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CRITICAL READING OF THE WUPPERTAL INSTITUTE STUDY

Greenhouse Gas Emissions from the Russian Natural gas Export Pipeline System

performed on behalf of
Cedicol

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SUMMARY

0. INTRODUCTION

In June 2004 (updated in February 2005), RDC Environment, at the request of Informazout, published a study entitled “Energy balance and greenhouse gas emissions throughout the life cycle of natural gas and fuel oil for domestic heating”. The study showed that the transition from a heating oil to a natural gas boiler in Belgium in 2005 will not lead to a significant relative decrease in greenhouse gas emissions. This was in particular due to the fact that for gas, the emissions due to processes upstream of combustion contribute in substantial fashion to the global balance of greenhouse gases.

A report by the Wuppertal Institute and the Max-Planck Institute entitled “Greenhouse Gas Emissions from the Russian Natural Gas Export Pipeline System” was published in February 2005. Among its conclusions, it underlines the fact that emissions made during the international transport of Russian natural gas are less significant than was previously thought. Consequently, the report concludes that total greenhouse gas emissions (direct and indirect) are lower for natural gas than for heating oil.

The objectives of this critical reading consist first and foremost in carrying out an analysis of the Wuppertal Institute report and in conveying the hypotheses and principal conclusions of said report. Secondly, an attempt will be made to establish whether the data provided in this report is compatible with the hypotheses retained in the RDC Environment study and, if necessary, to check whether the conclusions of the RDC Environment study are subject to change if the data from the Wuppertal Institute study is used.

1. ANALYSIS OF THE WUPPERTAL INSTITUTE STUDY

1.1. INTRODUCTION

This study is based on a measurement campaign carried out by the Wuppertal Institute for Climate, Environment and Energy and the Max Planck Institute for Chemistry at the request of E.ON Ruhrgas AG.

The objective of the campaign was to establish the indirect emissions associated with use in Germany of Russian natural gas. In fact, the combustion of natural gas involves less significant CO_2 emissions, in principle making it a very efficient fuel as compared to other fossil fuels with respect to greenhouse gas emissions. However, it is also known that indirect emissions associated with the production, treatment and transport of fuels play an appreciable role. In the case of natural gas, the two predominant factors are energy used in transport and gas leaks.

Up until recently, indirect emissions of natural gas from Russia were based on estimates alone. In the mid-nineties, a number of measurement campaigns took place (Ruhrgas and Gazprom, US EPA). However, these campaigns were either hindered by a lack of transparency or were only carried out for a limited number of sites. That is why a new measurement programme was developed with the Wuppertal Institute.

The IPCC describes three methods for the estimation of atmospheric methane emissions. The top-down approach consists in measuring global emissions of methane directly in the atmosphere. The second method is the establishment of a mass balance for methane. In the bottom-up approach, the emissions from each potential source are assessed and then extrapolated to obtain total emissions. It is the bottom-up method that was retained by the Wuppertal Institute. Further information relating to the various evaluation methods for atmospheric methane emissions may be consulted in the RDC study.

1.2. HYPOTHESES AND LIMITS OF THE STUDY

The Wuppertal Institute study considers greenhouse gas emissions linked to the production, treatment and transport of natural gas from Russia to Germany. It therefore takes account of CH_4 emissions (mainly leaks), and also of CO_2 and N_2O (combustion) emissions. Russian gas exported to Germany comes from West Siberia and is transported in two long-distance pipeline networks.

The quantities of gas emitted during the extraction and treatment of natural gas are taken into account. However, no new measurements were carried out for these two stages. The aim of the study is in fact first and foremost to measure greenhouse gas emissions from the transport network for Russian natural gas. Nevertheless, in order to compare the full energy systems, there is also a need to consider the data relating to the extraction and treatment of natural gas.

In order to establish emissions up to the German border, the results obtained for Russia are extrapolated to the pipelines situated in Ukraine, Slovakia, the Czech Republic, Belarus and Poland.

