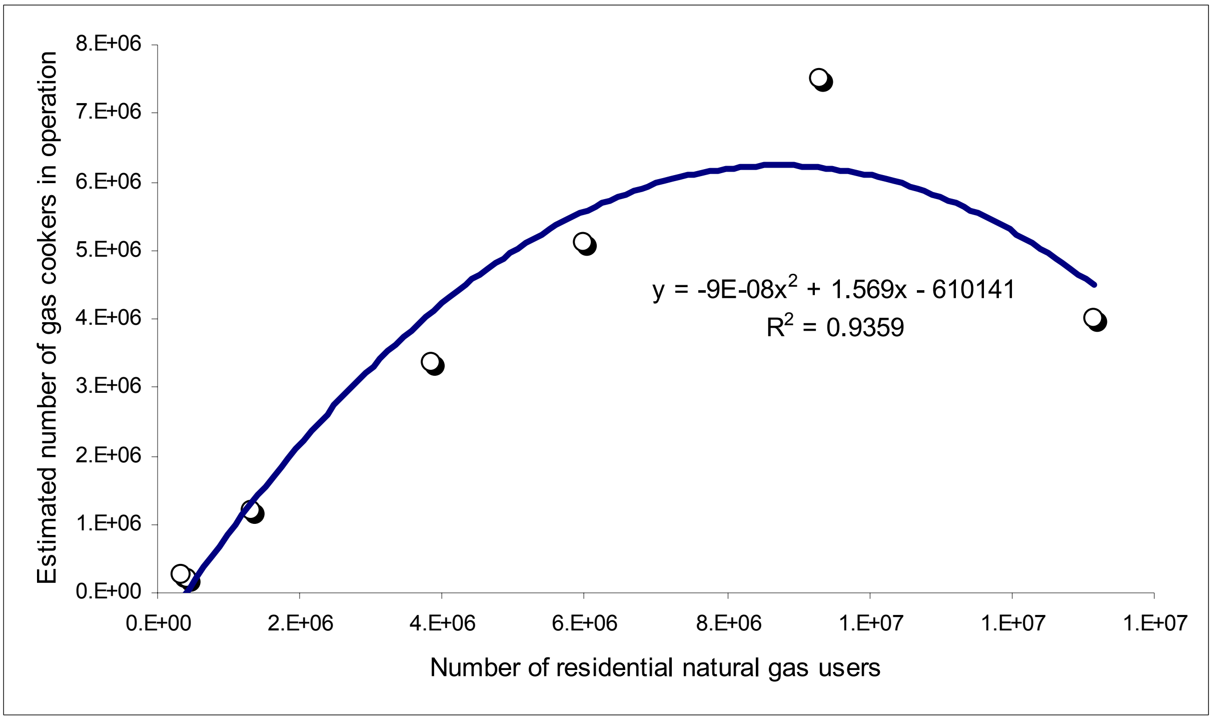

Figure 15: Regression formula – estimated number of natural gas cooking appliances in households sector vs. total number of residential natural gas consumers

There is a general lack of data covering net increase in natural gas units per year for several countries. Also, a large net increase for a specific country might be caused by an extraordinary situation only for the specific year (as in the case of Croatia where a new large distribution area has been put into operation recently).

The specific net increase (among analysed countries) is largest for Spain, which may be connected with intensive natural gas network expansion after the Maghreb line has been put into operation, and also with the tradition of town gas and LPG use.

The number of replacements is probably determined by different reasons (maturity of the market, DSM activities etc.).

Comments on the replacement process and flow

According to collected data, natural gas cookers are, in most cases, used to replace electric cooking appliances (50000 in France, 4000 in Slovakia and 51000 in Spain). In Spain and Croatia, LPG is more often than electricity replaced with natural gas when this is possible. The price of LPG from cylinders is in the range of the price of electricity, but LPG is used because food preparation is quicker. On the other hand, consumers that are using electricity instead of natural gas and LPG are usually "afraid of gas". In Spain, 119000 of LPG cookers are replaced annually with natural gas cookers. In areas without NG, some consumers find it more easy to use electrical cookers instead of LPG.

The advantages of using natural gas for cooking are that natural gas is, in most cases, cheaper, and gas cookers are quicker for meal preparation. State-of-the-art gas cookers with ceramic plate and radiant burners will probably further increase the gas market, although they are still not widely available on the market (for instance, in Slovakia).

Electric cookers with ceramic plate and "air-heating" electric oven are very popular and are the main reason for the decrease in the natural gas market. According to results of a questionnaire, natural gas users are, in case of switching to other fuels, switching strictly to electricity and not other fuels (1000 per annum in Denmark, 100000 in France, 300000 in Poland, 5000 in Slovakia and 80000 in Spain). This is probably connected with better design of electric appliances and no need for pipes (in the kitchen) for natural gas supply.

The cost of gas appliances (appliance costs, energy costs and maintenance costs) was one of the aspects that were studied. Ceramic gas cookers are considered too expensive on some markets, on which they are available (NL). Appliance costs are in most cases not a problem, but costs of installation and fitting are considered a problem, for example in Germany. For Japan, the first priority is to reduce appliance costs and the second is reduction of operating costs by efficiency improvements. Although gas appliances still hold competitiveness against IH stoves, active developments of the electric appliances are threatening the gas market.

But in most of the countries, customers are more oriented to design and comfort than to energy costs.

A simple calculation of the payback time if a customer chooses a state-of-the-art **gas cooker with ceramic plate** compared to its electric counterpart shows that in the USA the gas technology is only paid back after about 15 years. In most of the countries - despite the fact that the price of gas is cheaper - the payback time is longer than the expected life time of the appliance.

4.3 Cooling

Evaluation of the existing market. Data

Market data

Market data given here come from countries where gas cooling is developed or developing and that answered to the questionnaire.

Other countries like China, Korea or Italy have a significant gas cooling activity, but data are missing. Other Western Europe countries do not appear to have much interest in gas cooling. Some of the reasons being gas deregulation (like in Spain) or lack of significant market. Therefore, the data focus on France and Japan.

The estimated number of natural gas cooling units in operation is 233 000 in Japan and 500 in France. For USA, the number of units in operation is 20000 for domestic and 65000 for commercial, respectively. These first figures reveal one of the main differences between the markets: in France, air conditioning is recent. It began in the early 90's with electric air-conditioning while the natural gas offer really started in 1996. In Japan, the market has existed much longer and the saturation rate is high as shown in the table below:

Saturation rate (all energies, 1998)		
	Residential sector	**Commercial sector**
France	1.5%	18%
Japan	85%	100%

Table 3: Saturation rate

The USA is in between with saturation rates of 65% and 80% in residential and commercial sectors, respectively. The late development of air-conditioning in France is mainly explained by its temperate climate.

This new market implies a very high increase in natural gas cooling unit sales per year that varies from 60% to 200% between 1998 and 2002 in France. In Japan the annual increase is far lower with a variation from 7% to 16% per year between 1991 and 1999 due to the large size of the market and its saturation rate.

As far as technology is concerned, the two countries have different strategies. In France the market is exclusively absorption heat pumps for commercial use, whereas in Japan this is only 19%. The main market is domestic and with gas engine heat pumps.

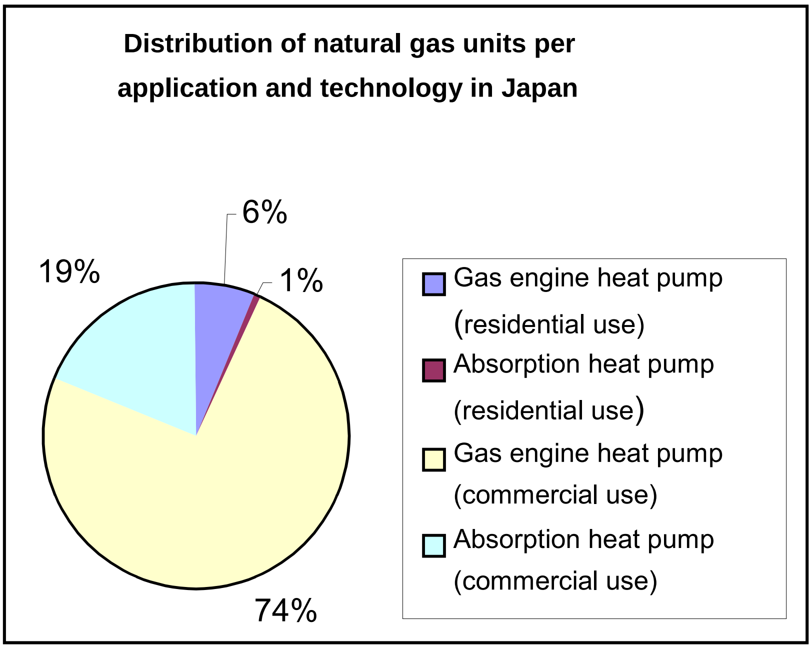

Figure 16: Natural gas units divided on application and technology, Japan

In Japan, both gas engine heat pumps (GHP) and absorption technologies are sold for commercial and residential applications. Gas engine heat pumps have about 80% of the market share when combining commercial and domestic.

Also, residential applications account for 7% of the total sales. The machines sold on the Japanese market have a cooling power from 6.7 kW to several MW.

In France, the situation is very different: only absorption units are sold and there is no offer on the residential market yet. As the market is emerging, the commercial sector was first addressed. The machines sold on the French market have a cooling power from 17 kW to several MW.

This difference can be explained by several reasons: Due to a well established electrical market in Japan (electric heat pumps) and a price difference between electricity and natural gas that is much higher than in France (roughly, gas price is 1/3 of the electricity price, while it is 2/3 in France), front costs and performance are the two main parameters to take into account.

In France, environmental aspects (no CFC and HCFC), reliability and differentiation were highlighted first and led to the promotion of absorption technology. Also, the maturity of the Japanese market made it a habit for residential and light commercial customers to buy heat pumps that are sold in general stores and supermarkets, like Hoovers for example. In order to fit customer habits, Japanese manufacturers have developed natural gas electricity-like heat pumps. This can be an explanation why gas engine heat pumps dominate the residential market in Japan.

Comments on the replacement process and flow

The increase of the gas market share in Japan is due to the replacement of appliances using electricity, fuel oil and renewable energy with appliances using gas. In France, the replacement process is different: due to the youth of the market, heating and cooling air-conditioning machines replace boilers or electric heating machines and not cooling machines.

Comments on marketing aspects

First, it is clear for most of the respondents that electricity is the main and only competing energy. Only Germany mentioned that fuel oil is also a competitor.

The main competing electric technologies are:
- monosplit cooling systems (one indoor unit for one outdoor unit)
- multisplit cooling systems (several indoor units for one outdoor unit)
- windows (a single apparatus through the wall)
- mobile units
- heat pumps (EHP) that meet both heating and cooling needs

Then, among the three main types of cost of gas air-conditioners (i.e. appliance, energy, and maintenance), all countries agree that the cost of the appliance itself is the main issue in terms of competition. Moreover, Japan mentions that maintenance costs is also a problem, but after appliance costs. France adds that appliance costs are decreasing over the years with the diversification of the French offer (new manufacturer entry).

Gas appliances are sold thanks to their overall lower costs compared to electric appliances. Overall costs take into account appliance front costs (higher for gas appliances), installation costs (lower for gas appliances as absorption machines can be installed in the boiler room), energy costs (lower by one third for gas in countries like France and Japan) and maintenance costs (in case gas is already in the house, it is lower for gas appliances due to less moving parts and a 25% longer life duration than for electric appliances).

The potential market changes and action needed to develop the market are elaborated in Section 5.

4.4 Home fuelling (VRA)

Please note that we have not received data from countries like Italy, USA etc. via the questionnaire. The data provided reflects the year 2001, 2000 or 1999 - depending on the country.

