Report of Study Group 5.2

“DOMESTIC AND COMMERCIAL GAS UTILISATION”

PRESENT MARKET SITUATION IN THE DOMESTIC AND COMMERCIAL SECTORS AND IMPACT OF THE NEW GAS TECHNOLOGIES

Rapport du groupe d’étude 5.2

”Utilisation domestiques et commerciales du gaz”


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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. The work in the SG was done in continuity with the work made in the previous triennium. In the last triennium the market situation was studied. The focus for this triennium was put on the risk to loose market shares in the gas utilisation sector.

Domestic and commercial use of gas represents about 10% of the total gross energy worldwide today, but it is uncertain whether this share will maintain the same level even though the development of the gas market is one of the most effective solutions for saving energy and reducing the CO2 emission.

Heating is the largest energy consumer in the domestic and commercial sectors for most of the countries. However, with the reinforcement of the house insulation legislation, there is a clear menace to the gas technologies. Would they be able to compete with electricity where the investment is much lower? Besides, there are developments of new technologies bringing new functions in the house. Combined heat and power production might revolutionize the gas utilisation in the domestic and commercial sectors, but the technology is not yet completely ready for extended use in the market. Before CHP will be widely developed, validated technologies might come on the market. For example the gas driven heat pump that can meet the consumer's need for more comfort and air conditioning. In some countries, NGV is developing rapidly and domestic refuelling stations might very well be the main gas appliances in future homes! Also so-called "garden" utilisation is developing (grill, patio heater).

The report points out a number of technical challenges for making this possible. One of the key issues is the price, which is true both for the existing market and for the emerging markets (e.g. China) that need cheap appliances more than smart appliances.

In the future, the gas market might expand in the sector of domestic and commercial use. The success of this expansion will greatly depend on economical factors (energy prices, appliance prices) but also on the capability of the gas industry to meet the identified technical challenges and to bring new forms of services to the market (electricity production, cooling, air conditioning).

RÉSUMÉ

Ce rapport fait la synthèse de la situation mondiale actuelle en matière d'utilisation du gaz dans le secteur domestique et commercial. Le travail de ce groupe d'étude s'est fait dans la continuité du précédent triennium. Lors de ce précédent triennium l'accent avait été mis sur la situation du marché alors que pour ce présent triennium, il est mis sur le risque de perdre des parts de marché dans le futur.

Les utilisations du gaz dans le secteur domestique et commercial représentent à l'heure actuelle 10% du total de la consommation énergétique de la planète. Rien n'est moins sûr que cette part va pouvoir se maintenir à ce niveau, même si le gaz est actuellement l'un des moyens plus efficaces en faveur des économies d'énergie et pour lutter contre les émissions de CO2.

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. Cependant, le renforcement des législations sur l'isolation thermique des bâtiments, fait peser un risque sur les technologies gaz. Pourront-elles résister à l'électricité bien moins couteuse à l'investissement? Dans le même temps, le développement de nouvelles technologies amène de nouvelles fonctions dans les maisons. La production combinée de chaleur et d'électricité pourrait très bien révolutionner les utilisations dans le secteur domestique et commercial, mais la technologies n'est pas tout à fait mûre pour un développement massif. L'avènement de la micro-cogénération va sans doute être précédée de l'introduction de technologies qui sont déjà prêtes et en particulier des pompes à chaleur qui amènent également une réponse au besoin grandissant d'air conditionné. Le développement rapide de la technologie et marché des véhicules à
gaz va sans doute amener le développement de solutions pour le “home fuelling”. Pour finir les utilisations de loisir (grill, chauffage de patio, lampe décorative) sont également en plein essor.

Ce rapport met en lumière un certain nombre de challenges liés au développement du marché du gaz. Un des élément cruciaux est le prix, ceci est vrai tant pour les pays ayant déjà une forte tradition pour l’utilisation du gaz tant pour les marchés émergents comme par exemple la Chine.

Dans le future, il y a un potentiel de développement dans notre secteur. Ce développement se fera ou pas en fonction de facteurs économiques (prix des énergies, prix des appareils) mais aussi en fonction de la capacité de l’industrie du gaz de résoudre un certain nombre de challenges techniques et de réussir l’intégration des nouvelles technologies et services telles que production combinée de chaleur et électricité, air conditionné
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Annex 02: Short explanation of the technologies covered by this report

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2. INTRODUCTION

The gas industry and the energy industry are in a transient phase with many changes. In Europe, the market liberalisation has resulted in a globalisation of the energy market. More and more gas providers are not only selling gas, but also other energies or services. At the same time, the emergence of new promising technologies, like fuel cells, might revolutionize the market of tomorrow. But before that we might see a development of micro-cogeneration based on gas engines, renewable energy and new gas utilisation due to the development of the leisure market ("garden applications", like grill etc.). Also, the development of NGV might make the compressor the most consuming gas appliances in the house of tomorrow.

But there are still a lot of challenges before these achievements become a reality. The present report is aiming at dressing a picture of the present situation and assessing the chances of the future technologies.

- First, we shall look at the existing market situation: What are the gas applications in the domestic and commercial sectors? What are the main coming applications and what is the state of the art of the appliances that are on the market today? For some aspects we develop on the specific technical problems encountered for some of the applications.
- Furthermore, we shall look at the market data: How many appliances are sold and where? What are the main challenges for the technologies of today? Here, we shall focus on the marketing and economical aspects.
- Cooling is treated as a detailed case study in a separate section where the Japanese, French and American situations are compared.
- After having studied the present situation, we shall look into the future and start with a provocative statement/question about the chances of gas to remain in the domestic and commercial sector. We shall use the facts from the market situation and data to conclude on the main hurdles for the gas technologies.
- Finally, we are going to look at the new gas technologies, and we shall both give a number of explanations of those and at the same time we shall try to assess their chances.
- The future will probably see a progressive mixing of actual technology with the newest ones. In the last section we show some examples on how this might be done and how the new technologies can/will integrate the houses of tomorrow. This very last point is detailed in an Annex where we try to summarize with practical examples what would be the house of tomorrow. Note that this will be subject to an oral presentation at the WGC.
3. THE PRESENT MARKET SITUATION

Before looking at the possibilities for introduction of new gas technologies, it is relevant to investigate what is the present situation for the gas appliances. What is the share of gas in the world and for what purpose is the gas used? This will allow us to gain a better idea of the impact of the domestic and commercial gas technology improvement worldwide. Note that the overall ambition of this work is not to give an accurate picture of the world-wide energy situation, but to have an approximate idea of the situation as reflected by the experts participating in the work of IGU: Technical gas experts and not marketing or economist estimates. For this part we have updated the information from the previous report of the IGU WOC 6 SG1 [20] Also Internet research was used to collect data. There are a number of countries for which we were not able to gather data, but this section reflects about 70 to 80% of the present market.

3.1 Gas position worldwide

![Total gross energy consumption (World-wide)](image)

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

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

About 40% of the total energy consumption is used for domestic and commercial purposes, and domestic and commercial utilizations of gas represent 7% of the total energy consumed worldwide. 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.

Today, 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 use 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 CO₂ reduction worldwide.

<table>
<thead>
<tr>
<th></th>
<th>Solid</th>
<th>Oil</th>
<th>Gas</th>
<th>El.</th>
<th>Heat</th>
<th>Renewables</th>
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<td>16.0</td>
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</tr>
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<td>0.9</td>
<td>89</td>
</tr>
<tr>
<td>Asia</td>
<td>233.0</td>
<td>195.4</td>
<td>20.0</td>
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<td>10.5</td>
<td>271.0</td>
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<tr>
<td>Latin America</td>
<td>3.9</td>
<td>44.4</td>
<td>9.0</td>
<td>13.5</td>
<td>0.0</td>
<td>0.9</td>
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<tr>
<td>TOTAL</td>
<td>325</td>
<td>863</td>
<td>466</td>
<td>413</td>
<td>150</td>
<td>464</td>
<td>2681</td>
</tr>
</tbody>
</table>

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.

3.2 The overall gas market today. What are the gas applications?

The questionnaire issued during the previous triennium was used here. Respondents were 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. Only minor changes have been registered since the work was done in 2003, so we will assume that for the purpose of this study the data obtained three years ago are still valid. There are of course some swiftly changing markets (e.g. the expansion of the Chinese market), but despite these dramatic changes the overall impact on the world market is still small. We have not been able for this triennium to get data from those rapidly developing markets (this can be put on the list of the tasks for the next triennium).
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 may possibly consider other applications such as cooking, drying etc. Heating is increasingly combined with hot water production. Cooking might not have a large share in the total consumption of households, but plays a more important role for the commercial sector. More and more customers want and can afford more comfort and in this respect cooling will develop in the future. But here we will have to cope with the competition with electricity as we will see further.

The decorative gas light is not a large market, but it is used for the prestige and image of gas and has become a part of the so called “Garden” appliances such as grills, patio heaters or even decorative lights have also appeared on the market, but we do not have market data for those.

Home fuelling with NGV enters the family of gas appliances despite being quite different from other members of the family. However, at this stage the technology has not yet penetrated the market.

Micro CHP and fuel cells are now also on the market, but these new technologies have up to now rather confidential sales and are, therefore, not included in the present statistics (see also the report from the Study group on distributed energies).

3.3 Market profile

Heating with CH boilers and air heating accounts for more than 90% of the total gas consumption. 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.

Air heating (with furnace) is almost entirely an American market, while CH boilers are used on the European market.
3.4 Analysis by country

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 found in the USA. Germany and UK also have a strong position with about 15 and 10%. The rest of the market is shared between other countries. But as said, there is a 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.