Three measurement campaigns were carried out at five different compressor stations in the spring and autumn of 2003. These stations were constructed between 1972 and 2001 and represent a total of 50 compressors with power of between 6.0 and 22.2 MW. In addition, around 2,380 kilometres of pipelines were flown over by helicopter so as to detect gas leaks. The number of measurements is relatively high and, according to the authors of the study, allows for calculation of mean data for the two pipeline networks. It should nevertheless be pointed out that these two networks include, according to the Wuppertal Institute study, 53 compressor stations and 1,564 compressors.

1.3. RESULTS AND CONCLUSIONS

According to the Wuppertal Institute study, methane emissions on Russian territory emanating from the natural gas transport network for exportation represent approximately 0.7% of natural gas arriving at Russia's western frontier. The sources of emissions are mainly due to leaks in compressor stations and, to a lesser extent, leaks in pipeline valves. Gas emissions associated with servicing, repairs and accidents are of lesser significance. The confidence interval for methane emissions was estimated using the Monte Carlo method. Methane emissions are between 0.4 and 1.6% with 95% certainty.

The values calculated for Russia were subsequently extrapolated up to Germany's eastern border. When the data takes into account the supply of gas into Germany, the characteristic emission value for methane is 1% of natural gas arriving at Germany's east border, with this value fluctuating between 0.6 and 2.4%.

Methane emissions are not the only significant emissions as regards greenhouse gases. The energy required to transport gas over the distances included in the Wuppertal Institute study, approximately 4,300 and 5,500 kilometres, is also considerable and generates CO_2 emissions. Indeed, CO_2 emissions for the transport of natural gas are twice as substantial as methane emissions expressed as CO_2 equivalent.

Greenhouse gas emissions are summarised in the table below. These involve indirect emissions for Russian natural gas up to the German border.

Table 1: Indirect greenhouse gas emissions for Russian gas up to the German border

	CO_2		**CH_4**			**Total**	
	t/TJ	g/kWh	t/TJ	t CO_2 eq./TJ	g-eq. CO_2 /kWh	t CO_2 eq./TJ	g-eq. CO_2 /kWh
Lower limit	7.8	28.08	0.12	2.6	9.36	11.1	39.96
Mean	8.7	31.32	0.20	4.3	15.48	13.4	48.24
Upper limit	9.7	34.92	0.46	9.7	34.92	19.1	68.76

This table is accompanied by a few comments:

- The conversion factor used to transform CH_4 emissions into CO_2 is 21, whilst the latest IPCC report estimated this factor at 23.
- The “Total” column also includes N_2O emissions, which are insignificant.
- The variation range for the total is lower than the sum of individual variation ranges, which can perhaps be attributed to the use of the Monte Carlo method.
- The data from the Wuppertal Institute study was converted by ourselves into g/kWh so as to facilitate comparison with the data from the RDC study.

1.4. CRITICAL ANALYSIS

The study was conducted by two recognised German scientific teams. The study programme seems complete and the measurement methods appear to be correct. Three measurement campaigns were carried out and the measurements made cover a relatively wide range of pipelines and compressors. The study is sponsored by E.ON Ruhrgas AG and required close cooperation with Gazprom, the Russian gas company for the selection of measurement sites. Some data, such as that relating to accidents, was provided directly by Gazprom. The reliability of this data remains relatively uncertain insofar as the independence of actors is not established.

Three measurement campaigns were carried out during spring and autumn. It is hard to estimate the effect on results brought about by the time of year at which measurements are made. In winter, the volumes transported are greater and consequently energy consumption and leaks may well be higher. On the other hand, as temperatures are lower, the density of the gas is higher and compressors may possibly be more efficient. A large number of effects are involved and it is in principle difficult to determine whether, in the end, the seasonal effect is positive or negative.

The report available includes the main hypotheses of the study and a summary of results. The full study documentation exists in the form of eight reports which are, however, branded confidential and are consequently not available to the public. These reports would nonetheless be useful since the data provided in the summary does not enable checking of the accuracy of all calculations made in the establishment of results.