Japan had 441 natural gas units of home fuelling in operation, consuming an average of 2 million m^3 CNG per year. Japan estimated that 62 units of home fuelling would be sold in the period August 2000-August 2001. Japan's VRA market is driven by its population, the gas companies, government, and the availability of a VRA that is manufactured domestically.

France reported that 100 units were in operation in 1999. However, units are no longer installed, and no increase in the number of units sold is foreseen. Over 200 FuelMaker VRAs have been sold to France. The main hurdle in developing the NGV market today is the cost of diesel versus gasoline. On average, every second car is powered by diesel.

In 1997, there were 300 units in operation in Benelux (the Netherlands and Belgium). However, the number decreased rapidly due to a safety problem that has been solved by now. In 2000, only 30 units were still in operation.

For the United Kingdom, only 10 units in operation in 2000 were reported by the respondent to the questionnaire. No increase of the market is expected, either However, according to a manufacturer, almost 100 VRAs have been sold to the United Kingdom. This illustrates the difficulty to get reliable market data.

In 2000, the Czech Republic only had 1 VRA in operation that consumed an annual average of 5000 m^3 CNG.

Also for Germany, there are discrepancies between the information gathered. According to a manufacturer, 800 VRAs have been sold to Germany, and 60% of those are currently being serviced. Germany plans to expand its infrastructure to 1,000 public CNG fuelling stations, which could result in 150000-300000 vehicles on the roads.

Evaluation of the existing market. Comments on marketing aspects

Gas companies are the main users of VRAs, except in Japan where government fleets are the primary users. This is followed by government and public companies. Within these groups, the types of vehicles powered by natural gas are fleet vehicles, forklifts and ice swobbers. Household users were not identified at all.

Overall, the main opinion of VRA users is positive. All countries stated that the units are safe and simple to operate, easy to install, and convenient. The cost, both appliance and maintenance, is the main negative opinion.

In the Czech Republic, France and the United Kingdom, there are no regulations for designing, building and operating VRAs. In Japan, the installation and maintenance are regulated by the bylaw of gas utility law. Indoor refuelling has a unique set of safety precautions in France and the Netherlands, but that appears to be the only restriction. Cf. Section 3.2.

There are approximately 300 CNG vehicles on the road today in the Netherlands. This is a result of promotional activities currently implemented by the Dutch NGV-Holland platform. A recent study, printed in the February 2002 issue of NGV Worldwide, indicates that the number of CNG vehicles on the road today is: 30 in the Czech Republic; 4550 in France; 10000 in Germany; 8884 in Japan; 835 in Great Britain; about 500 in the Benelux and 66 in Croatia.

Competing energies

Natural gas competes with other fuels such as petrol, diesel-oil and LPG. However, considering the energy content of each fuel, natural gas is cheaper than petrol, diesel-oil and LPG. In France, the main hurdle in developing the NGV market today is the cost of diesel versus gasoline. On average, every second car is powered by diesel (55% of the market is diesel).

It appears that the respondents do not want to sacrifice mileage for convenience. Japan stated that the vehicle should have the same range as a gasoline powered vehicle. The United Kingdom and France would like to see the vehicle go 100 miles and 250 km, respectively. The responses are coloured by the predominance of commercial use among the respondents - in the NL a typical commuter vehicle travels approximately 80 km per day, making mileage a non-issue. In the event that a user must travel more than the average distance, a dual-fuel vehicle provides additional mileage. Germany added that customers do not want to refuel more often or have to wait a long time for refuelling. With a VRA at home, refuelling takes place overnight or during non-use times, which removes the inconvenience of going to a gas station.

The costs related to the gas appliance

All countries agreed that the actual cost of the appliance is the number one issue. The average cost of a unit is USD 5000. However, the VRA model that is referred to in the questionnaire is the FuelMaker FMQ-2.5. This model is primarily designed for larger loads with more than one vehicle, typical of a commercial application. The latest model available is designed for a commuter vehicle and has a targeted list price of USD 999.

France, Japan and the Netherlands added that the maintenance cost is also an issue. This cost, along with the high appliance cost, does not make it cost-effective for domestic applications. Some new models have a shorter service interval than current models, which are set at 4000 hours - which results in a 50% reduction in maintenance costs. The HRA is designed with additional features, based on experience, which will (according the manufacturer) make it maintenance free for the life of the unit.

Customers in France and the United Kingdom would most likely lease a VRA rather than purchase the unit. Whereas in Germany, it is thought that customers will neither lease, nor purchase a home VRA. With the current price of a VRA, a leasing option would be the most cost-effective for a home user. But with the apparition of cheaper units (USD 999 for FuelMaker's) HRA might makes leasing structure unnecessary.

There are incentives available to some degree in each country ranging from conversion grants (the United Kingdom) over a portion of the fuel tax being deductible (France) to two thirds of the appliance and installation costs being subsidised (Japan). It is apparent that governments are actively promoting the use of natural gas vehicles in all countries except the United Kingdom. The most obvious indication of commitment can be seen through the various grant and incentive programs that exist.

Potential market changes

To date, VRAs are primarily used in commercial applications, and gas companies are the main users of VRAs, except in Japan where government fleets are the primary users. This is followed by government and public companies. Respondents did not identify household users. However, the introduction of a home based VRA will open the door to the natural gas vehicle consumer market.

Action needed to develop the market

All countries, except for Germany, stated that they would appreciate the convenience of home fuelling. In the EU, the unit must be CE certified, meet the gas safety regulation and the draft EU standard before it is accepted. It seems that the new product to be introduced will meet those requirements.

The most important action is to combine with the OEM NGV dealers over the countries to offer a VRA appliance as an extra feature with the car like radio or air-conditioning.

5. ACTIONS NEEDED AND RECOMMENDATIONS

In this section we are looking at the following aspects for each area (heating, hot water, etc.):

- Actions needed to develop the market
- The most promising technologies
- Hurdles
- Way to eliminate barriers
- Key success factors

5.1 Heating & Hot Water

<u>Heating</u>

5.1.1 Actions needed to develop the market

The boiler technology as of today might suffer in the competition against electric heat pumps that can provide heat a reasonable price as well as cooling. In the future, the development of **combined heat and cooling (and perhaps power)** systems would probably be the most appropriate answer from the gas industry.

Also the price of appliances shall be adapted to the different market segments. For a customer with a low heat demand, an expensive sophisticated boiler will have a too long payback time. Therefore, there is still room on the market for **less expensive boilers** that might not have the optimum efficiency. The gas industry must be attentive to and work against standardisation or labelling systems that might eliminate those from the market.
Also for the developing countries, there is a need for cheap appliances to compete with cheap technologies and fuels.

Solutions for achieving **low installation costs** shall also be worked out. Flexible piping is among the solutions allowing the installer to work quickly and thus decrease the installation costs.

The maintenance policy for boilers shall be carefully considered. Some studies have demonstrated that regular maintenance was not necessarily effective in all cases and there might be some room to optimise the procedure and frequency of maintenance in order to reduce costs. In the future, when entering the age of the intelligent house at reasonable costs, there will be a possibility of **tele-maintenance**. The controls will not be necessary, but the boiler will be equipped with sensors able to give a pre-diagnosis of the problem. Such a system has already been field tested in France.

Finally, the repair of boilers is also an area where cost can be decreased thanks to new technology. In the UK, the installer may use an **intelligent diagnostic system** to quickly detect the failure on a boiler and so have reduced maintenance/reparation costs.

With regard to the present problems, a system where the consumer does not own his boiler but **rents it from the gas utility** could answer to some of the questions above. As a matter of fact, the gas utilities would probably be able to reduce the installation price if they develop some standard technical solution and if the installation and servicing purpose is not to make a business, but a way to sell gas. The boiler cost and installation would be covered by a kind of renting fee. Such a system is already used in a few countries. The system is used in the Netherlands for different types of equipment and services. For instance, the energy distribution company Eneco has a separate firm, Energielease (www.energielease.nl), where the customer can lease all sorts of equipment (boilers, hot water equipment, etc.). There is a two-page contract and a list of prices for each type of equipment. The equipment is owned and maintained by the lease company. The customer pays for the installation cost and a monthly fee.

Considering the above together with the analysis made we can conclude the following action points needed to develop or maintain/consolidate the position of natural gas for heating purposes:

a) Improving the quality of the appliances on the market
- To decrease the electric consumption
- To lower NO_x without additional costs
- To integrate safety functions in the boiler technology
- To improve the reliability and make the maintenance cheaper

b) Solving the remaining installation problems
- To optimise the choice of boiler adapted to the installation
- To evacuate condensation water from a condensing boiler
- To decrease the installation and maintenance costs

c) Better information and promotion of the gas technologies
- To show the authorities that new developments in gas appliances (like condensing boilers, micro CHP and gas driven heat pumps) offer a good opportunity for less CO_2 emissions.
- To make a stronger promotion, especially for state-of-the-art central heating boilers; more effective advisory service and consumer education
- To promote the installer education
- To organise the consumer information (interactive tools on the Internet)
- To improve the matching boiler installation

d) Favouring the development of the new technologies
- To develop low-power gas heat pump and micro CHP

Note that the gas industry needs to co-operate with the boiler manufacturers, the installers and the authorities in order to organise the actions above. It is not the primary objective of the gas industry to develop new boiler technologies, but the gas industry shall *try to promote and stimulate the actions above and participate when relevant and possible.*

Research might be needed to achieve the results above. For some of the actions, the tools needed have already been developed. It is more a question of utilizing the tools. For the matching boiler installation and installer education, tools like BOILSIM can be used. The same applies for consumer information and interactive tools on the Internet.

Development and research are still needed to promote CHP and heat pumps. At a certain stage, standardisation will also be needed, and marketing shall help the dissemination of the technology.

5.1.2 What are the main hurdles for the development of the products (to obtain satisfactory products)?

A number **of technical specific challenges** have been mentioned by the respondents (e.g. material for the TVP cells), but the main non-technical hurdles are the following:

1) Appliance costs

As already mentioned before, the cost of the appliance is in some case too high in order that NG can compete against electricity.

2) Low consumer awareness

Very often consumers pay less attention to the choice of a new boiler (that is most of the time installed in an out-of-sight place) compared to the choice of a new refrigerator (that is installed in a more visible place).

Some commonly used methods of promoting educational and advisory programs for gas consumers and installers are the media channels, civil service (governmental offices), or municipal council offices. The gas industry, in general, is already very active and we shall continue to produce information on gas and gas products. With the Internet it is now also possible to offer a direct and flexible information tool (see for example http://www.boilerinfo.org)

Another type of consumer education is the organization of seminars, lectures, and public meetings which are aimed at providing information on all the advantages of using gas as an energy source for cooking, heating, hot water and cooling. It is also possible to promote the use of state-of-the-art gas appliances, especially central heating boilers, and to market the gas company's services and products. This should include methods of using gas most effectively, and ways of reducing thermal losses in residential installations.

3) New energy market situation

Another point is the new situation in several parts of the world: the **energy market liberalisation**. The gas industry has in the past been very supportive to new product developments and has been very actively engaged in research and development of new appliances and system, together with manufactures. But the new situation has resulted in a gas industry that is more reluctant to do further work in the development phase of appliances leaving this task to the manufacturers. They are also confronted with a lot of changes and mergers, especially in the EU after the "opening of the market". The manufacturers have grouped and have become bigger and are not necessarily dealing with one type of product. As a result, they sell gas, fuel oil or electric appliances and where a gas boiler manufacturer was formerly developing and promoting gas appliances; the marketing strategy of the new manufacturers could be oriented towards non-gas products. Therefore, we do not know if the manufacturers will still put the same effort into the development of gas appliances as they did before. It is thus important to keep a strong market demand: the gas consumer shall be satisfied with the product "gas" and insist on keeping it in the house.