Overall gas consumption with individual appliances for domestic and commercial

Overall gas consumption with individual appliances, domestic and commercial
3.5. Analysis by application

The figure above indicates the energy that is used in an average installation for the different applications considered.

Among the main conclusions that can be drawn from the figure is the potential impact on gas sales 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 we do not have data enough to work out accurate statistics, and the consumption in this case very much depends on the country, user habits and infrastructure for the gas fuelling. If this application develops in the future it may 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 variations 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 (e.g. in Japan the very low average heat demand - less than 5000 kWh - is probably due to a combination of low average housing surface, good insulation, and relatively high gas price).

For hot water production, the average annual consumption by units is also very dependant 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. A number of studies about the question of hot water demand have been carried out, and clearly some cultural aspects play a strong role. The family composition and habits as well as the price of water are among the factors that are of main importance. 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 cooking differences between countries explain part of those differences. The average gas consumption is about 800 kWh, but it may vary by a factor two.

For **cooling**, the estimated average gas consumption for commercial applications in France (1.84 GWh/year) is about ten times lower than that of Japan (17.5 GWh/year). This difference is due to the differences in climate and operation hours. For the domestic sector the average is about 8000 kWh.

### 3.6. State of the art.
Where are we in the development of the technologies (efficiency, emissions, etc.)?

#### 3.6.1. Heating and hot water

**Heating with CH boilers**

**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. For some countries, the higher cost of efficient appliances (as the condensing ones) was considered a problem few years ago, but today in many countries, however, the situation has changed and we can observe **a boost of the condensing technology sales** and as a result a reduction in the price of the appliances, which is now very close to the traditional boiler price. Also, the installer branch is now in many countries confident with the technology and does not hesitate to propose this technology to their clients anymore.

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**The example of the situation in Japan (source: TOKYO GAS)** (note that this was mainly the situation three years ago and that the present situation might be slightly different)

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 achieve up to 50 kW power 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:

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

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In the table below we present an overview of the actual energy performances and emissions of various ranges of products. The table is a result from the questionnaire work from the previous triennium, but the technology has not changed that much in the 3 last years.

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 (but cheap technology) boilers further explains the differences in the answers.

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

(*) efficiency under standard test conditions (60/80 for traditional CH boilers 30/40 for condensing CH boilers)

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 amount of installed boilers for boilers with pilot flame and atmospheric burner technology. Also 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 emissions from the gas appliance

Emission from appliances is a controversial question among experts from gas utilities when interviewed on this topic: About half of the countries consider the emissions (NOx) 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 from the appliances available on the market, but many low-NOx emission burners are available. The emission of CO is not really an issue for the environment (but can be for safety in case of a problem on the boiler/installation). 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 have to pay an extra price for getting those. As a result, emission is more an issue for the gas utilities, gas industry and the authorities. It is not a surprise that the emission issue is dividing the gas industry as it is difficult to relate to the real impact of heating on the environment. To clarify this topic we would need to compare the NOx emissions of boilers with other utilisations (e.g. cars) and gain a better knowledge on the real impact of heating and NOx emissions on the environment. The acid rain was very much discussed few years ago.
ago; we (in the SG 5.2 group) have no data on the present situation. The CO$_2$ emissions are easier to understand and evaluate and have also in the media taken over the NO$_x$ emissions.

However, there is no doubt that part of the positive image of gas (a “green” energy) is important and therefore 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 safety of the gas appliances**

Only few countries consider safety with gas appliances 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. The perception of the problem may vary from country to country depending on the fatalities statistics from other competing energies, and sociological aspects.

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 generally linked to accidents or caused by “voluntary action” (suicide or sabotage) which will always be difficult to prevent. The second category (poisoning) is in general linked to 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. For the explosion risk CH$_4$ detectors can be used.

A number of gas companies are not in favour of detectors, but prefer the gas appliance itself (and not an external component) to shut down the burner as soon as it produces CO. This philosophy makes the use of detectors unnecessary and also avoids 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.

In recent years, new discussions were related to the consequence of variation of the gas quality on the European market. As a consequence of the liberalisation of the market, there will in the near future appear larger variations in the gas composition distributed in the European countries. This might bring problems with safety, emissions and efficiency.

The control of the combustion was already a problem in the countries where the gas quality is subject to variations. Self-adapting systems (e.g. the so-called SCOT system) were developed in Germany. They are already integrated in commercially available boilers on the market.

**Noise, reliability and other issues**

The **noise of boilers** is not as an issue for most countries, but this could change. E.g. in France, there is a regulation that limits the boiler noise, and on the other hand not all boilers on the market are able to respect that regulation. New EU labelling plans might make noise regulation extend to other countries, as well. However, the noise depends very much on the individual installation, and the countries that have boilers installed in non-heated rooms (e.g. outside the living space) are probably not concerned by noise. For example, in Japan, appliances are usually installed on the outer wall of the house.

A similar issue is the **electricity consumption** of appliances. Only a few countries are actually measuring electricity from gas appliances. Therefore, only few consumers are aware of the real cost of electricity consumption of 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). Note that the average is between 200 and 400 kWh/year.

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
The reliability of appliances can be seen as a problem in some countries. The maintenance and repair costs (see further) are linked to reliability. 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 heating or hot water until the boiler is repaired). For the end user problems with the appliances will result in a bad image for the energy gas.

The ease of use. For average consumers, the technicality of some boilers might be too sophisticated. 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 sufficiently simple way. New designed boilers also have 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.

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 very important for the competition with other energies.

Heating with air heater

As the countries where this technology is mostly used are not represented in the SG we shall not elaborate on this topic here.

Hot water production

The technology is in most cases very similar to the CH boiler used for heating. Also the development of combination boilers either with water tank or instantaneously able to produce both heat and hot water is taking over the market of the appliance purely dedicated to hot water production (water heaters). Therefore, most of the facts on CH boilers also apply to hot water production. In the following we shall focus on specific issues for the hot water production.

Efficiency

Whereas 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 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 gas, and the technology should focus on saving water.

The comfort level offered by the gas appliances

The comfort is considered a problem for instantaneous appliances producing hot water. The variation of water temperature during tapping is a known problem and some of the manufacturers on the market are in the process of solving it by using capacity and control. This is probably the main issue for the hot water function (at least for instantaneous appliances). Also thermostats on the tapping points are generally able to give a good level of comfort and are relatively cheap.

Safety and health

An issue that is not related directly to gas is the problem of the Legionnaires’ Disease. 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 magnitude of the problem. The heating at
high temperature does not need to be permanent. Some manufacturers have implemented solutions
consisting in one high temperature heating per week.

3.6.2 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 heating so it has a relative small impact on 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
states an average net efficiency of 45%, but this is probably a question of interpretation of the
questionnaire and the definition of efficiency. The efficiency of the cookers depends indeed 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 emissions of cookers have been in focus in some countries. Recently, gas cooking was
suspected of producing micro particles in the air. IAQ is certainly an issue for the gas industry, but in
many countries the large sources of indoor pollutants are not related to gas and, therefore, there are
different opinions about this issue.

The ease of cleaning and design of gas cooking appliances are important parameters and on
both fronts it seems that electrical appliances are doing better than gas. There is a necessity to
improve the design of appliances to make the cleaning easier and to improve the appearance. On the
other hand, state-of-the-art gas cookers with ceramic plate and radiant burners are on the market, but
still not widely available according to some experts. They are also fairly high-priced.

Commercial

Emissions from gas cooking appliances in the commercial sector are considered a problem in
many countries as gas is compared with electric appliances. In general, NO\textsubscript{x} is not seen as an issue,
but CO is (likely to be a problem under poor ventilation conditions).

There is also a demand for appliances with lower heat radiation.

3.6.3. Home fuelling

Efficiency, noise, reliability

For this type of appliance we have not been able to collect new data so we shall maintain the three-
year old information below:

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\textsuperscript{3} compressed.

Noise and electric consumption are not considered issues for the development of the natural
gas home refuelling market.
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. The company FuelMaker has now developed a cheap VRA.
4. MARKET DATA FOR APPLIANCES

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

4.1 Heating and 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, that 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.

![Heating with CH boilers](chart)

The lifetime of a gas appliance is approx. 15-25 years. 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 per year. The data we have from other sources tend to show that the values above are probably 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, Switzerland, Denmark), and starts to have substantial market shares in other countries that were up to recently reluctant to adopt to the condensing technology.
Heating with CH boilers

Number of appliances installed for 1000 inhabitants

Estimated net increase in natural gas units per year

Even if some markets are in strong expansion, sales of boilers in most countries are in the replacement market, where the expansion is quite limited. However, globally gas is taking shares from the fuel oil and/or electricity. Nowhere in the world is the market decreasing. The central heating market is still an expanding market, but there are some threats (see below).

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. In a few countries, electricity is taking increasing parts from the gas market share. This trend can be confirmed in the future for new buildings for the following reasons:

- In case of multi-residential housing where the builder chooses the cheapest heating system and sells the house/apartments at more competitive prices.
- The building insulation regulation reinforcement can make the heat demand so low that the investment in CH installation is not justified anymore.

In 1996, AGA considered the US market stable, despite the fact that electricity was gaining market shares (over fuel oil) [1]. One characteristic of the US market is the development of air conditioning, where 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 lower installation costs, but in most countries the kWh price of electricity is much higher than the kWh price 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 introduced 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. However, the main barrier to the development of renewable energy today is the too low (relatively) energy prices for gas, electricity and fuel.

**Fuel oil** is another competitor, but not as strong as electricity. Fuel oil is generally well implemented in areas not covered by the gas grid.

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 power production. The energy that will provide this double/triple function at reasonable installation and running costs 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 who 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.