The report only deals with the impact of greenhouse gas emissions. This impact was calculated according to the supposition that one gram of methane is equivalent to 21 grams of CO_2 over a 100-year period. The latest IPCC report considers the effect of methane to be 23 times that of CO_2 over a period of 100 years. The retained value of 21 is justified by the Wuppertal Institute on the grounds that it is the value associated with the Kyoto Protocol. The value of 23 seems to us to be more correct, as it is based on a more recent assessment. The value of 21, which minimises methane emissions, is nevertheless still widely used, with the most important consideration remaining to produce comparisons based on equivalent value.

For the use of Wuppertal study data in the RDC study, we have used the same factor of 23 that was retained in the RDC study. Contrary to the RDC study, the report only considers greenhouse gas emissions over a period of 100 years. It was nonetheless possible to recalculate the results for periods of 20 and 500 years.

As the Wuppertal Institute report only deals with greenhouse gas emissions, it does not indicate energy consumption at the various stages in the life cycle. It is therefore extremely difficult to recalculate the energy efficiency chain. This point seems to us to be significant, as greenhouse gas emissions are dependent on the efficiency of the various processes from extraction to final use. We do not know how these efficiency levels were taken into account, in particular for figure 10 of the Wuppertal Institute report.

The allocation of greenhouse gas emissions is not clearly explained. The allocation criterion is based on the percentage of the volume of gas imported (and thus of the proportion of energy required) into Germany each year compared to the total volume transported on Russian territory. This value is estimated at 13%. The data provided in the report does not allow this information to be checked. Nevertheless, this value is very high, since it is using this percentage that methane emissions are converted to a precise quantity (Terajoules, etc.) of natural gas used in Germany.

Furthermore, it may be questioned whether the allocation rule chosen allows for an accurate representation of the breakdown of greenhouse gas emissions. By selecting an allocation rule based on the volume of natural gas, the distance factor may not be properly taken into account. It is therefore possible that the transport of identical quantities over different distances is considered to produce identical quantities of greenhouse gas emissions, which is not the case. In other words, an identical quantity of natural gas used near the deposit sites and near the Russia-Ukraine border could be allocated the same emissions. This would constitute an underestimation of emissions of natural gas used in Germany and Belgium. Unfortunately, the information available in the Wuppertal Institute report does not allow these hypotheses to be checked.

The authors of the study, when contacted on this subject, indicated that calculations were made for mean energy consumption per kilometre. Using this data, the energy required to transport the volume of gas imported into Germany was estimated, taking into account the total distance travelled by the gas. It therefore appears that the distance parameter was taken into account in the allocation rule.

This allocation rule represents one of the most important study parameters, and its selection is not clearly explained or justified in the study.

2. COMPARISON WITH RDC STUDY

In this section, the results of the February 2005 RDC study are compared with the results that may be obtained using the data from the Wuppertal Institute study for the extraction and transport of Russian natural gas.

The Wuppertal study data is provided in the form of table 1, i.e., as aggregated data for CO_2 and methane emissions from the extraction of natural gas in Russia up to its arrival in Germany.

In the framework of the RDC study, greenhouse gas emissions are calculated from the extraction of natural gas up to its use in Belgium. In the RDC study, five key stages were therefore analysed: extraction of the natural gas, liquefaction, international transport of the gas, national distribution, and, lastly, combustion in the boiler. International transport of the gas obviously takes place up to the Belgian border, and not up to the German border. In addition, natural gas is transported by pipeline from Russia (55%) and also from the Caspian Sea (20%), and by liquefied gas tanker from Algeria (12.5%) and the Middle East (12.5%).