Additional remark for hot water

For hot water the future seems to be a combination of heating and possibly solar hybrid systems. Therefore, we do not expect any significant development of technologies that are based on the production of hot water with the water heater technology we know today. One of the **challenges** will be control of the comfort of the instantaneous appliances, so we expect a significant development of electronics able to take care of the present problems.

5.2 Cooking

5.2.1 Actions needed to develop the market

a) Domestic

The most important topics related to natural gas cooking appliances are **design, ease of cleaning and modernity** (prior to operating costs, which explains why natural gas users switch to electric cooking appliances).

Appliance and maintenance costs are not considered to be a problem, but the costs of indoor gas installations and fitting of the appliance are a problem. In any case, development of gas appliances with good operation ability, design and functions should be promoted to decrease appliance costs and to keep competitiveness against electric appliances. Those efforts, including streamlining the marketing process, should be done in co-operation with manufactures and marketing companies.

Basically, state-of-the-art gas cookers with ceramic plate and radiant burners are still not widely available on every market. To increase the gas market, it is necessary to introduce more widely this technology (and develop closed extractor hood system). At the moment, the main competing fuel is electric energy used in electric cookers with ceramic plate and "air-heating" electric oven, and also IH cooking stoves. Because gas cookers with ceramic plate and radiant burners are not sufficiently present on the market at the desired level (like their electric counterpart), electric energy is increasing its market share, while the share of gas is decreasing.

Efforts should be made to provide more information to the potential consumers (especially regarding safety of the use of gas appliances). In a number of cases, consumers do not want to switch to LPG (if there is no natural gas connection) or to natural gas, because they are "afraid of gas". Therefore, marketing and promotion activities for modern gas appliances (especially regarding safety) as well as co-operation between the gas industry and the producers are needed.

The **most promising technologies** in this field are:
- Gas cookers with ceramic plate and radiant burners
- Electronics for control of the gas cooking appliances
- More aesthetic high-efficiency burners
- Easy-to-use gas appliances by information network (Instruction programs to download from the Internet)

The **main hurdles** to obtain satisfactory products are:
- National markets are often too small
- The cost of appliances and price of gas components: solenoid, safety, electronic parts
- Strong position of electric cookers with ceramic plate and "air-heating" electric oven (especially in new households)
- IAQ issues in general

To **eliminate these barriers** it is necessary to:
- Co-operate with manufacturers to improve the design and features of gas cooking appliances
- Set up the needed research to achieve the above goal
- Work further with education and information to consumers and installers

The **key success factors** are:
- To identify expectations of the market
- To use prototypes to test the market

Key factors as those presented above are necessary for any new product on the market. More specifically, for natural gas cooking appliances, more important factors are:
- The co-operation within the gas industry and with other industries, information network including electric appliances
- A higher level of promotion and more effective marketing support of state-of-the-art gas cookers

The main advantages obtained for the user are improvements in the operation ability, but consumers still expect gas cooking appliances to be: more aesthetic, safer, easier to clean and more functional

<u>b) Commercial</u>

The recommendations for actions in the commercial sector that would be needed to solve the problems and to develop the market are similar to the ones presented in the domestic sector:
- Better promotion of natural gas
- Better design and easier cleaning
- Introduction of micro-computer control
- Decrease of heat radiation from the appliance and central flue duct system
- Considering IAQ issues

The most promising new technologies in this field are connected with improvements of comfort level in the kitchen and operation ability (by introduction of micro-computer control).

One of the main hurdles to obtain satisfactory products is the successful development of highly efficient appliances with low heat radiation and development of efficient flue system optimized for various kitchen sizes and layouts.

5.3 Cooling

On mature markets like Japan or the USA, where the air-conditioning saturation rate is high, the improvement of gas air-conditioners efficiency and size are key issues to face electric competition.

In countries where the market is growing, it is important to diversify the availability of appliances, not only in proposing appliances with different functions, performances and prices, but also appliances with a wide power range. For example, this is a clear need in France for the residential sector.

In countries where gas air-conditioning is just or not yet started, (e.g. NL) the need is to create a market and to inform consumers about the existence of alternatives to electric appliances.

In terms of costs, the priority remains the front cost of the gas air-conditioners that needs to be reduced in order to be competitive with electric appliances. As Japan reminds, this is especially true for residential applications where the initial cost of appliances is much higher than the one of electric appliances, so that financial support from the government and/or gas companies is required in order to decrease summer electric peak consumption (this is not the case in France, where electric peak consumption occurs during winter time).

As a conclusion, let’s underline the main points:

Both absorption machines and gas engine driven heat pumps are promising technologies in gas air-conditioning on mature as well as new markets. Thus, today, the French gas company successfully supports absorption technology for the commercial market, which steeply increased every year since 1996. In Japan, absorption technology also has a good market share on the commercial market, while gas engine driven heat pumps dominate for residential and light commercial applications.

The **main hurdles** for the development of the products are different depending on the power range considered. For residential applications, the efforts must concentrate on having cost-effective products in comparison with the main competitor, which is electricity. The Japanese way to remove this barrier has notably been financial and promotion support from the government and gas companies. For commercial applications, the next challenge is to redesign the machines to allow an always better efficiency in order to fit the Kyoto protocol and to be competitive. Overcoming theses hurdles is the main key success factor for the development of the gas cooling market.

Indeed, **gas air-conditioning products** have great advantages over the competition. Regarding absorption technology, the main ones are:

- **Competitive global costs**
  - Limited investment costs, indoor installation cost reduction (existing boiler room) and investment cost reduction: a unique machine for cooling/heating
  - Reduced operation costs thanks to annual operation costs (heating + cooling) being lower than electric solutions (good energy cost/efficiency ratio)
  - Lower maintenance (few moving parts, boiler-like maintenance)

- **Environment-friendly appliances**
  - Use of refrigerant/absorbent without significant impact on global warming and ozone depletion
  - Low NOx emissions
  - Low noise levels

- **A Mature Technology**

- A great reliability thanks to a fifty years international experience of absorption technology
  - Long lifetime thanks to few moving parts: higher life duration than a compression machine
  - Flexibility: power modulation, remote management, high-tech electronics

- **Easy Installation**
  - No specific room is needed: absorption units are generally installed in boiler rooms.

- **Easy Operation**
  - Absorption units and boilers can be managed and maintained by the same crew (after a short training period) for they are very similar.

Regarding **gas engine driven heat pumps**, the main advantages are:

- **Competitive global costs**
- **Limited investment costs thanks to electrical infrastructure cost reduction, and investment cost reduction: a unique machine for cooling/heating**
- **Reduced operation costs thanks to annual operation cost (heating + cooling) being lower than electric solutions (good energy cost/efficiency ratio)**
- **Environment-friendly appliances**
  - Use of new HFC refrigerants
  - Energy savings thanks to a good heating and cooling average efficiency
  - Flexibility, power modulation, remote management, high tech electronics

5.4 Home fuelling

The number one way to drive the development of the market is to lower the price of the VRA making it cost-effective for home use. In addition to lowering the cost of the actual unit, it is critical that the maintenance be less costly and more efficient. And finally, with the help of active government sponsorship, home fuelling might be commonplace. The availability of a home based unit will provide the necessary infrastructure to drive the growth of the natural gas vehicle market, making natural gas a mainstream fuel.

As reported by the respondents, the existing refuelling technology, which is designed for commercial applications, is safe, convenient, and accepted by users. In order to be accepted for home use, the unit would have to be priced appropriately and be subject to only minor maintenance costs. It is clear that there is substantial market potential for natural gas home refuelling. Concerns regarding price and maintenance will be addressed with the recent development mentioned in this report.

Japan indicated that the most promising technology is a compact, high-efficiency, low-cost VRA. Increasing the life span of the unit will be the main development hurdle. Japan suggests that the structure and materials such as the cylinders, pistons and guide rings be optimized in order to overcome this hurdle. The Netherlands commented that price, energy and maintenance are the main hurdles, and further commented that the compressor must be a financial attractive alternative for diesel drivers in urban areas.

Japan stated that the main advantages of home fuelling should not be evaluated based on the appliance, but rather on the vehicles. Heavily populated areas should benefit from a decrease in pollution with the use of natural gas vehicles. Home fuelling must be feasible for urban drivers.

6. SCENARIO FOR IMPLEMENTATION OF HEATING TECHNOLOGY IN THE LONG TERM

In the previous sections, a number of actions needed to achieve the replacement of electric or fuel oil appliances with gas appliances were discussed. In this section, the theoretical potential development for gas appliances and the impact of this development are presented

The data gathered in the questionnaire and additional data from literature have been used to perform some calculations to project various scenarios for the future use of gas. The work carried out was difficult as it required a precise description of the world market, and because we have not always got the information needed, we have, therefore, made a number of assumptions that we have not been able to check for reason of time and resources. As mentioned earlier in the report, it has not been possible in the framework of this study to double check the information that was given in the questionnaire, nor to carry out detailed investigations for the determination of the data that was missing. Therefore, there is a given uncertainty in the global result presented in this report. The authors of this report suggest therefore to elaborate further on the present work in the next triennium.

The projection of the future use of gas is limited to the gas used for heating purpose with CH boilers or air heaters, as it is more than 90% of the gas consumption in the domestic and commercial sector.

The results obtained are showing some trends and have the merit to identify where the key points are. The future work should concentrate on the verification of the data, the hypothesis and the development of the calculations including also the district heating technology.

6.1 Calculation criteria

In order to obtain a realistic view of the situation, we have corrected some data with information from other sources that seemed to be more realistic than the data given as answer to the questionnaire. The main data changed are the number of installed boilers in France (5 million) and Italy (8 million). The new data were taken from the literature and Internet research. [Some of the sources are given in the reference at the end of the document]

For the calculations of the future use of gas, we need data describing the market profile, the share of gas for the applications considered and the fraction of condensing boilers etc. In the projection work it has not been possible to find in the questionnaire the detailed market data from all countries. Therefore, the projection will be given as an average value of the future use of natural gas in the following countries:

- AUSTRALIA
- BELGIUM
- CANADA
- DENMARK
- FRANCE
- GERMANY
- ITALY
- NETHERLANDS
- SPAIN
- UK
- USA

The actual cumulated use of gas for heating purposes given for the year 2000 (for CH boilers and air heaters) in the countries above is about 1,900 TWh per year, where it is 2,200 TWh per year for all the countries covered by the questionnaire. Therefore, the gas market that is covered by the questionnaire, but not included in the projection, is only about 10%. The questionnaire covered about 80% of the heat markets of the world (see section 2.3).

To complete the above view we can add that the actual share of gas (with CH boilers and air heaters) is about 50% of the heating market - all energies considered (estimated to 3,800 TWh), see Table 4.

	TWh/year	% of total
Gas	1,900	51.2%
Fuel oil	630	16.8%
Electricity	720	19.1%
District heating, renewable etc..	430	11.4%
Other not identified	59	1.6%
Total	3,800	100.0%

Table 4: Energy consumption for heating purposes

The above table is calculated from the data we have obtained from the questionnaires on the market profile (indicating the share of each type of energy for heating for each country considered - list of 6.1). The individual results obtained country by country are integrated to obtain the result above. Because the source of information is different from the data given in the section 2.3 (Fig. 1) and because the countries covered are not the same, the data of the table above might not always fit very well with the one of Fig. 1. This illustrates, again, the need to cross check the data in the future and work further for a more accurate estimate.

6.2 The potential development of the gas market for heating

6.2.1 Saturation of the market

There is a natural limit to the development of the natural gas market, namely the grid network. Remote areas far from the existing grid or with only a small population will never be connected and will have to use electricity, fuel oil, LPG, renewables etc.