*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 because it 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 does coal 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 new 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 (e.g. the USA), gas is still in a favourable position for further market development. For other countries (e.g. D; NL) the markets are close to saturation and the challenge is not to develop the market, but to maintain the customers. The further development of the gas grid in such saturated market is too expensive compared 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. But as already mentioned, the cost of installation and appliances are making CH with gas less and less competitive.

*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 heating).

Water heaters are still widely used. The total market size in the countries for which we have data (CZECH REPUBLIC, CHINA, CROATIA, DENMARK, FRANCE, GERMANY) is about 30 million units. In China, 10 million units are installed!
Some markets are in strong expansion (China 2 million = 20%), but for most of the countries, the sales of water heaters are either limited or strongly decreasing. The total replacement market is slightly over 2 million, which is corresponding well with a lifetime of 10 to 15 years. In Europe water heaters are mostly replaced with combi-boilers.

The introduction of combi-boilers is the preferred choice for many countries and presents several advantages:
- It groups the two functions (heat and hot water) in the same appliance.
- It eliminates from the market flue less appliances (not as safe as appliances where combustion products are carried out of the boiler through flue gas pipes).
- It opens for an optimum combination with solar. Solar can contribute in the hot water production during the summer. This results in savings and makes gas a more attractive product.

For many countries, the water heater is already considered an appliance from the past. However, in the very important Chinese market, they have shown a clear interest in solving a number of the problems mentioned (mainly too low efficiency). But we are missing details about the characteristics of the appliances available and details about the Chinese market. This point could also be added to the list of the important points for the next triennium.

4.2 Cooking

More than 100 million domestic gas cookers are installed throughout the world.
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 customer habits. Other countries, such as Slovakia, have a very large share (above 90%).

The main advantages of gas for cooking are the price and the fact that the appliances are quicker for meal preparation. Another advantage is the flexibility of the cooking with gas. It is possible to adjust the heat over a wide range (note that the new electrical IH (Induction Heat) cooker also has this feature.

Electric cookers with ceramic plate and electric convection oven are very popular and are the main reason for the decrease in the natural gas market. This is probably due to better design of electric appliances and no need for pipes (in the kitchen) for natural gas supply and so additional installation cost.

4.3 Cooling

See also Section 5 with the case study “HOW TO OPEN THE COOLING MARKET TO GAS APPLIANCES”

Evaluation of the existing market. Data

Market data from the previous triennium

Market data given here come from countries where gas cooling is developed or developing and for which we could obtain data. Other countries like China, Korea or Italy have significant gas cooling activities, but data are missing.

The estimated number of natural gas cooling units in operation is 233000 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:

<table>
<thead>
<tr>
<th>Saturation rate (all energies, 1998)</th>
<th>Residential sector</th>
<th>Commercial sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>1.5%</td>
<td>18%</td>
</tr>
<tr>
<td>Japan</td>
<td>85%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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 segment is only 19%. The main market is domestic and with gas engine heat pumps (see for explanation about the technology in Annex).

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, the 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 the 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.

4.4 Home fuelling (VRA)

In 2000, Japan had 441 natural gas units of home fuelling in operation, consuming an average of 2 million m³ 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. 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.
There are presently projects ongoing to develop the market for small domestic units.

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, the respondents to the questionnaire reported only 10 units in operation in 2000. 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.

According to a manufacturer, 800 VRAs have been sold to Germany, and 60% of those are currently being serviced. Germany presently expands its infrastructure to 1,000 public CNG fuelling stations, which could result in 150,000-300,000 vehicles on the roads.

**Competition**

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).

**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 cheap VRA model that FuelMaker designed for a commuter vehicle has a targeted list price of USD 999.

The maintenance cost is also an issue. This cost, along with the high appliance cost, does not make it cost-effective for domestic applications.
5. COOLING
A CASE STUDY “HOW TO OPEN THE MARKET TO GAS APPLIANCES”

This part of the report was made by GdF with the following Sources:

France: Gaz de France
United States: Energy Solutions Centre, Keyspan Energy,
Japan: Toho Gas

5.1 Overview of gas air conditioning

5.1.1 France

In France, natural gas accounts for 14% of total energy consumption, compared to an average of 23% for Europe as a whole.

The opening up of the French and European markets has led to major restructuring within gas companies, a consequence of which has been a marked reduction in their contributions to product development. Furthermore, energy distributors are becoming multi-energy players with an increasing focus on the development of service offerings.

By developing service offerings, energy distributors are endeavouring to provide their “marketer” with a competitive advantage. However, product development offers no competitive advantage to the extent that such developments can be turned to account commercially by all energy distributors, including those who have played no part in developing the products concerned. Today, the development of gas air conditioning falls into this category and can therefore only be achieved through the development of services.

Moreover, energy distributors are questioning the wisdom of their continued participation in the development of gas air conditioning since a comprehensive range of electrical solutions is already in place.

With regard to gas air conditioning manufacturers and equipment technologies present on the French market, Gaz de France chose to focus entirely on supporting development of absorption equipment, primarily to differentiate its offering from electrical products (compression equipment). This decision was to have a bearing on the development of gas air conditioning on the French market for a considerable period. Today, only a handful of absorption equipment manufacturers enjoy a significant presence on this market (Robur, Yazaki, Kawasaki, Hitachi, Trane and York).

5.1.2 The United States

In the United States, the market share for natural gas air conditioning has remained minimal in the face of the competition. It only reaches significant levels in the case of installations above 350 kW.

As in France, US gas companies have ceased selling air conditioning products directly, if they ever did so. However, the largest of such companies operate subsidiaries that distribute equipment in order to give them a competitive advantage and provide a comprehensive service offering. Certain gas companies actively supported gas air conditioning some years ago by subsidising purchase of equipment (Keyspan, for instance). This financial assistance was mostly discontinued in the mid nineties. Today, they still offer preferential rates but only for the sale of natural gas when a customer chooses an air conditioning solution.

Numerous technologies are used and represented on this market (absorption, gas engine compression, desiccant air conditioning, humidifier, hybrid systems, etc.). These low-power appliances for the home are largely comprised of absorption equipment such as Ambian (10 kW), Broad, Cooltec5 (17 kW) and Robur (17 kW), and desiccant air conditioning (dehumidification) systems such as NovelAire.
In terms of medium- and high-power air conditioning, the offering is primarily made up of absorption equipment such as Broad (0.125 to 9 MW), Carrier (0.350 to 2.4 MW), Cention (Century 0.140 to 5.8 MW), Energen (0.350 to 2.8 MW), Energy Concepts (0.05 to 0.5 MW), McQuay (0.35 to 5.3 MW), Thermax (0.175 to 4.9 MW), Yazaki (0.035 to 0.35 MW) and York (0.42 to 4.7 MW) or compression equipment operated by gas engines such as Alturdyne (0.105 to 3.85 MW), Tecogen (0.875 to 3.5 MW), Trane (0.6 to 14 MW), and York (1.4 to 7 MW; compression equipment which can also be powered by steam turbines).

5.1.3 Japan

The Japanese air conditioning market is very different from European and North American markets. The hot and humid Japanese summers require over-dimensioning of the air conditioning requirement, leading to problems with the electrical supply in summer. Given this supply problem, gas air conditioning has positioned itself as a useful alternative.

In 2002, 31,800 customers were equipped with gas air conditioning using absorption equipment (corresponding to the installation of 2,000 new appliances annually) and 91,000 gas heat pumps (representing the installation of around 40,000 new appliances annually). Gas appliances took 21.5% of the air conditioning market.

In the past, the three largest gas companies (Tokyo Gas, Osaka Gas and Toho Gas) distributed and sold absorption equipment in order to boost their sales of natural gas. This no longer applies for absorption technology but they actively distribute and sell gas heat pumps after developing them in partnership with manufacturers. They also offer maintenance agreements for these products in partnership with manufacturers so as to ensure a comprehensive and competitive offering. Finally, they offer commercial funding for all natural gas air conditioning systems and supply gas at reduced prices to customers using gas air conditioning.

The products and brands present on this market are exclusively Japanese with Kawasaki, Sanyo, Hitachi, Yazaki, Ebara (0.0175 to 10.5 MW) for absorption equipment and Yanmar, Sanyo, Aisin Seiki, Mitsubishi, Hitachi (8 to 84 kW) for gas heat pumps. However, Daikin plans to market gas heat pumps on the Japanese market as of 2006. It should be noted that in Japan, although absorption equipment uses a distribution system with a water vector, all gas heat pumps use a direct expansion system.

5.2 Identification of the main competitors on the gas air conditioning market

5.2.1 France

The French electricity market is particular in nature, since 85% of the energy source is nuclear and the selling price remains competitive in relation to other energies, including heating and air conditioning systems.

The French air conditioning market is largely dominated by the electricity offering which is much larger and enjoys a virtual monopoly when it comes to low-power appliances. Electrical products have the advantage of being much cheaper to buy and easier to install. However, in most cases, a back-up system is required if users wish to switch to the heating function. This back-up system compensates for the consequential loss in power during defrosting cycles. In practice, this back-up system is dimensioned in such a way as to meet all heating needs for buildings, in which case it no longer serves as back up, but is in reality the main heating system.

Gas air conditioning appliances have the advantage of being autonomous when operating in heat mode since absorption equipment does not require defrosting. Gas heat pumps can recover thermal energy from the engine to conduct defrosting. These appliances can therefore function without back-up systems, in most cases.

The purchase cost of gas appliances is generally higher than for their electrical counterparts. However, operating costs (maintenance, operation, etc.) are generally lower, especially for medium- and high-power appliances, which makes it possible to maximise returns. The return on investment...
will be even quicker when the installation of a gas solution makes it possible to avoid an increase in electrical power.