The data provided in the Wuppertal Institute study must therefore be adapted to take into account the greater distance covered up to the Belgian border. They subsequently replace the data relating to the extraction and international transport of Russian gas in the RDC study. In the studied carried out by RDC, the data relating to gas from the Caspian Sea was adapted based on data relating to Russian gas, with the assumption that transport distances are respectively 5,000 km for Caspian Sea gas and 7,000 km for Russian gas. The data for the extraction and transport of Caspian Sea gas was therefore also replaced by data calculated based on the Wuppertal Institute study data. The adaptation of this data took place as follows. For natural gas extraction, it was assumed that CO_2 emissions were identical to those of the RDC study, whilst CH4 emissions are equal to 0.11% of natural gas produced. The latter figure, lower than that estimated by RDC, comes from the Wuppertal Institute report and was confirmed to us by the author of the study. For international transport, it was assumed that CO_2 and methane emissions were equal to the mean values provided in table 1, from which the values relating to extraction were deducted. This value was then corrected taking into account a longer transport distance for the natural gas.

In the Wuppertal Institute study, natural gas is transported over a distance of 4,300 km via the north corridor (40% of gas from Russia going into Germany) and over a distance of 5,500 km via the central corridor (60% of gas from Russia going into Germany). The corrective coefficient is calculated for a transport distance of 7,000 km, equal to that retained in the RDC study. This distance seems a little high given that the distance between Germany's eastern frontier and the Belgian border is less than 1,000 km. By working in this way, the international transport distances for Russian gas are identical for the two scenarios studied. It is also assumed that greenhouse gas emissions are identical for the German and Russian networks. This despite the fact that it would appear reasonable to consider that the German network is better maintained, and that its leaks and energy consumption levels are lower.

The modified data for Russian gas and gas from the Caspian Sea is presented in the table below.

Table 2: Modified data

g/kWh	**Russian gas RDC**		**Russian gas Wuppertal**		**Caspian gas RDC**		**Caspian gas Wuppertal**	
	CO_2	CH_4	CO_2	CH_4	CO_2	CH_4	CO_2	CH_4
Extraction	3.96	0.5	3.96	0.078	3.96	0.5	3.96	0.078
International transport	44.3	1.42	38.15	0.895	31.64	1.01	27.25	0.64

The results of the comparison are presented in the figures below. The “RDC Gas” scenario corresponds to the results obtained with the mean hypotheses retained in the RDC study, while the “WI Gas” scenario is obtained by replacing the data relating to the extraction and international transport of Russian and Caspian Sea gas in the “RDC Gas” scenario with the data calculated from the Wuppertal study. The “Heating oil” scenario corresponds to the available information on heating oil in the RDC study, and has not been modified.

The results for the greenhouse effect were calculated over a period of 20, 100 and 500 years.