The saturation rate of the market is defined as the ratio between the future gas consumption (that can be expected) and the total future energy consumption (that includes all energy sources). For example when a saturation rate of 70% is given, we mean that 30% of the energy used for heating will be from other energy sources than gas, and that for various reasons the gas share will not be able to grow over this limit of 70%.

The saturation of the market is depending on the country infrastructure, population, geography, cost of developing the network etc. As a result, the saturation of the market can be very different from country to country, In the Netherlands, a small and densely populated country, the saturation level is about 95%. Whereas the UK, where the network cannot be as dense as in the Netherlands, has a saturation rate about **70%.** We assume that this last figure is probably a good estimate of the saturation level that can be expected as a worldwide average. We will, therefore, use it to calculate the potential expansion of the gas market.

6.2.2 The market profile

The fraction of market covered

- by gas
- by fuel oil
- by el
- by other

has been given (or found) for the countries in the table below.

Fraction of market covered	AUST-RALIA	BEL-GIUM	CANA-DA	DEN-MARK	FRANCE	GER-MANY	ITALY	NETHE RLAND S	SPAIN	UK	USA commer cial
by gas (%)	33	35.4	50	17	40	35	61	94	55	70	52.6
by fuel oil (%)	0	44	19	26.8	31	34	27	1.5	30	10	11.6
by el (%)	28	7	16	12	16	6	1	0	0	19	26.2
by other (%)	14	0	12	0	0	0	0	0	0	0	0

Table 5: Market profile

6.2.3 The theoretical expansion fraction

The theoretical expansion fraction is simply calculated as the difference between the potential market size at saturation and the actual market fraction.

The result in percent is as follows:

Country	Potential (%)
AUSTRALIA	37
BELGIUM	35
CANADA	20
DENMARK	53
FRANCE	30
GERMANY	35
ITALY	9
NETHERLANDS	0
SPAIN	15
UK	0
USA	17

Table 6: Theoretical expansion fraction

For the UK and the Netherlands, the markets are considered saturated and therefore the expansion is nil.

6.2.4 The theoretical potential expansion

The expansion potential is resulting from the percentage in the table above multiplied by the actual energy consumption in the given country. The calculation says the total overall potential is about **700 TWh/year**. This represents 38% of the actual gas market of today. From the data given in the questionnaire etc. this is considered to be the maximum theoretical potential expansion of the gas market by replacing electrical and fuel oil appliances.

By assuming that the increase of gas market is taking 50% of the heat produced by electricity today and 50% of the heat produced by fuel oil, the new market energy profile for heating is more or less as shown in the table below (please note again that this is a projection of the MAXIMUM estimated development for gas).

Energy	TWh/year	Percentage of total
Gas	2,650	69.5%
Fuel oil	320	8.3%
Electricity	360	9.4%
Other	59	1.6%
District heating	430	11.2%
Total	**3,800**	100.0%

Table 7: Theoretical future market share if NG reaches the maximum potential expansion

Apart from replacing electrical and fuel oil appliances, the gas market is also expected to increase by replacement of the older coal or fuel oil fuelled district heating by gas, and by building of new infrastructure (network etc) in China and in other rapidly developing countries (see also section 2.6)

6.3 The environmental effect of the gas market development

The data available from the questionnaire allow a number of calculations that can be used to estimate the impact of various scenarios on energy savings and environmental effects.

The future potential energy savings will be calculated by estimating the energy savings from the following replacement policies:

- the replacement of older gas boilers by new (traditional) boilers
- the replacement of older gas boilers by condensing boilers
- the replacement of fuel oil and electric heating by new (traditional) gas appliances
- the replacement of fuel oil and electric heating by new condensing gas appliances

6.3.1 Energy efficiency trends

Basic data and hypotheses have been found to be used for the evaluation of the energy savings. Mainly the questionnaire answers and "*Energy efficiency trends in the natural gas industry AGA 1991" [2] have been used.*

For simplification of the calculation we have ended up with Table 8 that indicates the end-use efficiencies (including the primary energy conversion efficiency in case of electricity) for different technologies. In order not to favour gas, the top end of the estimate of the efficiency (found in the literature e.g. [2]) of other energies has been used.

	Total net efficiency (in %)
Natural gas older than 10 years	82
Natural gas new traditional	90
Natural gas new condensing	100
Fuel oil older than 10 years	78
Fuel oil new	90
El. heat pump	75
Elec. resistance	35

Table 8: End-use efficiencies [2]

6.3.2 Replacement of older gas boilers by new gas boilers

The replacement of old appliances will occur whatever action is done. So the first projection that can be done is: **what will be the future gas consumption for heating if the market share and number of customers of gas is kept constant?**

In the future, the gas consumption will decrease due to the improved efficiency of the new appliances. In order to get a figure for the savings, an idea of the park of appliance age profile is needed. This question is far too detailed for the investigation that was carried out by the questionnaire. **Research from other sources of information shows, that a rough figure of 50% seems quite fair for the percentage of consumption of appliances older than 10 years**. 10 to 15 years is also in many countries considered to be the average life time of a gas boiler, so the hypothesis also seems quite reasonable in that respect.

To simplify the calculations only gas boilers are considered (not air heaters).

According to Table 8, replacement of an old gas boiler (>10 years) will give an average saving of 8% in case of replacement by a new traditional appliance, or 18% in case of replacement with a condensing one.

For the calculation of the potential energy saving by replacing the older park of boilers, it is assumed that the replacement rate is 10% pr. year and that the existing older park of boilers has a 82% net efficiency.

If the replacement rate is 10% of the older boilers per year, the yearly reduction will be:

- **8 TWh/year case of integral replacement with new traditional boilers**
- **17 TWh/year in case of integral replacement with new condensing boilers**

After 10 years, when the oldest 50% of the boilers are replaced, the actual gas consumption of 1,900 TWh/year will be reduced by:

- **80 TWh/year in case of integral replacement with new traditional boilers (8% less on 50% of the park)**
- **170 TWh in case of integral replacement with new condensing boilers (18% less on 50% of the park)**

Note again that this will occur whatever action is taken, as the appliances are to be replaced at some point. The question is how fast this will happen and what will be the share of the domestic technology.

The saving shows the importance of increasing the market share of gas if the sales shall be maintained at a constant level. Increasing the share of gas will also generate energy savings for the whole society. This will be described below.

6.3.3 Replacement of fuel oil and electric heating by new gas boilers

It was calculated above that if the gas market reached saturation on all large markets there would be an **increase in the use of gas by about 700 TWh/year**. We have used the hypothesis that that this **increase in gas market is taking 50% of the heat produced by electricity today and 50% of the heat produced by fuel oil**.

From Table 7 and 8, the energy savings by the replacement of oil or electricity can be calculated. The savings will, of course, depend on the gas technology used.

- **Replacing old fuel oil technology with new traditional or condensing gas technology results in savings of 12% and 22%, respectively (see Table 8).**
- **Replacing electric heating (this does not concern electric heat pumps) with new traditional or condensing gas heating results in savings of 47% and 57%, respectively.**

The hypothesis used of gas taking 50% of the electricity and fuel oil share will result in the following savings:
210 TWh/year if the traditional gas technology is used
270 TWh/year if the condensing gas technology is used

Note that the above figures are obtained once the 50% of the electricity and fuel oil market are replaced by gas. During the period needed to achieve this replacement rate, the savings are of course lower.

6.3.4 Overall maximum energy savings

When both older gas technology is replaced and electricity and oil share are taken over with the above hypothesis, we end up with the maximum energy savings as follows:

80 TWh/year + 210 TWh/year ***= 290 TWh/year*** *if the traditional gas technology is used*
170 TWh/year +270 TWh/year ***= 440 TWh/year*** *if the condensing gas technology is used*

Compared to the ***3800 TWh/year*** total energy used for heating purposes (in the countries considered in section 6.1) the gas can offer substantial savings.

6.3.5 Environmental impact

Apart from the considerable CO_2 reduction caused by the energy saving when replacing electricity and fuel oil by natural gas, a reduction in CO and NO_x can also be expected.

There are large discrepancies in the emissions of domestic boilers. When CO_2 emissions are directly linked to the energy efficiency, the emissions of CO and NO_x are mainly depending on the burner technology.

Considering the very low level of emissions (<10 mg/kWh both for CO and NO_x) for some of the new boilers on the market, and the actual average emissions (>100 mg/kWh) the potential improvements are rather large. However, the technology used for the burners is strongly influencing the emissions; it is, therefore, difficult to make any calculations without having a very precise idea of the burner technologies that need to be compared.

Unburned hydrocarbon or pollutants as formaldehyde might very well be the next focus on gas boilers. We have not, however, gathered data on those pollutants (suggestion for the next triennium).

7. OVERALL EXTENDED CONCLUSION

The development of the gas market is today one of the most effective solutions for saving energy and reducing the CO_2 emission. Today's general trend is an increase of the domestic and commercial gas market, even if some appliances are declining (water heaters increasingly replaced by combi-boilers).

Despite the already good position of natural gas, there are still some opportunities to expand, but different actions are needed, depending on the different markets considered.

7.1 The world situation

Because of its size (almost half of the rest of the world) the US market has a considerable potential impact on energy savings and CO_2 emissions. Not that much attention has been given to energy for heating in the USA, where transport is the main "domestic" energy consumer. So, people are more aware of using energy for transport than for heating. So already **today** there is a strong potential of saving by replacing older furnaces [= air heaters] by new ones or by introducing more efficient central heating equipment. The technology is ready - it is a question of motivating the market.

The European market of **tomorrow**: The EU countries are now a very large and (in principle) single market. With the recent extension and when the eastern countries join the market, this market will be the largest in the world with about 700 million inhabitants who need heating, cooling, cooking etc. This character of a unique market will be stronger as the standards and requirements will be the same for the whole market. In this respect, the effort of the EU Commission towards energy saving and emission reduction has resulted in the availability of high-performance appliances on the market of today. The Commission's plans will reinforce this policy, and it seems that we will go towards further improvement through mandatory requirements (EU directives, standards) or labelling systems.

Heating is indeed the largest energy consumer in the domestic sector for many European countries and, therefore, there will be a strong focus on boilers as a mean to fulfil the Kyoto agreements. In the past 25 years, Western Europe has quickly converted from coal to oil and gas. Eastern Europe is following this example. The demand in Central and Eastern Europe is for more modern, safer, more efficient, and more comfortable gas and oil technology. This could be new district heating systems based on gas, but also individual appliances. Efforts need to be done to secure gas for the new or replacement markets in Eastern European.

The **emerging** market in China: In the **future**, the new Chinese market will be considerable, whereas the appliances for the market are perhaps not quite up-to-date. Therefore, there is a huge potential for energy savings and CO_2 reduction simply by having the newest technology available in this market, Today's top appliances available have both high efficiency and low emissions. The question is to make them available at an affordable price.

7.2 The present technologies and need for new ones

For CH boilers, **the technology has reached maturity** (high efficiency, low emissions). The present state-of-the-art makes the future improvement of the performances of appliances expensive in regard to the potential gain still achievable. The developments on condensing appliances and low-temperature systems have enabled the technology to reach a point that is today close to the maximum possible performances in terms of efficiency and to a certain extent to emissions as well. However, the best technology is also more expensive and some markets are dominated by cheaper boilers that do not have the maximum possible performances. On the other hand, the "cheap" technology is also needed to compete with electricity and the most expensive boilers are not necessarily the best financial choice for consumers with a low heat demand.

Still, there are possibilities to realise savings by a better match between installation and boiler. So, efforts need to be made - not in the direction of technology improvement, but in the education of installers and the development of design tools. Furthermore, there are large saving potentials in the replacement of older technologies with the newest available. For some of the markets, the replacement of low-efficient boiler would also be the opportunity to have safer appliances installed. In the future, the probable rise in the energy costs, and the incentives to use renewables will make the **combination gas with renewables** (and especially solar) probably more attractive than it is today.