5.2.2 The United States

The US market, as in France, is dominated by the electrical appliances that are a third of the cost of gas systems. Moreover, this offering is supported by economic and environmental arguments. Some distributors even offer electrical equipment that is virtually maintenance-free.

However, gas appliances more or less present the same general advantages as on the French market if account is taken of the purchase cost and maintenance/operating costs, especially in terms of the return on investment, since the cost of operating a natural gas equipment during summer is roughly half that of an electrical appliance which can offset the higher initial outlay.

5.2.3 Japan

As in the other countries, electrical products dominate the air conditioning market. In the domestic appliance sector, virtually the entire market is covered by electrical offerings due to a lack of diversity regarding low-power gas appliances and their reduced performances. However, in the tertiary sector, gas enjoys a 21.5% market share and the share of natural gas could rise in the coming months due, in part, to the growth in office space and particularly air conditioned offices, as well as commercial funding granted to customers and electrical supply problems in the summer months.

Other energy sources have a significant share of the air conditioning market such as fuel (absorption equipment) and LPG (heat pumps driven by engines).

The advantages of natural gas air conditioning in Japan are the same as on the French and North American markets: primarily, low operating costs and a return on investment which increases with the power of the installation.

5.3 The principal obstacles to the development of natural gas air conditioning

5.3.1 France

Demand for air conditioning in France is below that of Southern Europe, North America or Asia. In the field of energy efficiency, French and European regulations are increasingly stringent (Kyoto protocol). Therefore, the public authorities actively encourage implementation of alternatives to air conditioning solutions (bioclimatic, passive air conditioning, cooling using renewable energies, etc.), which often benefit from tax incentives.

With regard to statutory requirements covering natural gas air conditioning, the most important are those imposed on installation of absorption chillers with ammonia (particularly in public buildings) and those relating to cooling towers (risk of Legionnaire’s disease). These constraints provide no obstacle to development and installation of such technologies as long as the sector has the necessary expertise.

Finally, the particular nature of the French electricity market (nuclear production and cost) means gas is unable to achieve sufficient differentiation to offset the extra outlay.

5.3.2 The United States

In the United States, regulations often differ between states. Certain states have regulatory frameworks which are extremely stringent and which, for instance, require specially trained personnel to be used for operating installations above 175 kW.

5.3.3 Japan

In Japan, there are no regulations specific to gas appliances which might hinder their development. The authorities try to encourage the use of natural gas for air conditioning by offering tax
incentives for the acquisition of gas appliances on installations of over 35 kW, sometimes by offering subsidies for buying equipment or even credit at preferential rates. These special measures make it possible to compete with the electrical offerings in financial terms.

5.4 Summary and analysis

Gaz de France stopped providing commercial funding for gas air conditioning products in 2004. In France, distributors of mixed products (gas and electrical air conditioning) remain present on the market. However, distributors of gas-only products are struggling to make inroads and are feeling the impact of the decision by Gaz de France to end commercial funding. Their gas solutions are easier to install on collective installations than in private dwellings due to the absence of economically viable, low-power products (<17 kW) on the French market.

The situation in the United States is virtually identical. Only a few gas companies are still offering preferential rates for the sale of natural gas in order to encourage the use of gas air conditioning. The purchase price of equipment is still fairly high and holding back development of the market. A few gas companies used to directly distribute equipment in the past but they have now withdrawn from the market. However, there are those who think that progress can still be made by means of lobbying with a view to increasing public awareness of these products and their reliability coupled with a reduced purchase price and more effective after-sales (particularly concerning availability of spare parts). US experts consider that over the next ten years the market is likely to stagnate or even shrink unless a partnership is established between users, installers and manufacturers.

In Japan, the active involvement of gas companies means that the market share of gas on a buoyant air conditioning sector can be preserved or even extended. Their involvement in the development of products also enables manufacturers to propose systems, which are increasingly reliable and effective (compressor output and effective recovery of heat from engines for gas heat pumps and improved effectiveness of absorption cycles). Finally, their financial involvement combined with that of the authorities enables gas products to be sold and installed at competitive prices in relation to the electrical offering. Japanese experts consider that the market share of natural gas on the air conditioning market will continue to increase, since more and more large-surface tertiary sector buildings are being constructed, which favours the installation of gas systems.

To conclude: In view of the situation in Japan, the United States and in France, it would seem that gas air conditioning has a major difficulty in finding a position on the market without considerable support from gas companies and the public authorities and that electrical systems present significant competition.

This situation can be explained by three principal factors:

- Gas air conditioning is generally reserved for installations with sufficient power for the return on investment to be significant and for manufacturers to develop diversified products that are effective and competitive.
- The position of gas air conditioning is often conditioned by the position of electricity on the energy market in the country in question. A reliable supply of electricity in summer at competitive prices clearly makes the development of gas products that much more difficult.
- The financial outlay required for installation of gas solutions must often be offset by funding (subsidies, tax rebates, discounts on gas prices) from gas companies or the public authorities in order to encourage installation of gas systems, even if the operating and maintenance costs work in favour of gas systems.

It can therefore be concluded that, with the exclusion of countries which experience difficulties related to electricity production, especially during summer, or which are unable to produce electricity due to high costs, the gas air conditioning market will only be able to achieve real development with the significant and long-term support of gas companies or public authorities (regulations, tax incentives, etc.).

This support would seem to be essential to the development of products, which are effective in technical terms and competitive in commercial terms.
But even with this support, future development of gas air conditioning would seem to be restricted to installations with fairly high output.

The development of gas air conditioning also depends on changes to national and international regulations regarding energy efficiency in general and, more particularly, the position of the public authorities on air conditioning in buildings and on the role of natural gas among the range of available sources of energy.
6. PROSPECTS: 
IS THERE A FUTURE FOR GAS IN DOMESTIC AND COMMERCIAL SECTOR?

6.1 Introduction

Up to recently there were good reasons to be optimistic about the development of gas utilisation.
- The gas price was favourable to gas in most countries.
- Gas products were improved thanks to research with a strong commitment of the gas utilities.
- The gas benefited from a “green” and positive image in most countries.

This has not changed from day to day, but we have entered a new period with changes that could make the gas market more difficult in the future: Because of the energy conservation legislation and due to the Kyoto agreement, there is a trend in most countries to reduce 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.

Beside this, there are new facts that can possibly turn to threads on the future market:

1. Gas research from the utilities’ side has reduced significantly.
2. The new products (fuel cells, MCHP, and to a certain extent heat pumps) are not yet ready (need for further research, developments, test, demo etc.) or are still too expensive.
3. The gas technologies have difficulties in entering the promising market of cooling.
4. The heat demand is generally decreasing due to reinforcement of regulation. As a result, the payback time of gas heating is becoming longer for new installations.
5. Alternative energy will receive preferential treatment in the future; are the gas technologies ready to integrate e.g. solar energy?

Besides the reduced involvement of the gas industry, the worldwide transformations of the market, the merging of large energy utilities makes the question “how to promote gas” less relevant. In many situations the gas utilities are multi-energy providers and the electricity or district heating delivered to homes might very well be produced by burning gas in larger plants. Therefore the fact that the end consumers are not directly using gas does not necessarily mean he is not contributing to the gas market expansion.

In this situation it is difficult to identify the “gas customer” and difficult to clarify what could be a common strategy for the gas industry as there are large differences between the countries’ market organisation, but the question “how to increase the number of gas customers?” might very soon be an irrelevant question.

On the other hand we are in a transient period with the emergence of new technologies and fuels and this can be a real chance for gas to keep a predominant role in the future.

- What will be the place and role of the new MCHP technologies opening also for hydrogen?
- How much will the increasing demand for energy services benefit gas technologies?
- Will the leisure market - "garden" applications - develop?
- Will NGV develop?

There are some clear threats, but also real opportunities for the gas industry.
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 manufacturers. 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.

The regulative situation, example of EU
In the EU, the regulative situation will have a very strong influence on the market. The EU Commission are achieving the market transformation through various directives. Those directives shall be implemented in the member states with various degrees of flexibility.

Here are a number of directives that will definitively change the future market profile:
- The Energy Performance of Buildings (EPB). This regulation requires the reinforcement of building insulation and the utilisation of high-efficiency components. In many countries, the practical implementation makes the utilisation of traditional boilers impossible/illegal.
- The Energy Service Directive. Even though this directive is not yet in force, it seems that the Commission will make it mandatory that energy utilities shall sell a given percentage of their energy as "service". This means that the appliance (e.g. for heating) will at least partly been under the responsibility of the utility. There is no doubt that this will change the present market habits quite a lot and this might lead to the development of new technical solutions for the heating, cooling and electricity production in the domestic and commercial sectors. This can be a chance for the new emerging technologies (micro CHP, fuel cells etc.).
Support for Renewable Energy. RE is subject to large research programmes and the ambition of the EU is to achieve a substantial increase of the share of RE in the overall energy balance. There is no doubt that this will also bring a number of market changes for the gas appliances.

6.2 What are the principal hurdles and challenges for the present technologies?
Recommendations for the existing market/appliances
In this section, we summarize the lessons from the present study and we shall develop some recommendations.

6.2.1 Heating and hot water

Cost of the installation. The boiler technology of today might suffer in the competition against electricity. Considering the lowering of heat demand, electricity will certainly take some of the gas market shares because the payback time of gas installations will be too long for a number of new installations. Also electric heat pumps that can provide heat as well as cooling at a reasonable price will be an attractive product. In the future, the development of combined heat and cooling (and perhaps power – see below) systems would probably be the most appropriate answer from the gas industry.
Also, the price of appliances needs to 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. This is happening in many EU countries. Also for the developing countries, there is a need for cheap appliances to compete with cheap technologies and fuels.