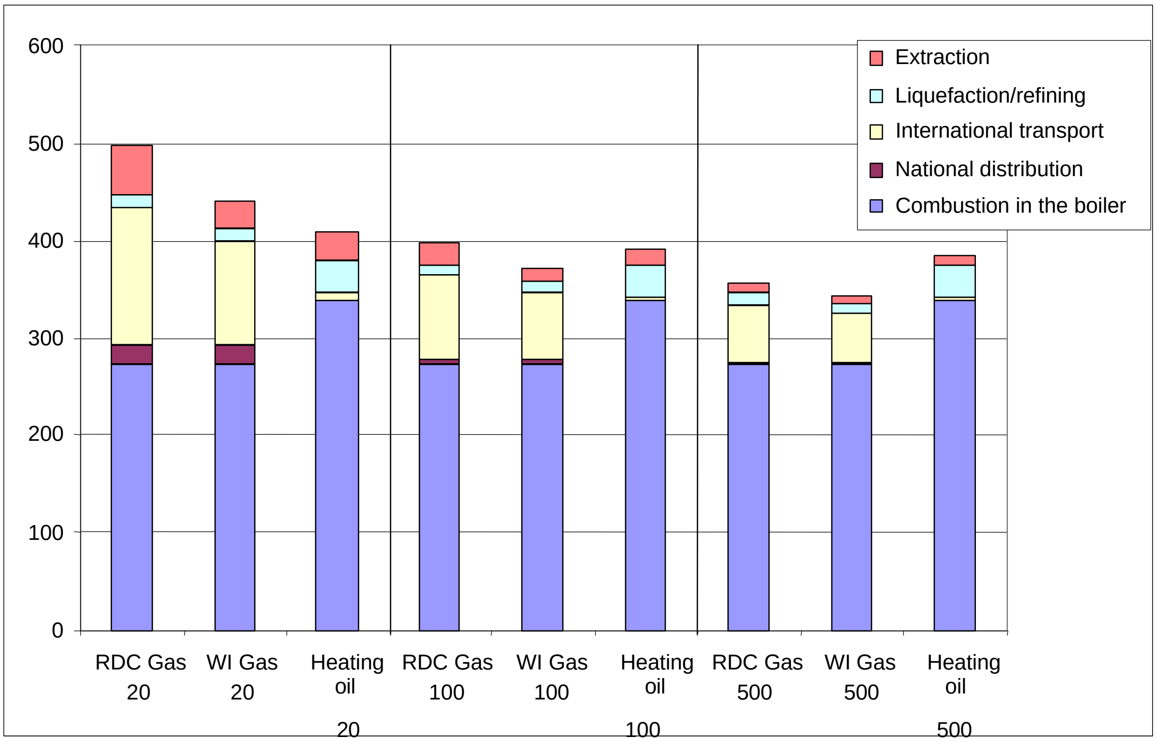

Figure 1: Contribution to the greenhouse effect of gas and heating oil boilers over 20, 100 and 500 years – Breakdown of GHG emissions by stages

Generally speaking, we observe that greenhouse gas emissions are lower for the gas system when the Wuppertal Institute study data is used. However, heating oil remains preferable when the greenhouse effect is calculated over a period of 20 years. For the 100-year and 500-year scenarios, gas becomes the fuel that contributes the least to the greenhouse effect.

The data relating to international gas transport from the RDC and Wuppertal studies take account of the uncertainty over methane emissions. The Wuppertal Institute data also makes it possible to take into consideration uncertainty over methane emissions during the extraction of Russian natural gas and over CO_2 emissions during international transport. These uncertainties, which are partial and not altogether comparable, are represented in figure 2 by error margin bars. This figure allows the observation that uncertainty over data is generally greater than the difference between the scenarios studied. The differences measured are therefore not always significant.

