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Reduction of Greenhouse Gas Emissions in North-West Russia – Finnish Business Opportunities

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Preface

This study has been carried out in the project "Reduction of Greenhouse Gas Emissions in Russia – Finnish Business Opportunities" which has been realized under the technology program CLIMBUS of the Finnish Funding Agency for Technology and Innovation (TEKES). The report is a general study about the reduction possibilities of greenhouse gas emissions in Russia. It aims to point the most rational means to reduce the emissions so that the emission rights could be utilized effectively and the projects would benefit both Russian and Finnish participants. The study is focused mainly on the city of Saint Petersburg and Leningrad region. The research group consisted of the researchers Sami Kokki and Päivi Friari from Lappeenranta University of Technology (LUT), associate professor Vladimir Zakrzhevsky from Saint Petersburg State University of Engineering and Economics, professor Mika Horttanainen and professor Lassi Linnanen from LUT. The research group gratefully acknowledges the financiers of the project: TEKES, Fortum, Komatsu Forest, Stora Enso, UPM Kymmene, Vapo Energy and Wärtsilä. The authors are also grateful for the editorial assistance provided by Oula Kerkelä, Kati Koikkalainen and Hanna Värri.

Abstract

The aim of this report is to investigate what the most rational means for Finnish business enterprises are in the near and farther future to reduce carbon dioxide emissions in Russia, particularly in the regions of St Petersburg and Leningrad. In this work, both technical and economic data is gathered, on which basis it is possible to indicate the most potential emission reduction targets.

St Petersburg is Russia's energy engineering centre, where approximately 70% of Russia's energy engineering-related markets are situated. In addition, the region's energy production is strongly weighted towards fossil fuels. The greatest potential for the minimization of greenhouse gas emissions is clearly found in measures connected with reducing the use of fossil fuels along the entire energy chain. In this report, the possibilities of reducing carbon dioxide emissions from the perspectives of various energy production modes, the transfer of energy and the use of energy have been clarified. The potential of diminishing methane emissions at landfills has also been evaluated.

Contents

List of acronyms

CH_4	Methane
CHP	Combined Heat and Power
CHPP	Combined Heat and Power Plant
CO_2	Carbon Dioxide
$CO_{2\text{-ekv.}}$	Carbon Dioxide Equivalent
DE	Oil-gas vertical water-tube steam boilers with natural circulation
DKVR	Vertical water-tube double-drum steam boilers
DOC	Degradable Organic Carbon
FOD	First Order Decay model
GHG	Green House Gases
GRES	State Regional Power Plant
IPCC	The Intergovernmental Panel on Climate Change
KVGM	Hot water boilers
LFG	Landfill Gas

Energy units

	MWh	GJ	Gcal
MWh	1	3,6	0,860
GJ	0,2778	1	0,239
Ccal	1,163	4,187	1

1 Introduction

1.1 Background

The impact of greenhouse gas emissions in reinforcing climate change has become a threat which must be taken seriously throughout the entire world. The latest research findings indicate that the average temperature of the earth has risen approximately 0.6 ºC by reference to the mid-1800s (IPCC 2001). According to the European Union, the rise of the world's average temperature must be limited to below two degrees, so that the most serious consequences of climate change may be avoided with reasonable certainty. This requires that the world's emissions can be decreased over the next 15 – 20 years. A dynamic rise in climatic average temperature shall cause formidable consequences in our environment which are impossible to predict in advance with sufficient precision. We have already seen changes in the weather, e.g., in rainfall, record temperatures, storms and tropical hurricanes.

The main reason for the rapid rise in climatic average temperature is regarded as greenhouse gas emissions resulting from human activity. Of the greenhouse gases, the one which has the greatest significance from the perspective of the climate is carbon dioxide (CO_2), which is mainly formed from the use of fossil fuels. Another important greenhouse gas is methane (CH_4), which forms as a result of human activity in, for instance, the decomposition of wastes anaerobically at landfills. The warming effect of methane on the climate—its' heating potential'—is approximately 21 times by comparison to carbon dioxide.

The climate policy of the European Union is based on the Kyoto Protocol and the goal set therein to restrict greenhouse gas emissions to a certain level. Amongst the parties to the ratification of the Kyoto agreement, mechanisms have been agreed towards the achievement of the emission reduction aims, which enable the implementation of emission reduction projects where they are most economically profitable. From the point of view of these climate-related projects, Russia is a particularly appropriate target, as its greenhouse gas emissions are enormous, and on the other hand their reduction potential is also immense.