In order to keep the payback time as short as possible, solutions for achieving low installation costs shall also be worked out. Flexible piping is among the solutions that allow the installer to work quickly and thus decrease the installation costs. Many of the present boilers are equipped with sensors able to pre-diagnose the failures as they occur. This also contributes to optimise the maintenance costs.

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). With the Internet it is now also possible to offer a direct and flexible information tool (see for example http://www.boilerinfo.org).

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 appliances.

6.2.2 Cooking

a) Domestic

The most important concerns related to natural gas cooking appliances are design, ease of cleaning and modernity (prior to operating costs, which explains why many natural gas users switch to electric cooking appliances). To a certain extent, the costs of indoor gas installations and fitting of the appliance are also a problem.

Gas cookers with ceramic plate and radiant burners are still not widely available on every market and are expensive. Moreover, they have a lower efficiency compared to traditional gas cookers and they do not offer the same flexibility (more inertia). To increase the gas market it might be necessary to introduce more widely this technology (and develop closed ventilation hood system). At the moment, the main competing fuel is electric energy used in electric cookers with ceramic plate and electric convection oven, and also IH cooking stoves.

Although gas appliances still hold competitiveness against IH stoves (see description in Annex), active developments of the electric appliances are threatening the gas market. 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 lifetime of the appliance (mainly because the average energy need for cooking is rather low).

However, in most cases one can say that the gas price/energy use is not the main reason for the lack of success of gas cooking. In most countries, customers are more oriented to design and comfort than to energy costs.

Indoor Air Quality is another important aspect of gas cooking. In order to eliminate the presence of flue gas, particles etc. in the kitchen the use of ventilation hoods has proven to be efficient, but add to the price of the installation. A recent development in Spain might bring the ultimate solution for the IAQ problem: a blue balanced cooker.
According to the experts in the IGU, IAQ issues in general are a problem in some countries, where there is a strong focus on the question.

The appliance, which is mainly responsible for IAQ problems, is the cooker, and CO, NOx, and micro-particles are the components in question.

The CO detector and adequate ventilation system are thought to be the measure for IAQ improvement. But CO detectors are used only in some parts of the world, as some groups consider them to give a bad signal to the consumer (“gas is unsafe - use CO detectors”), and they believe that an active system on the appliance would be more appropriate.

Recently, asthma allergy - so-called sick house syndrome - caused additional problems caused by chemical substances used for building materials. This has in many countries set the focus on building products and not on gas combustion products.

The use of hoods for the evacuation of water vapour and flue gas is generally solving the problem of IAQ. Note that extraction hoods are also used for electric cookers.

b) Commercial

Commercial cooking has a good potential. The most promising new technologies in this field are connected with improvements of the comfort level in the kitchen and operation ability (by introduction of micro-computer control). Also, a better design, easier cleaning and the decrease of heat radiation from the appliance and central flue duct system would be important future developments of this market. Finally, IAQ issues are also of concern in the commercial sector.

6.2.3 Cooling

See Section 5. Cooling - a case study “How to open the market to gas appliances”

6.2.4 Home fuelling

The number one way to drive the development of the market is to lower the price of the VRA, thus 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, eventually, with the help of active government sponsorship, home fuelling might become commonplace. The availability of a home based unit will provide the necessary infrastructure to drive the growth of the NGV market, making natural gas a mainstream fuel.

6.3 Conclusion, challenges related to existing applications

The existing applications and appliances are all menaced in some way or the other by the technological progress, the energy prices and the measures taken by states to promote some energies or technologies.

The issues mentioned below will be determining for the future of natural gas in the houses of tomorrow.

(1) Installation costs
(2) IAQ
(3) Combining gas and renewables
(4) Developing the gas market for air conditioning
(6) NGV development and home fuelling
(7) Micro CHP

Will there be gas in the house of tomorrow? The answer to that question depends on the capability of the industry to provide satisfactory answers to some of these challenges, and in particular the ability to integrate the new technologies.
7. THE MOST PROMISING TECHNOLOGIES AND PROSPECTS FOR THE FUTURE

7.1 Introduction

What will be the future for the gas technologies in the house of tomorrow? It is difficult to speak about new technology without speaking about the system. Because the future might not only see the emergence of new appliances it might also very well see the emergence of new system philosophies:

- Appliances will be multi-service/multi-energy. So they will not be dedicated to a single function but combine several: heating, cooling, hot water production, electricity production and even transport. They will use different energy forms: gas (also hydrogen and biogas), electricity and renewables and might produce from one energy form (e.g. natural gas or hydrogen) another form (electricity).
- Appliances might not be inside the house, but outside; possibly shared between several owners or a service provider.

Therefore, the new technologies for gas will develop when the infrastructure needed for the new constraints will be there. This infrastructure comprises the electricity net arrangements (organisation of the electricity produced and not used), the distribution systems for the energy services, the development of solutions to combine gas and electricity etc.

But the points mentioned above will be not sufficient. The new technologies must be competitive and the payback time must be attractive enough for the customer to afford a solution based on gas technologies.

It is difficult to predict which technology will win the challenge in the near future, as too many factors are interacting (technology development, technology price, energy price, policy, incitements, promotion etc.). Moreover, the external factors that can affect the developments vary from country to country (energy market, fuel prices, incentives, policy etc.). However, most experts agree on the following:

- The heat pump is the technology that is ready now and can be a first step in replacing the existing boiler technology at higher efficiency and at the same time bring a new function (cooling).
- The micro CHP technology based on gas engines is almost ready and might be the next technology that will bring decentralised production of electricity in the houses (domestic and commercial).
- The fuel cell technology (SOFC ad PEM-FC) is not yet ready for a wide dissemination, and some experts do not even believe in it (anymore). There are still some unsolved technical issues and the time horizon given for the technology to penetrate the market is often 6 to 10 years, although several pre-commercial field tests have been made (in Japan).
- There will be a development of “energy services” where the production of heat, cooling and electricity will not be the user’s responsibility. This might lead to a new type of installations (e.g. slightly larger appliances for servicing several houses).
- There will be more and more combination of energies to obtain the highest degree of flexibility and to optimise the prices. The above mentioned energy service will open for better possibilities to combine gas with renewables.

7.2 Review of the new technologies available today

In the following, we are listing a number of appliances that we have identified as being interesting and that are on the market or very close to being on the market. The compilation work carried out by the SG in collaboration with Marcogaz and GERG with a great support of an external organisation, ASUE, has been organised on a website:

http://gergpc.dgc.dk/public/Appliances_database/list_of_appliances_by_applicatio.htm [22]
This site is still under development and will be so for the next triennium. This first version is a demonstration of what is possible to do. Neither the site nor this report is pretending to be exhaustive, and manufacturers are welcome to contact us if they have products that can be interesting for the database (isc@dgc.dk). The collaboration with manufacturers will be organised for the next triennium.

7.2.1 Engine based mini and micro CHP

For more details and technical explanations please refer to the Annex.

The technology has not yet had its major breakthrough in this power range, and the appliances are generally considered expensive and are not always very reliable. However, there are products already available on the market or on their way to be. At the same time, there are several developments, lab. tests and field tests going on. These developments are done mainly in Europe, Japan and USA.

Engine-driven CHP units have a typical electrical output of 1 to 5 kW together with a thermal output of 2 to 25 kW. The targeted electricity efficiency is about 25 % for an overall efficiency announced at about 90%. The price targeted is about 1500 Euro/kWₑ.

The appliances need maintenance (every 2 or 3 years or so),

Stirling engines have a typical electrical output of 1 to 8 kW together with a thermal output of 2 to 10 kW. The targeted electricity efficiency is announced to be in a range from 12 to about 35 % for an overall efficiency announced at about 105%. Many manufacturers are already selling units (e.g. Microgen 2800 Euro, Whispergen 4500 Euro in the UK). In the UK there is a plan to install 80,000 units (WhisperTech) before the year 2010. Such an operation can very much be a catalyst for a large development of the market. This appliance that will be sold for the operation above, has at max. 1.2 kWₑ output and up to 8 kWₜₜ output.

The leading appliance (manufacturers) [21] for micro CHP with sterling engine are:
- Whispergen (probably the most accomplished available technology today)
- BG Advantica/Sunpower
- ENATEC
- SIGMA
- SIG
- SOLO

The main appliances using the microturbine technology are the following:
- Capstone
- Turbec
- Bowman

Finally, among the Internal Combustion technology (IC):
- SENERTEC (DACHS)
- ECOPOWER
- HONDA

The challenges of the mini CHP technology

Most of the information for this part of the report is from the report MICROMAP [21]. The MICROMAP study carried out in 2002 was aiming to clarify facts about the CHP market. Most of the conclusions still apply today. The following consists of an update of the above project.

There are still a number of challenges for the CHP technology:

1. Reliability and maintenance: CHP will compete with CH boilers and should, therefore, have equivalent or better maintenance and reliability performances.
2. Economical consideration (cost of the appliances, running costs).
3. Integration with the electricity distribution network.
The challenges of the mini CHP technology

4. Market mechanisms for the delivery of micro CHP.
5. Possibility of cooling with MCHP.

Standards are being developed (CEN) to facilitate safe and cost-effective connections. In practice, for the small units, it is expected that CHP will simply replace CH boilers. For larger units, the route might be different. A consortium of interested parties (energy distributors, finance houses, service organisations, etc.) could offer a more effective solution for the installation, running and maintenance of larger units selling services (see the “energy service” section) to big users or several smaller users.