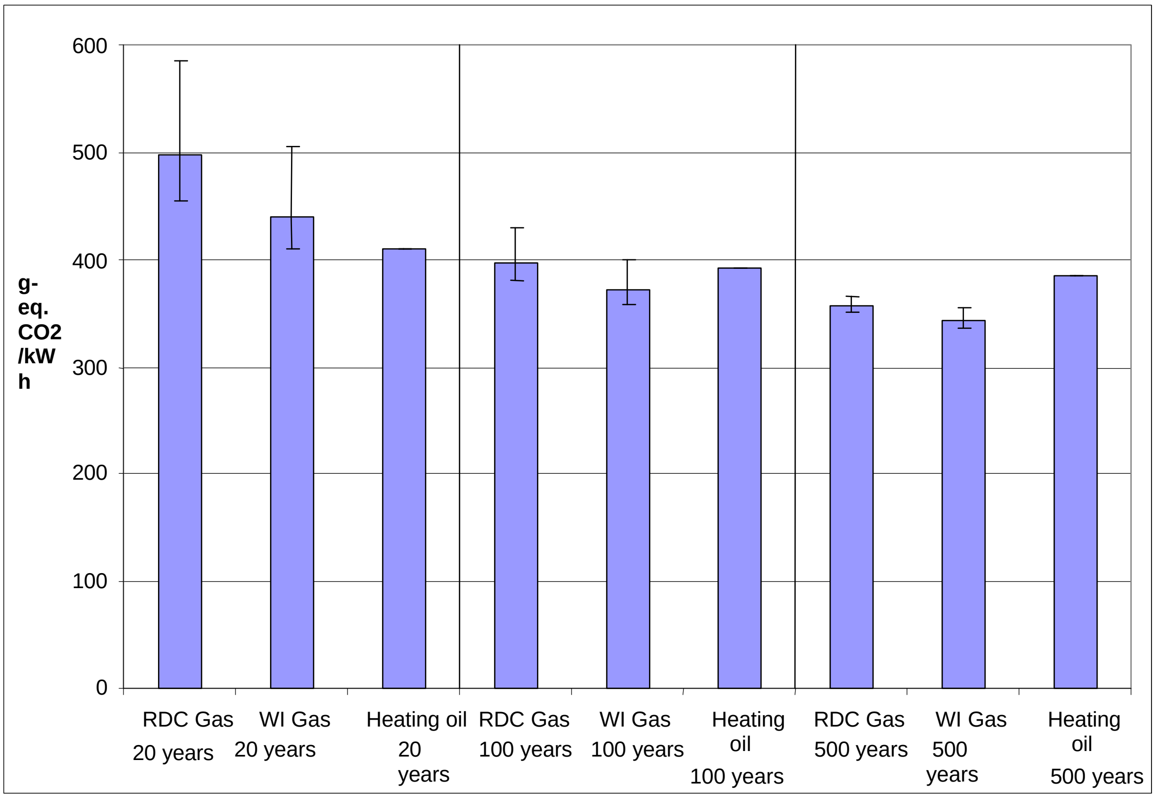

Figure 2: Uncertainty over data regarding the extraction and transport of natural gas

The validity of the data presented in table 2 was checked through consultation of the databases generally available for the performance of life cycle analyses.

With respect to **the extraction of natural gas** in Russia, methane emissions are estimated at 3.42 g/m^3 (ETH-ESU 96 database) and 3.15 g/m^3 (Ecoinvent database). If the NHV of Russian gas is 35.6 MJ/Nm^3 (RDC data), this respectively corresponds to 0.35 and 0.32 g/kWh. By comparison, the emission values for methane in the Wuppertal study (0.078 g/kWh) appear relatively low. As a reminder, no new measurements were made for the natural gas extraction stage. The value cited by the Wuppertal Institute was that previously published in Dedikov et al[1]. Dedikov's value was adapted by the Wuppertal Institute following a more conservative hypothesis regarding duration of flare operation (in Dedikov, the flare is operational 70% of the time and methane emissions are estimated at 0.06%, whilst in the Wuppertal Institute study, it is only operational 33% of the time and methane emissions are estimated at 0.11%).

CO_2 emissions are estimated at 73.2 g/m^3 (ETH-ESU 96) and 103 g/m^3 (Ecoinvent), which corresponds to 7.40 and 10.42 g/kWh (3.96 g/kWh in the RDC study). It should, however, be observed that these data take into account CO_2 emissions during infrastructure construction and the exploration of gas fields. This could partly explain the higher values obtained.

The methane emissions for the **international transport** of Russian gas are estimated, in database sources, at 2.40 g/(t*km) (ETH-ESU 96) and 2.21 g/(t*km) (Ecoinvent) respectively, which corresponds to 1.42 and 1.30 g/kWh when a transport distance of 7,000 km is considered. By way of comparison, the emissions for Germany are estimated at 0.191 g/(t*km) (ETH-ESU 96) and 0.235 g/(t*km) (Ecoinvent) in the same databases. These values are considerably lower than those proposed for the transport of gas in Russia. Consequently, it is clearly apparent that the mere use of a corrective coefficient for distance leads to an overestimation of methane emissions for the transport network in Germany, since it is thereby implicitly assumed that methane leaks for the gas transport network in Germany are identical to those for the Russian transport network.

CO2 emissions for the transport of Russian gas are estimated at 79.7 g/(t*km) (ETH-ESU 96) and 71 g/(t*km) (Ecoinvent), which respectively corresponds to 47.17 and 41.92 g/kWh when a transport distance of 7,000 km is considered. These data also take into account CO2 emissions for infrastructure construction. These values are relatively close to those of the RDC and Wuppertal studies.

[1] Dedikov et al. (1999): "Estimating Methane Releases from Natural Gas Production and Transmission in Russia, Atmospheric Environment".

3. CONCLUSIONS

The remarks and conclusions directly linked to the Wuppertal Institute study are present under paragraph 1.4 of this document. We will not repeat them here.