The market for central heating systems with air is almost a North American exclusivity, where warm-air heating dominates with 93%. We do not know much about the state-of-the-art of this technology and it is not clear if the latest progress achieved on the European boiler market has also been achieved on the furnace market. This is one of the points that could be treated in detail during the next triennium of the IGU.

In general, there is a trend of lowering the heat demand, and as a result a need for smaller units has arisen. In many cases a boiler of 10 kW or even less would suffice to cover the heat demand in the domestic sector. This power is often not enough to cover the sanitary hot water demand

Design aspects are becoming more and more important for domestic applications. The appliances need to look good and for some markets, like Japan, the size is a determining parameter.

One characteristic of the future market (or already existing US market) is the **development of air conditioning**. The electric heat pumps have a strong position for providing both heat and cooling. In general, electricity has the advantage of the cheaper installation cost, but in most countries the price of electricity kWh is much larger than the gas kWh. The trend of lowering the heat demand is clearly an advantage for the electricity. The payback time of a gas installation for very low heat demand is too long. In that respect, electricity is becoming competitive on the market of heat pumps for the production of heat and cooling. This is not yet a challenge in all the markets, but if it is confirmed, the boiler technology of today is not adapted to compete against such system.

In the future, the development of **combined heat and cooling and power** systems would probably be the most appropriate answer from the gas industry. Therefore, technologies as **CHP and fuel cells** are probably the future for natural gas cooling/heating. The technology will also need to be adapted to the future fuel: **hydrogen**.

As regards **cooking** with gas, the **indoor air quality** will increasingly become an issue in the future. There is certainly a challenge there.

The best solution is probably to evacuate the combustion product out of the kitchen. Adapted and cheap solutions are to be developed. This is indeed a general need for the gas installation: having lower installation cost through new technologies.

Today, consumers hesitate to purchase **natural gas vehicles** due to the lack of a viable fuelling infrastructure. Similarly, auto manufacturers hesitate to produce natural gas vehicles due to the lack of demand. Current products, such as the FuelMaker, can be used for residential fuelling, however; it is not an attractive purchase due to the associated costs. There is a huge potential to expand the natural gas market through the success and ultimate growth of the consumer natural gas vehicle (NGV) market and the NGV refuelling market. With affordable **home fuelling**, consumers will create the demand for natural gas vehicles. This demand could be an ideal opportunity for gas utilities to increase their market share.

7.3 Development of heating technology in long term

In the future, it is expected that there will be an expansion of the gas market for heating and we have made a number of calculations to see the impact of this expansion. Other applications (e.g. cooling) will certainly grow, but at this stage it is difficult to make any prevision of what the future will be, therefore we only worked on the heating function.

It is estimated that the overall saturation rate of the market for central heating by natural gas is about 70%. The limit is a financial limit for the extent of the grid network for natural gas. Using 70% saturation rate and assuming that the new market is taking 50% of the heat produced by electricity today and 50% if the heat produced by fuel oil, the maximum expansion is estimated to be **700 TWh/year**. This represents 38% of the actual gas market for heat production today.

The expansion of the gas market by replacing electricity and fuel oil generates energy savings for the whole society. Additionally, there will be a reduction in CO and NO_x.

Apart from the energy savings by expansion of the gas market, considerable energy savings by replacement of older gas boilers with new ones with high-efficient boilers is expected. The total maximum energy saving in the long term (10 years) by expansion of the gas market and replacement of old gas boilers is estimated to be:

290 TWh/year if the new boilers that are installed are traditional gas boilers
440 TWh/year if the new boilers that are installed are condensing gas boilers

The above figures only deal with heating. In the same time, new gas applications as cooling or home fuelling can have a considerable impact on tomorrow's energy world.

There is no doubt that gas has clear advantages in comparison with the competing energies. All indicators show that the gas market will expand in the sector of domestic and commercial use. The magnitude of this expansion will greatly depend on the capability of the gas industry to bring an answer to the technical challenges presented in this report.

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IGU SG6.1 members who have answered the questionnaire

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ANNEX 1
VARIATION IN GAS QUALITY

By Heiko Zingrefe, HeinGas Hamburger Gaswerke A.G.

INDEX

VARIATION IN GAS QUALITY

0. Abstract

In the past the problem of different gas qualities almost seemed to be a special German situation. This has changed a little bit. It may become a European problem, and also China expects problems with different gas qualities in the future.

How to overcome these problems was answered rather generally in the questionnaire. Apart from the information given at WOC 2000 in Nice no new developments for gas sensors or self-adapting appliances was reported. Answers were received from thirteen countries and summarized below.

1. Introduction

The objective of this part of the report is to update the map of variations, differences and similarities of distributed gas in interconnected as well as isolated pipeline systems listed in the report "Variable Gas Quality in Domestic and Commercial Use" presented at the WGC in Nice in 2000.

Information was contributed by

- China	- Portugal
- Czech Republic	- Slovakia
- Denmark	- Spain
- France	- Thailand
- Germany	- United Kingdom
- Japan	- USA
- Netherlands	

Table A.1.1: Contributors

Members of WOC 6 were asked to give their answers to the following items in a questionnaire:
- Requirements for the gas quality and important specifications
- Data about distributed gas qualities
- Reasons for different gas qualities
- Existing problems
- Possibility of different gas qualities in the future
- Expected problems and reasons for it in the future
- Solutions to these problems

The summary of the answers is listed in a table given below.

2. Basic information on gas quality

Information about existing requirements of gas quality and the important specifications are given in the table below on item 1 and 1.1. From the replies it appears that most countries distribute more than one range of gas qualities. Several countries have limits for the sulphur content.

3. Reasons for different gas qualities

Different gas qualities may be caused by:
- supply from different sources/contractors
- changing loads moving the boundary between different qualities in a pipe system
- third-party access
- peak shaving by injection of
  - LPG/air mixtures or
  - gas from underground storages or
  - gas from sources outside the required gas quality

- feeding gas from sustainable energies into the distribution system
    - bio gas or
    - gas of land fills or
    - gas of sewage treatment plants or
    - other (e.g. bio mass or wood-distilling plants)

Many countries answered that gases with different gas qualities were distributed, caused by the supply of different sources.

In the future, more countries expect different gas qualities because of third-party access or LPG/air mixtures for peak shaving. Feeding gas from sustainable energies is not yet expected.
For details see the table below, item 2.

4. Existing or expected problems

Possible reasons for problems with appliances, engines, fuel cells etc. may refer to:
- wide range of Wobbe index
- wide range of calorific value
- wide range of flame velocity/methane number based on
    - content of CO_2
    - content of N_2
    - content of H_2
    - content of C_xH_y
- content of sulphur and ammonia (corrosion on condensing appliances, poisoning of catalysts, air polution)

The problems may be:
- too wide range of load
- too low convenience
- disruption of service by safety devices
- flame stability not sufficient
- too low efficiency
- too short life time of appliances
- too high corrosion
- knocking at engines

Only three countries (China, Denmark and Germany) expect problems with different gas qualities. This variation may cause a wider range of the Wobbe index of the distributed gases and a wider range of the flame velocity. Changing contents of CO_2 and H_2 (because of gases from sustainable energies) are only expected from Germany.
See the table below, item 4 and 5.0.

5. Solutions to the problems

There are several possibilities to solve the problems, such as:
- designing appliances for a wide range of Wobbe index, calorific value and acceptance of a
    - wider range of output
    - wider range of efficiency
    - higher content of pollutants in the flue gas, as CO and NO_X
    - shorter appliance life time
- treatment/blending of the distributed gas
- changing of gas pressures
- requirements of self-adapting appliances
- gas sensors detecting representative values of the gas at the customer for a treatment of the gas or adjusting the appliances
- knocking sensors for engines

The use of knocking sensors for engines is expected by several countries, only few countries are thinking about gas sensors.

Five countries mentioned that there are possibilities for solving the problems. The Netherlands will treat the gas to get a constant quality. Germany, Denmark and Spain will expect a wider range of output and only China and Germany prefer self-adapting appliances.

Details are given in the table below, item 5.1 – 6.3.

IGU WOC 6 SG 6.1 "Gas Appliances for the 21 st Century"

Questionnaire on Services

Item 1

Part 1 "Variation in Gas Quality" [desired values in MJ/m3 (1013.25 mbar, 0°C), mol-%]

	CHINA	CZECH REP.	DENMARK	FRANCE	GERMANY	JAPAN
1. Requirements for the gas quality	yes GB 17820 for transmission and distribution systems	yes for the distribution system	yes for the distribution system	yes for the transmission and distribution systems	yes for the distribution system	yes for the transmission and distribution systems
1.1 Specifications	yes national standards H_2S = 20 mg/m³ CO_2 < 3 % Q > 31.4 MJ/m³	yes national standards	yes legislation EN 437	yes decrees Industrial Department order of 16.09.1977 : W_S : H: 38.52 - 46.08 MJ/m³ L: 34.20 - 37.80 MJ/m³ Industr. Dep.order of 28.01.1981 : H_2S : avarage < 15 mg/m³ 8days-avarage < 7 mg/m³ total sulphur < 150 mg/m³	yes legislation (law about gauging) codes of practice (DVGW-Arbeitsblatt G 260) acts W_S : H: (43.2)[1]) - 46.1 - 56.5 MJ/m³ L: (36.0)[1]) - 37.8 - 46.8 MJ/m³ H_S : 30.2 - 47.2 MJ/m³ d : 0.55 - 0.75 (higher relative density is possible, if peak shaving with LPG/air) inlet pressure : 18 - 24 mbar O_2 : ≤ 3 % (only	yes legislation (Gas Utility Industry Law) acts W_S : 52.7 - 57.8 MJ/m³ H_S : 44 - 46 MJ/m³ flame velocity : 35 - 47 cm/sec inlet pressure : 1.0 - 2.5 kPa (10 - 25 mbar)

	NETHERLANDS	PORTUGAL	SLOVAKIA	SPAIN	THAILAND	UNITED KINGDOM	USA
1. Requirements for the gas quality	yes bound in contracts ./.	yes for the transmission and distribution systems	yes for the transmission and distribution systems	yes (governmentalrequirements) for the transmission and distribution systems	yes (by PTT - a state enter- prise, the Petroleum Authority of Thailand) ./.	yes for the transmission and distribution system	no
1.1 Specifications	yes decrees national standards W_S : 43.7 MJ/m³ (average) H_S : 35.01 MJ/m³ (av.) CH_4 : 81.3 % (av.)	yes decrees (Nr. 658/2000 dated 29th August) W_S : 52.09 MJ/m³ H_S : 42.0 MJ/m³ d : 0.6500	yes natinal standards H_S : 35.70 MJ/m³ CH_4 : ≥ 85 % C_2H_6 : ≤ 5 % C_xH_y : ≤ 7 % O_2 : ≤ 0.02 % inert gases : ≤ 7 % H_2O : dew point < -7 °C (at 40 bar) S_{total} : ≤ 100 mg/m³ H_2S : ≤ 7 mg/m³	yes decrees New Requirements: W_S : 48.25 - 57.81 MJ/m³ H_S : 36.93 - 47.74 MJ/m³ N_2 : < 7.5 % CO_2 : < 3.0 % H_2O : < 80 mg/m³ S_{total} : < 150 mg/m³	yes Gas Sales Agreement (GSA) H_S : 950 - 1150 btu/ft³ variation in 30 days ≤ 3% H_2O : ≤ 7 lb/MSCF H_2S : ≤ 100 grains/100 ft³	yes legislation [GasSafety(Management)Regulations] acts (Gas Act/Utilities Act) W_S : (≥ 49.1)[1]) - 49.8 - 54.2 - (55.8)[1]) MJ/m³ O_2 : ≤ 0.2 mol-% H_2 : ≤ 0.1 mol-% S_{total} : < 50 mg/m³ H_2S ≤ 5 mg/m³ ICF : < 0.48 -(1.49)[1]) SI : < 0.60 H_S : 38.9 - 44.6 MJ/m³ and dewpoints, N_2 - and CO_2 -levels (additional Entry Point Agreements between supplier and transporter)	./.