For southern countries with high demand in cooling, the MCHP could provide a solution to reduce the summer peaks demands. However, the technology is not yet ready.

As the micro CHP unit is intended to replace the conventional gas boiler in a central heating system, the performance requirements and constraints are particularly onerous and are significantly different from those of conventional CHP. Micro CHP systems must be able to operate reliably with service intervals equivalent to annual gas boiler maintenance.

The presence of CH in the dwelling is a key parameter. When considering the replacement of a boiler by a CHP appliance the presence of the energy distribution system is a main advantage. The presence of district heating will also facilitate the integration of CHP (maybe with decentralised larger plans).

Technologies most likely to be successful in the long term are dedicated gas engine units, Stirling engines, within the next 2-3 years, followed by fuel cells within a 10 year timeframe.

Today, there are three Stirling engine developers producing 1 kW_e units aimed at the individual homes market. WhisperTech of New Zealand utilise an engine with relatively low electrical conversion efficiency (12%), but with heat to power ratio and other physical characteristics making it suitable for larger family homes as a floor-mounted unit. Both BG Group and ENATEC have produced wall-mounted units with a combi-boiler function based on linear free piston technology with low vibration and higher efficiency generators (16%). However, it is believed that their relative sophistication may require a longer time to market than the WhisperTech unit which was planned for commercial availability in 2003. Sigma are developing a 3 kW_e engine, with high electrical efficiency (>25%) and expect to have a commercial product available by 2005.

The two leading micro cogen fuel cell developers are Vaillant, using the PlugPower stack as the basis of a modulating 5 kW_e unit suitable for multi-residential applications, and Sulzer Hexis, using a SOFC (Solid Oxide Fuel Cell) to produce 1kWe with the facility to add 35 kW_t to enhance thermal performance. Both companies are involved in field trials in collaboration with energy companies, but do not expect to have truly commercial units for at least 5 years. Fuel cell systems are expected to have electrical generation efficiencies of 30-60% with overall efficiencies of 70-90%.

One of the commercially available IC (internal combustion) engine based units is produced by Senertec in Germany with an electrical output of 5.5 kW_e and 10 kW_t thermal. However, at this scale it is a multi-residential unit with relatively high noise level making it suitable only for plant room applications. The need for catalytic emissions control, acoustic attenuation and extended service intervals impose severe cost and size constraints on the unit. It is understood that Honda are developing a 1 kW_e unit suitable for individual homes, but the limited reports in the public domain indicate that acceptable performance has yet to be demonstrated.

Mini CHP systems for multi-residential groups use conventional internal combustion engines or the newly available micro-turbine technologies, which are being developed with fairly good performance, electrical generation efficiencies of up to 40% and overall efficiencies above 70% expected within 8 years.
The challenges of the mini CHP technology

Issues such as integration with the electricity distribution network and the home energy system are in the process of being addressed. In particular, network connection standards are being developed at EU level (CEN Workshop Agreement) and in the UK (by the Electricity Association) to facilitate the simple, safe and cost effective connection of micro CHP units.

Information on the following appliances is published on the website [22]:

- Micro CHP ENGINION Steamcell (1)
- Micro CHP WHISPERGEN
- Micro CHP DACHS SE
- Micro CHP ECOPOWER (3)
- Micro CHP SOLO STIRLING
- Micro CHP MICROGEN (2)
- Micro CHP OTAG Lion Powerblock
- Micro CPH ENATEC
- Micro CHP HONDA

Most of those appliances are designed to be installed indoor (design).

7.2.2 Fuel cells

A number of statements from the above section are also valid for fuel cells. But in terms of technology development, the fuel cell technology is behind the micro CHP technology and the appliances known are mostly in the final testing and field test phase before commercialisation. One of the leading manufacturers was said to have abandoned the development of domestic fuel cell appliance. However, this seems not to be truth anymore (see below).

MEDIA RELEASE
Swiss Investor for Sulzer Hexis

The fuel cell business of Sulzer Hexis will be continued by a foundation. It will finance the future development work.
As of January 1, 2006, a Swiss foundation will acquire 100% of the shares of Sulzer Hexis AG. This will allow the development of fuel cells to be continued at the established site. The company will be renamed Hexis AG as soon as possible. Dr. Alexander Schuler, currently head of systems development at Sulzer Hexis, will be the managing director of the Hexis AG.

This move will have no material impact on the previously announced charge to Sulzer’s operating income.

Winterthur, 22/12/2005
Compared to the Stirling engine technology, the fuel cell technology has advantages and inconveniences:

**The advantages are:** In principle, the electrical efficiency is much higher, no NO\textsubscript{x} emissions or particles and a very flexible adaptation of the load (full modulating range from zero to nominal load), no noise.

**The inconveniences are:** Cost and complexity of the technology. More than 20 main companies/actors of appliances/components have been identified [21] in this rather changing market.

Among the main actors/products:
- Vaillant (GE)
- H Power (CAN)
- Sulzer Hexis (CH) (see also above)

Information on the following appliances is published on the website [22]
- Fuel cell Vaillant (picture above)
- Fuel cell Viessmann
- Micro CPH SULTZER
- Fuel Cell by Panasonic and TOKYO-GAS

Fuel cell micro cogen units have a typical electrical output of 1 to 3 kW together with a thermal output from 2 to 7 kW. The targeted electricity efficiency is about 25 to 35% for a total efficiency of 80%.
Fuel cells field test in NL and GE (from http://www.gasuniereresearch.nl)

An EU-sponsored field trial project started in 2003, by putting into operation the first Vaillant fuel cell central heating system at Gasunie Research in the Netherlands.

This first field trial unit was installed at Gasunie Research in January 2003 and integrated with the existing heating installation.

In the framework of an EU project, in which a large number of German, Dutch, Belgian, Spanish and Portuguese energy companies and institutes are participating (including Vaillant, Eon, EWE, Ruhrgas, Gasunie, Cogen, and Plug Power) about 30 of these fuel cell central heating boilers will be installed in a field trial in the coming years, of which twelve have been installed in the Netherlands.

In December 2005, according to Vaillant all fuel cells together have now produced a total of one million kWh of electrical energy.

The prototypes developed by Vaillant and the American fuel cell company Plug Power generate a maximum electrical output of 4.6 kW and thermal output of 9 kW. This can cover the basic needs for power, hot water and heating in blocks of flats. Parallel to the field tests, which will continue until the end of 2006, the fuel cell technology is being developed continually with regard to costs and its practical maturity. Fuel cell heating appliances are not expected to be ready for the market before 2010.

7.2.3 Heat pumps

Heat pumps are considered by many the next large development of gas application in the residential ad commercial sector. Heat pumps are able to produce heat with a high efficiency and at the same time produce cooling, which is an increasing market demand. However, the development of the market depends on a number of parameters; see Section 5 of this report.

Principle

Gas engine-driven heat pumps are basically working the same way as electric heat pumps. A natural gas engine powers the heat pump compressor. During the winter, heat recovered from the engine exhaust (or and an optional gas boiler) provides supplemental heating to the indoor space.

Most gas engine heat pumps are built with variable-speed engines and fans that match the equipment capacity to the actual building load. The heat pump compressor can be either mechanical or thermo-chemical.

Information on the following appliances is published on the website [22]:

- Gas heat pump Japanese development
- Gas heat pump BUDERUS Logano
- Gas heat pump Vaillant
- Gas heat pump (air) - ROBUR
- Gas heat pump (water) - ROBUR
- Gas heat pump SANYO ECO G
- Gas heat pump AISIN SEIKI and SANYO
- Gas engine Heat Pump MITSUBISHI HEAVY INDUSTRY
- Gas heat Pump SANYO SGP-E190J2GU2W
7.2.4 Energy service

Energy service might very well be a new way to provide users with heat, electricity and cooling (instead of selling gas). Such a system, where the consumer does not own his boiler, but *rents it from the gas utility*, could solve some of the questions as appliance, installation and service costs. As a matter of fact, the gas utilities would probably be able to reduce the installation price if they develop some standard technical solution. The boiler cost and installation could be covered by a kind of renting fee. Such a system is already used in a few countries; for example 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 leasing company. The customer pays for the installation cost and a monthly fee.

Another solution is to place the appliance outside the user building and have one appliance servicing several houses.

7.2.5 Combining gas and solar (Heating hybrid systems)

There is a need for gas appliances that are designed to be used in combination with solar energy, and there is a need to have standard solutions for the installation of such appliances.
Information on the following appliances is published on the website [22]:

- Hybrid gas solar boiler JUNKER ZBS 16 solar (picture)
- Hybrid gas solar boiler ATAG combi HR SGC
- Hybrid gas solar boiler SIEGER
- Hybrid gas solar boiler BLOCSOL COMBI PSD

7.2.6 Cooking

Oranier cooker

Glass ceramic cook top for gas applications is now a technology that cannot be considered new anymore despite sales being limited.

Among the newest developments in this area we can mention:
- 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.
- New design for easy cleaning and better look.
- Natural gas development of flue balance appliance.

For commercial cooking new technologies, are mainly aiming at improving efficiency and reliability. 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).