Moreover, although the indirect greenhouse gas emissions estimated in the Wuppertal Institute study for the Russian natural gas system are lower than those retained in the RDC study (they are, however, situated within the variation range of the study), the majority of the conclusions of the RDC study remain valid. The conclusions of the RDC study are recapped below in italics and discussed briefly in this context.

Switching from a heating oil boiler to a gas boiler in Belgium in 2005 does not bring about a relative decrease in GHG emissions (at 100 years).
The two systems present relatively similar results and we have shown that the differences between the two systems were less significant than uncertainty over the data. In general terms, the impact of greenhouse gas emissions is "on average" identical for the gas and heating oil systems when the hypotheses of the RDC study are used for Russian gas, whilst the gas system scores a little higher when the Wuppertal hypotheses are retained. The differences between the gas and heating oil systems do not, however, appear sufficiently significant to exclude or favour one or the other system on the basis of greenhouse gas emissions.

For gas, emissions arising from processes upstream of combustion contribute significantly to the GHG balance.
It seems evident from figure 1 that, for all scenarios, indirect emissions for the natural gas system are higher than for the heating oil system. This is linked to methane leaks during the international transport of natural gas, and above all to the energy required for this transport. There is potential for an improvement in the reduction of leaks in Russia in particular, yet also in countries east of Germany, and this potential should establish itself at a rate still to be determined, the potential for increased energy efficiency in long-distance gas transport is, however, not clearly in evidence.

The distribution over time of the impact of GHGs is stable for heating oil, and is more concentrated in the first 45 years for gas.
The more substantial methane emissions for the natural gas system have a greater environmental impact in the short term. As a result, the impact of greenhouse gas emissions for the natural gas system is more concentrated over the first few years. Due to a lack of data, it was not possible to recalculate figure 25 of the RDC report using the hypotheses of the Wuppertal study for Russian gas. As the data retained in the Wuppertal study is less significant than that of the RDC study, the trends illustrated in this figure are likely to be reversed sooner.

The use of high-efficiency boilers presents considerable reductions in GHG emissions, by contrast to a change of fuel.

This statement still remains true. Indeed, the two systems present relatively similar levels of greenhouse gas emissions. In this case, the potential for a reduction in greenhouse gas emissions is certainly greater using a high-efficiency boiler, rather than switching fuel. Moreover, use of a high-efficiency boiler leads to a reduction in energy consumption, which is beneficial for the energy chain and consequently allows for a reduction in greenhouse gas emissions from fuel extraction.

The true efficiency of boilers and true emissions during combustion are key factors over which there is considerable uncertainty.
This point was not checked in this critical study, but it is clearly apparent that in the RDC study these data are not well known, whilst it has a significant impact on results.

There is a great deal of uncertainty over key data: gas losses (methane) from the gas industry in Russia and Algeria.
With respect to gas losses for the Russian gas industry, it was emphasised once again that uncertainty was considerable in this area. The same is true of CO_2 emissions linked to international gas transport. The less reliable data for the Russian gas industry is highlighted in the RDC study and in the Wuppertal Institute study, as well as in other recently published studies such as that entitled "Life Cycle Inventories for the Nuclear and Natural Gas Energy Systems, and Examples of Uncertainty Analysis".[2]

It should also be added that transport distance is another important parameter that has not been evaluated very accurately up to the present. In the RDC study, the distance for the international transport of Russian gas from the extraction site to Belgium is estimated at 7,000 kilometres based on map analysis, whilst the authors of the Wuppertal Institute study consider a distance of 4,300 km or 5,500 km up to Germany's eastern frontier. As methane leaks and CO_2 emissions linked to the transport of gas are proportional for this transport distance, this parameter is well and truly significant and should be evaluated seriously, even if the measurement of transport distances within a meshed, interconnected network is not carried out directly.

[2] Dones R., Heck T., Faist Emmenegger M., & Jungbluth N. (2005): "Life Cycle Inventories for the Nuclear and Natural Gas Energy Systems, and Examples of Uncertainty Analysis". Int J LCA 10 (1) 10-23