Item 2

IGU WOC 6 SG 6.1 "Gas Appliances for the 21st Century"

Questionnaire on Services

Part 1 "Variation in Gas Quality" [desired values in MJ/m^3 (1013.25 mbar, 0^{0}C), mol-%]

	CHINA	CZECH REP.	DENMARK	FRANCE	GERMANY	JAPAN
2. Gases with different qualities have been distributed by the same grid	yes	yes	no	yes	yes	no
2.1 Range of Wobbeindex	± 5 - 10 %	53.1 ± 0.5 MJ/m³	51.9 - 55.8 M	H: 48.24 - 56.52 MJ/m³ L: 42.48 - 46.48 MJ/m³	H: (43.2) - 46.1 - 56.5 MJ/m³ L: (36.0) - 37.8 - 46.8 MJ/m³	./.
2.2 Range of gross calorific value	4.2 MJ/m³	39.9 ± 0.3 MJ/m³	43.0 - 45.2 M	H: 38.52 - 46.08 MJ/m³	30.2 - 47.2	./.
2.3 Range of flame velocity	./.	./.	given by testgase	./.	given by test ga	./.
2.4 Range of variations of the gas composition	N_2 CO_2	N_2 : 0.6 - 1.0 % CO_2 : 0.04 - 0.15 %	./.	S_{total} < 150 mg/m³ H_2O: 46 mg/m³ at 80 bar or dew point < -5 ^{0}C	O_2 : 0 - 5 % depending on peak shaving by LPG/air as supple-mental gas	
2.5 Range of yellow tipping index	./.	./.	./.	./.	./	./.
2.6 Range of the methane number	./.	96.3 ± 1	./.	./.	./.	./.
2.7 Reasons for different gas qualities - supply from different sour-ces/contractors - changing loads moving the frontier between different qualities in a pipe system - third party access - peak shaving by gas from sustainable energies -other reasons	yes - - - -	yes - - - -	yes - - - -	yes - - - -	yes yes - yes (expected in the future) yes (underground storages filled in summer from	./.

	NETHERLANDS	PORTUGAL	SLOVAKIA	SPAIN	THAILAND	UNITED KINGDOM	USA
2. Gases with different qualities have been distributed by the same grid	yes no	no	no	yes	no	yes (only within accepted limits)	yes
2.1 Range of Wobbeindex	./.	./.	./.	~ 52.2 - 55	./.	~ 50.0 - 54.3 MJ/m^3	./.
2.2 Range of gross calorific value	./.	./.	./.	~ 39.3 - 43	./.	~ 39.0 - 44.7 MJ/m^3	~ 900 - 1100 btu/ft^3
2.3 Range of flame velocity	./.	./.	./.	./.	./.	./.	./.
2.4 Range of variations of the gas composition	./.	./.	./.	N_2 : 0.1 - 5.7 % CO_2 : 0.001 - 0.2 % H_2O : < 80 mg/m³ (n)	./.	N_2 : 0 - 5 % CO_2 : 0 - 3 % O_2 : 10 ppmv H_2 : 10 ppmv S : 5 - 10 ppmv H_2O : 10 - 30 ppmv	./.
2.5 Range of yellow tipping index	./.	./.	./.	./.	./.	./.	./.
2.6 Range of the methane number	./.	./.	./.	~ 64 -	./.	./.	./.
2.7 Reasons for different gas qualities - supply from different sour-ces/contractors - changing loads moving the frontier between different qualities in a pipe system - third party access - peak shaving by gas from sustainable energies -other reasons	./.	./.	./.	yes yes yes (expected in the future) - -	./.	./.	./.

Item 3, 4 and 5

IGU WOC 6 SG 6.1 "Gas Appliances for the 21st Century"

Questionnaire on Services

Part 1 "Variation in Gas Quality" [desired values in MJ/m3 (1013.25 mbar, 0°C), mol-%]

	CHINA	CZECH REP.	DENMARK	FRANCE	GERMANY	JAPAN
3. Different gas qualities expected in the future	yes	yes	yes	yes third party access	yes (same reasons as given to	no
4. Existing problems	yes	no	yes (appl. and engines)	no	yes	no
4.1 Problems with						
which appliances	yes		water heater			
which type of burner	not specified		space heater		pre-mixed	
Reasons:					burners	
4.1.1 Wide range of load	-		-			
4.1.2 Low convenience	-		-		-	
4.1.3 Disruption of service by					yes	
safety devices	yes	./.	-	./.		./.
4.1.4 Flame stability	yes		yes		yes	
4.1.5 Low efficiency	-		-		-	
4.1.6 High emissions	-		-		-	
4.1.7 Short life time of appl.	yes		-		yes	
4.1.8 Corrosion	yes		-		-	
4.1.9 Knocking	-		yes		-	
4.1.10 Generation of soot	yes		-		yes	
4.1.11 Miss-control of appl.	-		-		-	
4.1.12 Other	-		-		-	
					yes	
5. Expected problems by different gas qualities in the future	yes	no	yes	no	yes	no
5.1 Reasons for expected variations of the gas quality	./.	./.	./.	./.	same reasons as given to question 2.7	./.
5.2 Expected reasons for problems in the future	yes	./.		./.		./.
5.2.1 Wide range of Wobbeindex	yes		yes		yes	
5.2.2 Wide range of calorific value	yes		yes		-	
5.2.3 Wide range of flame velocity because of	yes					
CO2	./.				yes	
N2	./.		./.		-	
H2	./.				may be in the	
CxHy	./.				future	
					yes	
5.2.4 Pollution as	./.					
- sulphur			./.			
- ammonia					-	
					-	

	NETHERLANDS	PORTUGAL	SLOVAKIA	SPAIN	THAILAND	UNITED KINGDOM	USA
3. Different gas qualities expected in the future	no	no (expected after 2003 when LNG gains more share)	yes (diversifying of gas resources is expected)	yes (range of variation as	no	yes	yes (given data are not clear)
4. Existing problems	no	no	no	yes	no	yes	no
4.1 Problems with							
which appliances				burner systems			
which type of burner				(not specified)			
Reasons:						There are potential	
4.1.1 Wide range of load				-		problems	
4.1.2 Low convenience				-			
4.1.3 Disruption of service by						but actions are taken to	
safety devices	./.	./.	./.	-	./.	avoid	./.
4.1.4 Flame stability				-		them	
4.1.5 Low efficiency				-			
4.1.6 High emissions				-			
4.1.7 Short life time of appl.				-			
4.1.8 Corrosion				-			
4.1.9 Knocking				yes			
4.1.10 Generation of soot				-			
4.1.11 Miss-control of appl.				-			
4.1.12 Other				-			
5. Expected problems by different gas qualities in the future	no	no	./.	no	no	yes	no
5.1 Reasons for expected variations of the gas quality	./.	./.	./.	./.	./.	./.	./.
5.2 Expected reasons for problems in the future	./.	./.	./.	./.	./.	./.	./.
5.2.1 Wide range of Wobbeindex							
5.2.2 Wide range of calorific value							
5.2.3 Wide range of flame velocity because of							
CO2							
N2							
H2							
CxHy							
5.2.4 Pollution as							
- sulphur							
- ammonia							

Item 6

IGU WOC 6 SG 6.1 "Gas Appliances for the 21st Century"

Questionnaire on Services

Part 1 "Variation in Gas Quality" [desired values in MJ/m³ (1013.25 mbar, 0°C), mol-%]

	CHINA	CZECH REP.	DENMARK	FRANCE	GERMANY	JAPAN
6.1 Solving of the problems for gas appliances		./.		./.		./.
a. Treatment of the gas	-		-		-	
b. Changing of gas pressures	-		-		-	
c. Acceptance of	-					
- wide range of output/efficiency			yes		yes	
- higher content of emissions			-		yes	
- shorter life time of appl.			-		-	
d. Requirement of self adapting appliances	yes		-		yes	
e. Other feasibilities	-		-		-	
6.2 Solving of the problems for gas engines	./.	./.		./.		./.
a. Treatment of the gas			-		-	
b. Knocking sensors			yes		yes	
c.Gas sensors for						
- adjusting the engine			yes		yes	
- treatment of the gas			-		-	
- other			-		-	
6.3 Solving of the problems for fuel cells	./.	./.	./.	./.		./.
a. Treatment of the gas				yes : requirement of	-	
b. Other feasibilities				adapted appliances: improved gas treatment (additional fil-	yes (to be developed)	

	NETHERLANDS	PORTUGAL	SLOVAKIA	SPAIN	THAILAND	UNITED KINGDOM	USA
6.1 Solving of the problems for gas appliances		./.	no information available		./.		./.
a. Treatment of the gas	yes		./.	-		problems are avoided by appropriate actions	
b. Changing of gas pressures	-			-		yes	
c. Acceptance of							
- wide range of output/efficiency	-			yes		-	
- higher content of emissions	-			-		-	
- shorter life time of appl.	-			-		-	
d. Requirement of self adapting appliances	-			-		-	
e. Other feasibilities	-			-		-	
						-	
6.2 Solving of the problems for gas engines	./.		./.		./.		./.
a. Treatment of the gas		-		-		yes	
b. Knocking sensors		yes		yes		yes	
c.Gas sensors for						yes	
- adjusting the engine		-		yes		-	
- treatment of the gas		-		-		-	
- other		-		-		-	
6.3 Solving of the problems for fuel cells	./.	./.	./.	./.	./.		./.
a. Treatment of the gas						yes	
b. Other feasibilities						-	

ANNEX 2
NEW TECHNOLOGIES AND MATERIAL FOR GAS INSTALLATION
MAINTENANCE OF APPLIANCES

MAINTENANCE OF APPLIANCES

The maintenance cost is one of the overall problems for gas appliances and particularly boilers. One expert diagnosis system has been developed by Advantica in order to decrease the gas appliances servicing. The product is commercialised under the name of Xsol and allows a quicker diagnosis of the failure and thus lower maintenance costs.

NEW MATERIAL FOR THE INSTALLATIONS

Pipework systems with flexible pipes make the installation work easier and cheaper. The studies carried out around the world have demonstrated the safety and savings by using those materials such as Aluminium-Polyethylen. Savings up to 25% are given by some investigations [14].

ANNEX 3
EXAMPLE OF THE QUESTIONNAIRE

This is the questionnaire for heating. The questionnaires for other kinds of equipment and applications are similar to this one.

FORM - A 1

Equipment:	**Independent water heater (for hot water production only)**
Application:	**Sanitary hot water production.**

Part 1. Evaluation of the existing market. Data

Market		*Write the data in the cell below*	***COMMENTS***
Estimated natural gas units in operation (ref. year)	Number		
Estimated average gas consumption **for the application** (ref. year) (approx.)	kWh/yr.		
Estimated net increase in natural gas units per year	Number		
Estimated replacement per year	Number		

Efficiency and emissions		***Range From***	***Range to***	***Average***	***COMMENTS***
Net efficiency (*) of units older than 15 years	**Net** %				
Net efficiency (*) of new units	**Net** %				
NO_x emission for units older than 15 years	mg/kWh				
NO_x emission for new units	mg/kWh				

(*) For hot water production with a typical pattern (send details if available)

Replacement		*Write the data in the cell below*	*Indicate which energy is replaced by gas or replaces gas (delete when inappropriate)*	***COMMENTS***
of appliances using other energy with appliances using gas (increase of gas market)	Number/ yr.		- electricity - fuel oil - renewable - other	
of appliances using gas with appliances using other energy (decrease of gas market)	Number/ yr.		- electricity - fuel oil - renewable - other	

FORM - A 1

Part 2. Evaluation of the existing market. Comments

Please indicate the situation in your country in relation to the application and equipment concerned.