Information on the following appliances is published on the website [22]:

- Cooker Arrow gas top from Caldera
- Cooker Prometeusz gas hob GPC 600 S
- Cooker Oranier vitro ceramic

7.2.7 “Garden” applications

Garden applications have developed in the last few years. The development of leisure and welfare brings new demands from the market, and grills and patio heaters are offering new ways of cooking and leisure. Plug-in systems are needed for those non-permanent applications.
Outdoor grill

- Grill AZ Gastechnik (picture above)
- Grill Delmar / Magma
- Grill Magic

Patio heaters

- Heatware Patio heater
- Guandong Natural Gas Stainless Steel Outdoor Patio Heater
- Rewilliam patio heater
- Arctic Sun patio heater (picture)
- DCS patio heater

7.2.8 Home fuelling

Information on the following appliances is published on the website [22]:

- Vehicle Refuelling Appliances (VRA) FUELMAKERS (picture)
- Vehicle Refuelling Appliances (VRA) FUELMAKERS "Phill"
7.2.9 Other

Washing machines

Information on the following appliances is published on the website [22]:

- Washing machine MIELE (example)
- Washing machines and dryers comparison (in German)
8. THE FUTURE, SOME EXAMPLES

In this section we will discuss what we think (as gas industry) would be the perfect answer to the needs (heating, cooking, cooling etc.) in the domestic sector.

The first exercise is purely theoretical as we imagine the ideal appliance(s) (8.1) but we try to give a more realistic view on the future taking into account the present knowledge on technologies (8.2, 8.3 and 8.4).

8.1 The ideal appliance concept

The ideal appliance(s) would produce all needed services inside the house; this can be done with 3 to 4 different independent units or modules. To optimise the energy saving the appliance would combine gas with renewable energy (PV, thermal solar). The appliance would have very low emission, either by optimized burner design or by flue gas cleaning.

To facilitate the maintenance, the appliance parts would need to be accessible for the maintenance operation without penetrating in the building/house. The appliance would be connected to a maintenance/service company able to follow on-line a possible failure. The appliance might either belong to the service organisation or to the house owner.

The cost of such appliance would probably be higher than the price of the appliances we know from today’s market, but considering that the appliance would produce more services: all electricity of the house (and maybe more that can be sold) + the car fuelling etc., the total cost shall be considered with regard to the total saving including all the services.

Such appliance does not exist for the time being, so let us look at future scenarios for the gas utilisation in the domestic sector.

In the following section we have considered several options or possibilities
8.2 No gas (in the house)

One might think this is the worst option, but not necessarily. Not if electricity is produced by effective gas plants (e.g. turbines) and district heating. This centralized energy production might be a good solution and an answer to a number of challenges, such as maintenance and installation cost and safety.

Due to the below facts gas will become too expensive to use for new buildings and possibly also for existing installations.

- The implementation of very severe insulation regulation on buildings has resulted in a very low heat demand of a house (e.g. 4000 KWh/year or so).
- A steep increase of water price will have some secondary consequences, such as a strong optimisation of sanitary hot water systems also reducing the demand to e.g. less than 1000 kWh/year (it is about 2000 today).
- The electricity price (compared to gas) becomes more favourable due to the economical and technical situation.
- Etc.

8.3 Only gas (and electricity produced with gas)

This is the most optimistic scenario. Suppose the electricity price increases, the equipment in the house is exclusively gas and we are almost in the ideal configuration mentioned above, but today there are no large integrated appliances; all services are produced by dedicated appliances. In a way this is a kind of intermediate step before the ideal solution of 8.1.

Below we show a possible design configuration of such a house:

- Cooking (flue balanced)
- Heating cooling (Fuel cell/heat pump, smart distribution systems, controls)
- NGV (domestic refuelling station)
- Washing and drying
- Decorative fire place
- Grill/patio heater/decorative gas light

In an even more futuristic approach we could image a fuel cell car that would also provide the electricity for the whole home.

In the Annex of this report we have elaborated on some of the ideas related to the gas technologies that would be present in the future houses.
8.4 Local net

The principle of what we call the local net is that the production of services (heat, cooling, electricity etc.) is not integrated in the house but outside. Moreover, the production is dedicated to more than one house. This concept is very well adapted to the energy service concept. The main advantage is that the relative cost of the investment for the production appliance is shared and should therefore be competitive. So is the maintenance. This might therefore make it easier to incorporate new technologies and renewable.

8.5 Gas-Electricity mix

For this last case, we are in the situation we know today, where gas and electricity are mixed. This is also the most probable scenario unless there is a very strong change in the energy prices that will make one of the above scenario solutions more attractive. For this last case, the way electricity and gas will balance very much depends on the technology development and appliance prices.
9. CONCLUSION

Is there a future for gas in the house of tomorrow? The answer to this provocative question is yes! At least for the existing installations gas will remain in a strong position, because with an existing infrastructure, gas has an attractive price.

A more difficult question is what will be the share of gas in the domestic utilisation in the future? Nobody can give a reliable answer to this, but we can list a number of parameters that are key elements for the success of the energy gas:

**Economical key factors**
- Energy prices
- Reducing the costs (installation/appliances/maintenance)
- Possible financial incentives

**Technical key factors: the capacity of the industry to solve a number of challenges**
- Reducing the costs.
- Succeed in introducing cooling/air conditioning with gas and taking electricity market shares (first in the commercial sector).
- Succeed in solving the technological developments of micro CHP and optimising the control and design of the installations.
- Succeed in developing attractive combinations of gas with solar technologies.
- In general succeed in integrating the new technologies in houses.
- Succeed in developing energy service solutions.

The work of the SG 5.2 was to gather data and information about the market and prospects. This work will hopefully help the gas industry to develop adequate actions to further the development of the market for gas utilisation. This rapport shows that there is an existing high potential for development.

For the future we can conclude in giving a number of suggestions about the work in the next triennium in order to achieve continuity of the work done during the last three years. The idea is to bring a number of results and knowledge to the group of experts of the next triennium so that they are not going to start from nothing.

Some of the tasks and objectives of the work could be as follows:

1. **Inform about and demonstrate gas utilisations.** There is a need to exchange information within the gas industry and a need to inform interested parties outside the gas industry about the technologies and their integration (targets are gas industry, authorities and users). For this purpose we would suggest to continue the development of the innovative appliance website and open it to the manufacturers who could contribute directly. Also, we need to develop example cases showing the integration of gas technologies.
2. **Maintain our knowledge about market data.** (Keep the database on appliances updated). This consists of market data and performance data of the appliances. It is important to keep this updated so the gas industry can rapidly answer to questions on the impact of gas utilisations. This work was done three years ago and needs an update in the next triennium
3. **Gas technology impact assessment.** Carry out case studies on specific applications demonstrating how gas technologies compare with other technologies with regard to environment and energy savings.
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ANNEX 01: UNITS, CONVERSION FACTORS AND ABBREVIATIONS

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 \times 10^3 J

1 toe is a ton of oil equivalent. This is 10 million kcal or 41.86 Gjoule
Note that 1 m³ 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
- IC: Internal Combustion engines
- IH: Induction Heat (electrical cookers)
- LPG: Liquefied Petroleum Gas
- NG: Natural Gas
- NGV: Natural Gas Vehicle
- PEM: Proton Exchange Membrane
- PV: PhotoVoltaic
- RE: Renewable Energy
- SOFC: Solid Oxide Fuel Cell
- VRA: Vehicle Refuelling Appliance
ANNEX 02: SHORT EXPLANATION OF THE TECHNOLOGIES COVERED BY THIS REPORT

1. Heating and 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 into 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.

2. Cooking

The cooker technology design is widely known. Generally, it 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. Up to recently, the combustion products are going into the room where the appliance is installed. Now, ventilation systems to evacuate the combustion products from the room are being used more and more (also for electric cooking, where it is for evacuation of water vapour). 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. 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.

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/H₂O) fluids. Only gas combustion energy is used for generation of H₂O gas from LiBr/H₂O in single-effect absorption chillers. Gas combustion and condensing energy of H₂O is used for generation of H₂O gas from LiBr/H₂O 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
A triple-effect absorption chiller has three generators, which are called HGE, middle-temperature generator (MGE) and LGE.

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.

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.
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 (50,000). In the USA, probably more people are familiar with gas lamps than anywhere else in the world.

6. Micro CHP (from [21])

Although the energy flows indicated in figure 1 apply to Stirling engine based units, the illustration can be applied conceptually to other technologies including fuel cells.
Natural gas is consumed in a Stirling engine (or other prime mover) to provide heat and electricity for use within the home. (Note that the figures in the diagram above are for illustrative purposes and depend on the specific technology as well as the actual product under consideration.

Typically, more than 70% (GCV) of the energy value of the gas is converted into heat, principally in the form of hot water which is used for space heating and domestic hot water as in a normal central heating system. Between 10-25% is converted into electricity, and the remainder (5-15%) is lost in the flue gases.

7. Fuel Cells (from [21])

A fuel cell is an electro-chemical device that typically converts hydrogen and oxygen into water, whilst producing DC electrical power from the reaction. Heat is also produced since the process is not 100% efficient. Emissions tend to be very low because fuels are not combusted and high efficiency is possible, especially if pure hydrogen is the fuel.

A single cell produces little power alone, so practical fuel cell systems are built in multiple units, or cell stacks. In addition, few cogeneration plants run on hydrogen or supply DC power and, therefore, two other components are usually required: the gas reformer and the DC power conditioner.

The main technology characteristic that distinguishes one fuel cell type from another is the electrolyte. The five principal types are:
- Proton exchange membrane (PEM)
- Alkaline fuel cells (AFC)
- Phosphoric acid fuel cells (PAFC)
- Solid oxide fuel cells (SOFC)
- Molten carbonate fuel cells (MCFC)

Two fundamental technology paths are being pursued for fuel cells: high temperature and low temperature operation. PEM, PAFC and AFC fall into the low temperature category whereas MCFC and SOFC make up the high temperature options. Although fuel cells all operate on the same principle, operating temperature has important implications for balance of system design and application fit. Specifically, low temperature fuel cells require more complex fuel processing (i.e. a separate reformer) since they can only convert hydrogen to electricity. These fuel cell types are also more sensitive to carbon monoxide (CO) poisoning. High temperature fuel cells are able to directly
convert hydrogen and CO to electricity and can internally reform simple hydrocarbon molecules into these compounds.