Marketing aspects	*(delete when inappropriate)*	***COMMENTS***
What are the main competing energies?	- electricity - fuel oil - renewable - other	
Are any of the costs related to gas appliance a problem? (Appliance costs, energy costs and maintenance costs).	- Yes - No	

Technical aspects	**Are any of the issues below considered a problem?** *(delete when inappropriate)*	***COMMENTS***
The efficiency of the gas appliance	- Yes - No	
The emissions of the gas appliance	- Yes - No	
The comfort level offered by the gas appliances	- Yes - No	
The safety of the gas appliances	- Yes - No	
The noise from the gas appliances	- Yes - No	
The electric consumption of the gas appliances	- Yes - No	
The reliability of the gas appliances	- Yes - No	
The ease of use of the gas appliances	- Yes - No	

Conclusion	***COMMENTS***
What actions would be needed to solve the problems and develop the market? Please give your recommendations**.**	

FORM - A 1

Part 3. New technologies (appliances and components)

Please indicate any **existing new technology or development of new technology** in your country (or another one) in relation to the application and equipment concerned. This could be the development of a new appliance, but could also be the development of a new component for the application. Please indicate, when possible, the **efficiency**, the **emissions** or other relevant information.

If possible, compare to electric appliances: advantages and drawbacks. What are the results expected from the present developments and which are the main difficulties to solve?

If possible, send also documents, articles etc. describing the new technology

List of documents:

FORM - A 1

Part 4. Field tests

Please indicate any existing field test results with details (reports?), if available.

Conclusions

What are the most promising technologies in this field?

What are the main hurdles for the development of the products (to obtain satisfactory products)?

Which way to follow in order to eliminate these barriers?

What are the key success factors?

What are the main advantages obtained (for the user, for the environment) in terms of emissions (NO_x, CO, CO_2, CFC, etc), noise, energy savings, others?

ANNEX 4: ADDITIONAL RESEARCH OF DATA (IN SUPPLEMENT TO THE QUESTIONNAIRES)

Please note that in this section we have kept the original units from the source. For the conversion please refer to the beginning of this report.

China
Main Reference: "What goes up: Recent trends in China's Energy consumption" J. Sinton, David G. Fridley. Lawrence Berkeley National Laboratory, February 2000 [16]

Today, coal represents almost 60% of the energy source in China. NG, which now represents 2.4%, is, however, expected to expand in the near future. China is the second largest emitter of greenhouse gases. But between 1996 and 2000 the primary energy use has fallen by 4% by declining the direct use of coal. One of the reasons being that urban dwellers move into apartments with central heating and consumers switch to electricity and gas for cooking and water heating.

The prospects for natural gas are uncertain because a significant growth would require long-term investments. However, the target expansion is to increase the national use from 23 Bm^3 to 50 Bm^3 in 2010.

According the same references [16], the actual share of residential use of natural gas is about 12% of the total natural gas consumption. Probably, this is mainly cooking and hot water production.

According to the author [16], the country would to a large extent benefit from replacement of coal based power generation systems by gas (turbines). Also the large-scale replacement of household coal use by gas is presently on going in major cities. This will have immediate consequence on the improvement of human health, as the pollution will be strongly reduced.

Australia
Main reference: www.abs.gov.au [17]

Natural gas has been growing fast during the last decades. About 386 PJ are used for domestic and 210 PJ for commercial.

Gas is the primary energy used for room heating (33% of the dwellings) (note that some are not heated at all, and gas accounts for 41% of the heated dwellings). Water heating is done with gas in about 35% of the dwellings and cooking accounts for 40% of the dwellings. Electricity is the major energy source for the two last applications.

We do not have data for the distribution of the domestic and commercial energy consumption on applications. Probably heating and cooling are the main applications.

For a first estimate, we would suppose that 80% of the energy is used for heating, knowing that the real value is probably lower, since hot water, cooking and cooling are also taking their share of the total.

Total use commercial + domestic	596 PJ
Total use for heating (hypothesis 80%)	475 PJ
Total share of gas for heating (statistics says 33%)	157 PJ (43.7 TWh)

Canada
Main reference: www.nrcan.gc.ca [18]

Canada has large natural gas resources and exports 60% of her own production to USA. About 11000 PJ of primary energy have been consumed in 2000 (37% petroleum, 27% gas, 19% electricity, 12% coal). The primary energy is used at 13% for commercial use and 18% for residential use.

The total market for natural gas is 79E+09 m^3 distributed on residential (18E+09 m^3), commercial (12E+09 m^3) and industrial (31E+09 m^3). Electricity generating (5E+09 m^3 and other uses are 13E+09 m^3.

All energy considered in **the commercial sector**, space heating is about 50% of the consumption of energy demand (total = about 1000 PJ in 1997) Water heating is about 8% and cooling is about 5%. .

In **the residential sector**, natural gas has increased from 40% to 47% between 1990 and 1997. 62% of the energy is used for space heating, 20% for water heating. Space cooling is still very low in Canada (less than 1%). The average energy efficiency has improved by 10% between 1990 and 1997. It is expected that the energy demand will decrease on the residential market, and the residential gas share is expected to fall by 6%, when electricity is expected to increase by the same amount. The improvement of the technologies and new standards (especially for the heating) should result in the change of the current stock.

Data for the statistics and calculation (basis of 1997)			
	Commercial (kWh)	**Residential (kWh)**	**Total**
Total	1.25316E+11	1.87975E+11	**3.13E+11**
Heating (90% of total hypothesis)	1.13E+11	1.69E+11	**2.82E+11**
Hot water(10% of total hypothesis)	1.25E+10	1.88E+10	**3.13E+10**

Table A.4.1: Estimation of the residential and commercial gas market in Canada

The appliances on the Canadian market seem to be - as for the US market - furnaces that are mostly air heaters. Also condensing furnaces are available on the market. Manufacturers claim up to 97% annual fuel utilisation efficiency (AFUE). That definition is not clear to the authors of this report, but the AFUE is a kind of annual efficiency. Older appliances have efficiencies up to 30% lower (according to one manufacturer (www.bryant.com)

One of the problems that seems to be connected to the furnaces is comfort. The distribution of the temperature in the room may pose a problem.

According to the HRA (Heating, Refrigeration and Air conditioning Institute of Canada), the sales (shipments) of residential furnaces in Canada (gas, oil and electric) are about 260,000 units a year.

In Canada, the heat is produced mainly by individual appliances (district heating in Canada is very small according to the Office of Energy Efficiency Natural Resources Canada). When we calculate the number of appliances with the above data we end up (when taking an average heat demand of 17000 kWh/year) with a number of 5,64E+06 installed appliances. The resulting replacement rate is about 5%.

According to Canada's energy outlook, the demand for gas will increase from 79E+09 m^3 (1997) to between 127 and 150E+09 m^3 by 2020.

The Office of Energy Efficiency Natural Resources Canada also gives detailed data on the stock. The efficiency of the appliances is either described as "normal" (about 90% of the appliances), "medium" (3%) or "high" (7%).

USA

"A look at residential energy consumption in 1997: US energy information administration" [9] has been a useful source to complement the data submitted by the IGU member. Below, we give the main information from this report [9].

The total household energy consumption is 10 quadrillion BTU a year with the gas share being 5.3%. For the gas, 68% is used for heating.

A single-family house (single-family houses account for about 73% of total US households) is consuming on average 60 MBTU/year (28 MBTU in dwellings) for the heating.

The houses equipped with air conditioning are using 6 MBTU by household (electricity).

In 1997, about 78% of the heated houses were heated with a central heating system (either furnace or boiler). Heat pumps increased from 2% (in 1978) to 19% in 1997. During the same time, furnaces have also increase by 5% (total = 55% of the houses) while CH with hot water or steam decreased by 5% (total =13% of the houses).

Russia

The section below was submitted by PROMGAZ. We have kept most of the original text submitted. For this part of the report, the terminology "central heating" was used by the author in opposition to "decentralized heating".

Heating market of Russia

Russian Federation is one of the biggest heat consumers in the world. Providing citizens with heat and satisfying public and industrial needs prove indispensable for national safety strategy formation, while being most important in terms of new economic policy formulation. At the same time Russian temperate climatic conditions minimize expenses on air-conditioning in summer. Such circumstances considerably influence technologies employed exclusively in heating and hot water production. It distinguishes Russia from other countries where heating, hot water production and air-conditioning are treated together. In the following t.e.f. is ton equivalent fuel.

1. Respective share in Russian central heating system covered by gas, fuel oil, coal boilers

Text	Fuel consumption – total, M t.e.f/%				
		coal	gas	fuel oil	others
Fuel consumed by central heating, total	54,3/100	9,2/16,9	43/79,2	2,1/3,9	0

2. Share of individual electric heating and that of central heat supply in Russia

Electric boilers in central heat supply, %	0,7
Centralization of heat supply, %	74,7

3. Fuel used for centralized heat supply

Consumption of boiler-furnace fuel by central heating boilers in Russia in 2000

Text	Total fuel consumption				
		coal	gas	fuel oil	others
Cogeneration plants	100,3	25/24,9	63,8/63,6	6,2/6,2	5,3
Industrial boilers,	117,2	16,5/14,1	78,6/67,1	12,1/10,3	10/8,5
including:					
District boilers	18,7	4,6/24,6	12/64,2	1,7/9,1	0,4/2,1

1. Tons of equivalent

Currently about 430 million tons of equivalent fuel (t.e.f.) or approximately 45% of total energy consumed in the country are used for heating. The quantity of fuel used for power generation is 2,3 times less. During unusually cold winters quantity of fuel for heat generation can annually increase by another 30-50 million t.e.f. or even more.

Distinctive feature of heating is its social importance in providing vital activities of Russian population. Heating of and supplying hot water to residential users and to non-productive sphere accounts for 40-45% of total heat consumption. Policy of improving heating industry in terms of reliability, quality and efficiency has no alternative. Failing of such is fraught with serious negative consequences, which can prove disastrous for economics and social situation in the country.

Central heating (natural monopoly) provides for 4/5 of total heat produced with non-productive losses amounting to 164,8 billion rubles and more (while in decentralized sector these losses make about 58,8 billion rubles). At the same time corrosion and other damaging factors affecting 260 thousand kilometers of heat networks have shortened their standard service life by half. Situation with heating from decentralized sources is not much better.

It is important that additionally to direct gains in energy and economics, intensive reconstruction of heat facilities will have positive social impact, improve productivity of fuel and energy complex and assure increase of energy carriers export potential. Heating of and supplying hot water to non-productive sphere make 40-45% of total heat consumption. Consequently economics of housing and communal services and population well-being are greatly dependant upon situation with and development of non-productive sphere heating.

Residential demand for heat on the whole is still unsatisfied especially in rural areas. Residential users are not to blame for the fact that majority of heat is used ineffectually and total heat losses are uncontrollably great. Payment for heat makes 42,5% of population housing expenses. The forthcoming reformation of housing sector cannot make the burden of heat excessive use the residential users' sole responsibility as such a step will impair interests and budgets of vast majority of Russian families. Supply of population with heat and hot water cannot be regarded as adequate under international standards and its spread is regionally lop-sided. Table 1 shows distribution of population per heating service.

	Central heating				Decentralized heating
	Heat and hot water by heating system	Heat and hot water by gas water heaters	Heating without hot water production	Total	
Total population	63,3	9,3	5,0	77,6	22,4
Urban population	79,0	8,0	5,0	92,0	8,0
Rural population	19,2	12,9	4,9	37,0	63,0

Table A.4.2: Estimated heat supply of Russian population, %

At least 2/3 of the country's population enjoy heating and hot water from heat networks. Every seventh inhabitant provided with central heating has to make personal arrangements to be supplied with hot water for sanitary purposes. However such relatively comfortable situation with heat supply is often disturbed by breakdowns at heating mains, scheduled maintenance shutdowns and because of power shortage.

On the whole heat saving potential in Russia is currently estimated at 18-22% of summary heat supply volume. Nevertheless, such estimates seem to mark just lower bottom line for extravagancy of heat usage, while real heat saving will directly depend on economic efficiency of heat saving solutions. These solutions are formulated for new technologies, materials, equipment and buildings, used in material production, housing and public spheres, and reconstruction and modernization of old ones.

Urban heat supply presents a serious ecological problem. Development of cogeneration plants resulted in redundant electricity production exceeding urban demand by 30-40% and even more. This circumstance gravely affects urban ecological situation and increases costs of environment protection and rehabilitation. Urban-industrial environment has most remarkably deteriorated in cities of the Urals, Siberia and Far East regions, where cogeneration plants are coal-driven.

Paternalistic state and pricing policies of former Soviet Union resulted in dominancy of consumer central heating by cogeneration and big boiler plants, these plants producing 4/5 of total supplied heat and providing for 93% of industrial heat needs and for 2/3 of non-productive heat consumption (mostly urban).

At the same time rural population, social sphere and manufacturing enterprises as well as individual housing in urban settlements and in the city suburbs were directed to de-centralized heating from autonomous sources. 4/5 of the heat produced by autonomous sources are supplied to non-productive consumers.

Trends of urban development prove that small towns and urban settlements with heat demand lower than 0.3 Gcal/h will continue prevalent and cover over 95% of towns. Construction sites are mostly developed in areas with low density of heat demand. Such settling model is to increase due to growing construction of cottages and low buildings. Summary heat demand in small towns and urban settlements is expected to remain at the level of 1/3 of total urban heat demand. It is exactly in such towns with thermal demand for heating and hot water production that autonomous heat supply systems as based on modular boiler systems can be made use of. This solution can be applied in majority of Russian towns.

Advantages of autonomous heating systems include small investment costs, low materials consumption, short installation period, efficient control, absence of big volumes of heat-carrier (water) in the system; modest quantity of power consumed for heat-carrier pumping, good ecological parameters. Small investment costs involved in constructing and operating autonomous heating systems combined with high energy-efficiency of such systems guarantee quick recoupment and allow to increase heat capacities.

We have already pointed out that international experience proved advisability of combining central heating with decentralized systems. Due to high level of control systems automation and safety of heat generators decentralized heating systems can be more widely used. Compared to central heating decentralized systems allow heat generation patterns to better match those of heat consumption. Gas decentralized systems proved the most economically efficient.

The following decentralized gas heating systems are presently popular in Russia: roof-mounted modular boiler systems and container boiler systems, heating boilers and air-heaters, infrared systems, autonomous modular cogeneration units, mini cogeneration plants and other systems for combined production of electricity and heat, the latter being the most preferable in terms of thermodynamics and most promising for power supply of factory shops and residential buildings of gas-transport enterprises and other processing units.

Each decentralized gas heating system has its specific area of the most efficient application. Sometimes new opportunities in heating are created thanks to decentralized heating through application of isolated automated gas-driven boiler systems. Theoretically speaking, central heating based on cogeneration remains the most efficient way of fuel utilization, but huge heat losses across networks amount to 20-25% and stultify all power saving efforts. Decentralized boilers are manufactured as ground-based container (or may be mobile) or roof-mounted modular boiler systems. Under fire safety requirements the latter ones cannot be mounted on the roofs of the buildings having more than 9 storeys. Presently the boiler systems are mounted at operation sites, however abroad individual plug-and-play boiler systems are used.

Production of such boiler systems should be organized in Russia, where domestic and foreign-made modern automatics, efficient compact plate-type heat exchangers, noiseless circulation pumps and ball stop valves could be used in manufacturing of these systems.

Modular boilers based decentralized heating lessens fuel consumption by 10-30% as compared to central heating, while metal consumption decreases 2-5 –fold due to metal saving at transportation network. Construction period shortens considerably as mounting of a modular boiler system takes about a week or two.

Air heating systems are used at industrial premises of special fire- and explosion proof characteristics. As a rule, these systems are combined with ventilation on the base of isolated gas air-heaters (recuperative, direct-contact, catalytic).

Performance index of recuperative air heaters gains to 92%. These heaters warm industrial and residential premises by delivering air heated to 60-70º into ventilation or exhaust channels.

PROMGAS is designing a range of floor- and wall-mounted boilers for private houses and cottages. Gas boilers are widely used for heating and hot water production. Recently it has become a tendency to install such boilers in each apartment of 5-9-storyed blocks of flats. Operation experience confirmed that these boilers maintain automatically controlled comfortable temperature regime not only during the so called "heating season", but on nasty spring and autumnal days. Real charge for temperature comfort in such houses is 5-6 times less than in the buildings with central heating.

Gas meters installed in each apartment make energy tracking quite simple. Heat supplying center providing for apartments in individual houses comprises single-circuit and double-circuit boilers, circulating pumps and expansion vessels for heating and hot water production systems, return and safety valves. In single-circuit boiler system hot water is conditioned in capacitance and plate-type boiler-heat-exchanger. Safety valves protect the system against fracturing under excessive work pressure. Double-circuit boilers rating up to 30 kW and equipped with circulating pumps and expansion vessels can be installed in individual houses and flats not exceeding 200 m2. Single-circuit boilers of higher capacity are recommended for larger premises, while boiler-heat-exchangers, circulating pumps and expansion vessels should be chosen depending on the type of heating system and hot water demand.

To develop gas using appliances market we must design and manufacture modern equipment incorporating the latest scientific and technological international achievements.

2000-3000 units per year of more or less powerful central gas heating boilers (not domestic ones) are sold in Russia, and natural gas accounts for approx. 80% of the central heating boiler market.

Pollutants concentration (CO and NO_x) in stoichiometric dry combustion products

Standard boiler	**CO**	**NO_x**	
1. Central heating gas boilers, equipped with atmospheric burners with rated capacity of 70 kW (GOST 51733-2001, corresponding EN 297-1994)	0,05% -using reference gas under normal or specific conditions	Boiler class	mg/(kW/h)
		1	260
		2	200
	0,20% - using saturated gas for rough (partial burning)	3	150
		4	100
		5	70

Standard boiler	**CO**	**NO_x**
2. Heating water-boiler with heat efficiency up to 100 kW (GOST 20548-87)	At t_0=0°C; mg/m^3	P_0=760 mm of mercury; mg/m^3
Light liquid fuel	115	229
Natural gas burned in		
Atmospheric burners	119	240
Burners with forced air draught	119	4
Anthracite	10000	-
Black coal with devolatilization up to 17%	24000	-
Black and brown coal with devolatilization of 17-50%	48000	-

Standard boiler		**CO**	**NO_x**
3. Heating boiler with heat efficiency of 0,10-3,15 MW (GOST 10617-83)			
Fuel	Boiler heat efficiency, MW	mg/m^3	mg/m^3
Black coal	0,10-0,50 0,50-1,00 1,00-3,15	1100 750 375	750 750 750
Brown coal	0,10-3,15	2000	750
Light liquid fuel	0,10-1,00 1,00-3,15	250 200	300 300
Fuel oil	0,40-3,15	250	300
Natural gas	0,10-3,15	130	250

4. Heating water-boiler with heat efficiency 0f 0,63-209,0 MW (GOST 21563-93)	Norms for boilers working	
Specific release of nitric oxides, kg/GJ, with α=1,4, no more than	In basic mode	In basic or peak mode
Gas	0,09 (0,23)	0,12 (0,30)
Fuel oil	0,13 (0,34)	0,15 (0,38)
Brown coal	0,17 (0,40)	0,17 (0,40)
Black coal	0,21 (0,50)	0,21 (0,50)

Steam generating units. Heat-mechanic equipment (boiler power units with capacity of 80-1200 MW, and boilers with steam rate of 160-3950 t/h) (GOST P 50831-95)				
Standards of particulate matters emissions for steam generating units (introduced on January 1, 2001, for solid fuels)				
Boiler heat capacity Q, MW, (steam rating D, t/h)	Adduced ash content, kg/MJ	Particulates emission per heat unit, g/MJ	Particulates emission, kg/t.e.f.	Particulates concentration in flue gas, mg/m^3 *, A=1,4
To 299 (to 420)	> 0,6 0,6-2,5 < 2,5	0,06 0,06-0,10 0,10	1,76 1,76-2,93 2,93	150 150-250 250
300 and over	<0,6	0,02	0,59	50
420 and over	0,6-2,5 > 2,5	0,02-0,06 0,06	0,59-1,76 1,76	50-150 150
*Under normal conditions (t=0º C; p=101,3 kPa)				

GOST P 50831-95

Standards for specific sulphur oxides emissions by steam generating units installed at cogeneration plants since January, 1, 2001. To be applied for solid and liquid fuels.

Boiler heat capacity Q, MW (steam rating D, t/h)	Adduced ash content, S_{ad}, % * kg/MJ	SO_x mass emission per heat unit, g/MJ	SO_x mass emission, kg/t.e.f	SO_x mass concentration in flue gas, mg/m^3*, A=1,4
To 199 (to 320)	0,045 and less over 0,045	0,5 0,6	14,7 17,6	1200 1400
200-249 (320-400)	0,045 and less over 0,045	0,4 0,45	11,7 13,1	950 1050
250-299 (400-420)	0,045 and less over 0,045	0,3 0,3	8,8 8,8	700 700
300 and over (420 and over)	-	0,3	8,8	700
*Under normal conditions (t=0º C; p=101,3 kPa) and calculated for dry gases				

Standards for specific nitric oxides emissions by steam generating units installed at cogeneration plants since January, 1, 2001.

Boiler heat capacity Q, MW (steam rating D, t/h)	Fuel	NO_x mass emission per heat unit, g/MJ	NO_x mass emission, kg/t.e.f	NO_x mass concentration in flue gas, mg/m^3*, A=1,4
To 299	Gas	0,043	1,26	125
(to 420)	Fuel oil	0,086	2,52	250
	Brown coal: Dry-ash removal Slag-tap removal	 0,11 0,11	3,20 3,20	300 300
	Black coal: Dry-ash removal Slag-tap removal	0,17 0,23	4,98 6,75	470 640
300 and over (420 and over)	Gas	0,043	1,26	125
	Fuel oil	0,086	2,52	250
	Brown coal: Dry-ash removal Slag-tap removal	 0,11 -	3,20 -	300 -
	Black coal: Dry-ash removal Slag-tap removal	0,13 0,21	3,81 6,16	350 570
*Under normal conditions (t=0º C; p=101,3 kPa) and calculated for dry gases				

Standard specific emissions of carbon oxides by steam generating units, with excess air ratio equalling 1.4, cannot exceed:

For gas and fuel oil – 300 mg/m3 under normal conditions (t=0º C; p=101.3 kPa)

For coals:
Boilers with dry-ash removal – 400 mg/m3 under normal conditions (t=0ºC; p=101.3 kPa)
Boilers with slag-tap removal – 300 mg/m3 under normal conditions (t=0ºC; p=101.3 kPa).
Standard specific emissions of liquid fuel ash are not prescribed. Standard emissions of fuel oil ash by power stations and cogeneration plants are determined only for such parameter as vanadium content calculated as maximum admissible average daily concentration of fuel oil ash (per vanadium unit) 0,002 mg/m^3.