8. Micro-Turbines (from [21])

It works as follows: Incoming air is compressed and then passes through the recuperator where it gains heat before entering the combustor. Here, compressed natural gas (or other fuel) is introduced and the hot high pressure gases are exhausted through the turbine which extracts energy and uses it to drive the compressor and shaft-mounted alternator. The exhaust gases are then fed through the recuperator and into a boiler or absorption chiller for CHP and cooling applications. The alternator is a high speed device (typically rotating at 75,000 to 100,000 rpm) producing a high frequency output; this is converted to the desired mains frequency and voltage in the power conditioner.

9. IC technology

There are two main types of internal combustion (or reciprocating) engines used for power generation and cogeneration applications, namely:

(i) Spark ignition (gas) engines. Most modern gas engines work on the Otto principle where the fuel is premixed with air before compression in the cylinders. The mixture is ignited by a spark and burns rapidly and relatively evenly in the whole combustion chamber. They run mainly on natural gas for power and CHP applications.

(ii) Dual fuel compression ignition (diesel) engines. These operate on the diesel principle whereby the fuel is injected after compression of the air in the cylinders and heat release is controlled through the combustion phase. Compression ignition machines rely on the continuous supply of a medium or light fuel oil for their operation and consumption of this pilot fuel must be maintained at a minimum level of between 5 and 10% of the total fuel input; it may also be increased to represent 100% of input (i.e. oil firing). Dual fuel machines have the advantage of a degree of fuel flexibility and this can represent an important consideration when dealing with interruptible gas supplies. One disadvantage is that fuel storage facilities must be provided and this can be a limiting factor where space is at a premium.

Reciprocating engines have been commercially available and in widespread use for more than 50 years. They present a relatively inexpensive and efficient means of producing electrical power with electrical efficiencies in the range 25 to 41% and overall system efficiencies in excess of 80%. However, traditional IC engines have been developed for uses other than power generation and have higher noise and emissions levels than other prime movers being developed for small scale cogeneration markets. A further drawback is the high maintenance requirements and correspondingly high O&M costs (3 p/kWh @ 10 kW_0, 0.9 p/kWh @ 40 kW_0). As a result, a number of manufacturers are developing small, new generation, IC engines aimed specifically at the micro CHP market.
ANNEX 03: GAS IN THE HOUSE OF TOMORROW, EXAMPLES OF TECHNOLOGIES AND INSTALLATIONS

This is the background for the presentation entitled “Technology for low-energy housing Natural gas and oil” by Bjarne Spiegelhauer, Danish Gas Technology Centre. The initial presentation was adapted with the result of the study in SG 5.2 and will be used as a collective presentation of an example of the SG5.2 work. This Annex might repeat some of the sections of the report; this was necessary to keep this part as an independent report for a presentation. This Annex can be considered a light version of the report.

Introduction

The energy consumption in individual housing is globally decreasing and the technologies are evolving together with the consumer request for more comfort. We might ask ourselves the question on the competitiveness of the gas technologies in the future. Will the gas technologies be able to meet the market demand at competitive price?

This presentation will shortly look at the heating technologies and heat distribution systems and will conclude on the chance and challenges for future heating with gas technologies of housing with low energy demand.

Energy consumption in individual housing

All over the world the concern about CO₂ emissions has resulted in the reinforcement of the building insulation regulations, for example in Denmark. (This is also representative for many countries, especially in the EU):

- New requirements in the upcoming Building Regulations
- Heat loss approx. 30 % compared with existing requirements
- To be reduced by a further 25 % from 2010 to 2015

- Low-energy housing
- Heat loss approx. half of that of an ordinary single-family house
- Perhaps no requirements for type of energy supply

At the same time there are new requirements for boiler efficiency.

To illustrate this, the graph below shows the annual energy consumption evolution. (Still the same example for Denmark for both standard housing and for low-energy housing (pink dots)).
Energy consumption in individual housing

The following example is based on the Danish situation.

The typical energy consumption of a traditional new single-family house of 125 m$^2$ is

- Heating, cooling, ventilation: 9,300 kWh
- Sanitary hot water: 1,700 kWh
- Electricity consumption: 4,500 kWh

Total: 15,500 kWh

The natural gas consumption for heating and sanitary hot water is therefore about 1,000 m$^3$ per year.

The typical energy consumption of a new low-energy single-family house of 125 m$^2$ is

- Heating, cooling, ventilation: 3,800 kWh
- Sanitary hot water: 1,700 kWh
- Electricity consumption: 4,500 kWh

Total: 10,000 kWh

Natural gas for heating and sanitary hot water is therefore only half of the above ~ 500 m$^3$ per year.

Heating technologies

Today the most common technologies for heating are gas- and oil-fired boilers or furnaces and electric radiators.

To a certain extent, gas-fired radiators and heat pumps, electrical and gas-fired, are also used to some extent depending on the county considered. Wood burning stoves and thermal solar energy is also used mostly to complement another form of heating. However, in some countries, solid fuels (wood, coal) are used as main heating. Those are countries where wood is abundant (e.g. Sweden) or where solid fuels are the cheapest option (e.g. China).

Micro CHP systems are not yet really on the market, but we see the beginning of the technology introduction.
Today, heating with boilers is quite efficient and there are very severe regulations on boiler efficiencies (e.g. in the EU). However, the requirements are generally given on nominal performances measured in the laboratory while the real performance of the appliance is also depending on the installation: The graph illustrates a typical variation of annual efficiency (y-axis) of two boilers depending on the annual heat demand (x-axis).

It is feared that due to the decrease of the heat demand, the relative cost of a central heating installation will be too high to compete with electricity, at least for the sector of new construction. The new gas technologies might keep gas in the house, but there are a number of challenges.

The new gas technologies

Annex 2 explains the new technologies (micro CHP, heat pumps etc.) and how they work. We will not repeat this here, but will concentrate on the integration and economical aspects instead.

The replacement of CH boilers by MCHP appliance is possible, but not always straightforward as it brings a number of questions to the installation design. The main difference is the electricity production and there are still open questions about the organisation of the use of extra electricity production. The way to adapt the operation of the system to the customer need shall also be clarified. How to optimise the system to produce the required heat and electricity need? Appliance sizing? How to manage the peak demands, etc.
Below is shown an example of a system that integrates a peak heater module.

The Complete Fuel Cell Heating Appliance System

Picture from Vaillant

Cheap and simple?

The economical and technical challenges of the new technology are not easy to solve. When the technical barriers are solved, we still might have appliance that are much too expensive compared to electricity (because of the decreasing heat demand).

Therefore an alternative is to consider the present technologies in simple and cheap version.

- Gas radiators could be an alternative to electrical radiators.
- Cheap a simple boiler? When the heat demand is only 5000 kWh, the efficiency is not really an issue, but the cost of the appliance is. Therefore, a very simple and cheap boiler might be an interesting product for the future. Such a boiler could be placed in a place accessible from outside the house. The service could be made without the presence of the house occupants. Moreover there will be less safety issues (gas and flue gas are not in contact with the indoor air).
New material for the reduction of the cost of the installation. New material can make the installation easier and so cheaper.

**Smart?**

But the cost is not necessarily an issue for all the users. For the customer who do not care about the costs, but want to have smart and well designed heating systems, the traditional distribution system as we know it (radiators) could be replaced by convector that are fully integrated in the building construction. Keeping gas in the house is also a question of making sure that gas solutions are smart and with an appealing design.

In the example above the distribution system is integrated in the window frame and thus becomes invisible.
New gas utilisations

As mentioned above, the heat demand is decreasing and so is the gas consumption. A way to persuade the customer to keep gas for heating is to develop new gas utilisations.

- **Cookers**: Not really a new application and has already a strong position on many markets, but electricity is taking market shares in almost all countries. Maybe a new generation of cookers (balanced flue) will bring the same comfort (ease in cleaning) compared to electricity and at the same time solve the indoor air quality problem.
- **Tumble dryers, washing machines, dishwashers**: Technologies are present, but have not yet achieved taking a significant share of the electric appliances market. One of the problems again is the installation cost. When bought separately those appliances will have important installation costs. Part of the solution is to have design solutions ready for at least new buildings, where the gas technologies and installation could be bought as an integrated package in an adapted building architecture.
- **Outdoor grills, Patio heaters and gas light** are developing and could gain a growing market share in a society where leisure is gaining in importance.
- **NVG refuelling stations**: A new type of gas utilisation that will be able to beat any other domestic utilisation in terms of gas volume sales. The average consumption is not known, as it depends too much on national, regional or individual cases, but in any case it will in a large majority of cases give much larger consumption than heating.

Conclusions - How to keep the gas customers?

**Simple and low-priced systems**

As described in this report the cost of the installation is becoming a major challenge. The competition with electricity will be harder in the future, and one of the key elements of success for the gas application will be the cost.

**Efficiency**

The efficiency of a gas appliance is one of the strong features and advantages of gas over electricity. The present level of efficiency should be maintained despite new challenges (e.g. appliances need to cope with a wider band of Wobbe indexes because of the development of LNG market).

**Heat distribution and comfort**

To a greater and greater extent the customer’s priority is the comfort. Here there are also a number of challenges with many applications. For instance cooking (ease of cleaning), hot water production (constant temperature level)
Finally, the future will open new opportunities, like for instance the energy service approach. The new emerging technologies are making the near future an exiting challenge for the gas industry. The success is depending on the capacity of the gas industry to solve the technical problems and to integrate the new technology in the homes of tomorrow.