Interest in projects reducing emissions has increased since Russia's ratification of the Kyoto Protocol, which came into effect on 16 Feb. 2005. This being the case, Russia can also engage in trade with emission rights and emission reduction units if it fulfils the prerequisites of the Kyoto Protocol. Indeed, it is anticipated that the implementation of climate projects in Russia shall become easier and more profitable. What impacts profitability on its part is the pricing development of emission reduction units. During 2005, the value of emission reduction units increased from approximately €7.5 to a level of approximately €20, having been 28 €/t_{CO2} at its highest. The emission reductions generated in the projects can be transformed into emission reduction units and sold on the market, thereby easing the financing of the project.

1.2 Objectives

The aim of this study was to clarify what the more rational means for Finnish companies are in the near and farther future to diminish CO_2 emissions in Russia, particularly in the regions of St Petersburg and Leningrad. The goal was to gather and analyze technical and economic data connected with greenhouse gas emission sources, on which basis emission reduction targets with more potential can be indicated, producing a realistic picture for Finnish actors of the business possibilities in the region concerned.

1.3 General picture of St Petersburg and Leningrad Oblast

St Petersburg is the largest city in the Baltic region and Russia’s second largest city after Moscow. Inhabitants in the region of St Petersburg total approximately 4.6 million, and there are about 1.6 million residents in the surrounding Leningrad Oblast region. This represents Russia’s main industrial region. The most important industrial fields are the preparation of foodstuffs, machine construction and the energy industry. St Petersburg is indisputably Russia’s centre of energy engineering. Russia’s energy engineering markets are concentrated approximately 70% in the region of St Petersburg. The region’s energy production is strongly weighted towards fossil fuels, of which natural gas, fuel oil and coal are utilized the most.

2 General picture of GHG emissions in Russia

Most of Russia’s greenhouse gas emissions are formed as a result of the use and production of fuels. Through examining the fields of operation by reference to Fig. 1, it can be noted that the energy sector-related share of greenhouse gas emissions is over half. The categories describing the energy sectors in the diagram include energy production and the production of fuels as well as their transport.

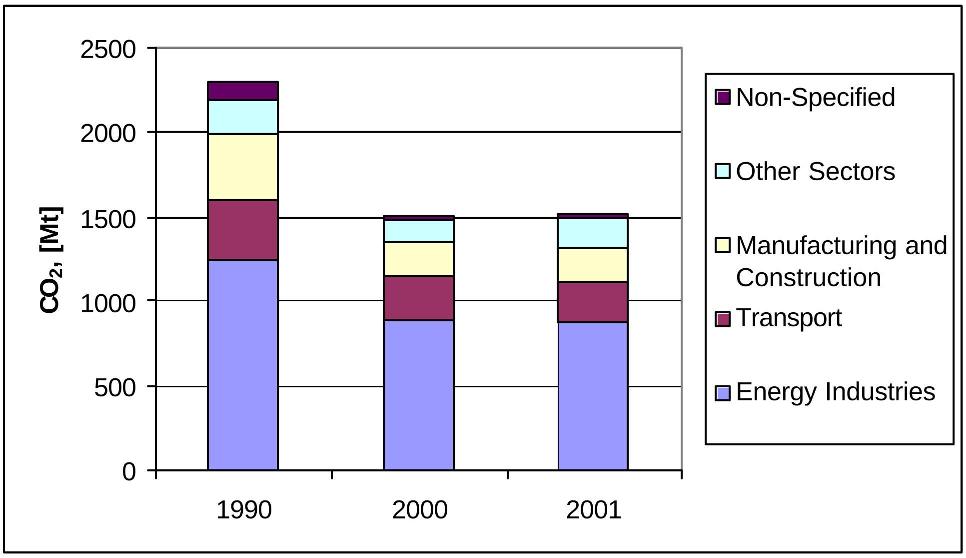

Figure 1. Energy-related CO_2 emissions in Russia by major source categories (CENEf, 2004).

Of the fossil fuels utilized in Russia, energy is produced the most by means of natural gas (over 50%), which is also visible in examining greenhouse gas emissions on a fuel-by-fuel basis. From Fig. 2, it can be noted that CO_2 emissions are generated from the use of fuels in gas form the most, even if the difference compared to solid and liquid fuels is insubstantial. That the largest proportion of fossil fuel-derived emissions is from natural gas is, from the perspective of this examination, advantageous, since if the same amount of energy were to be produced by means of other fossil fuels, the emissions would be considerably larger. Indeed, the goal is to increase, alongside biofuels, the share of natural gas in energy production.

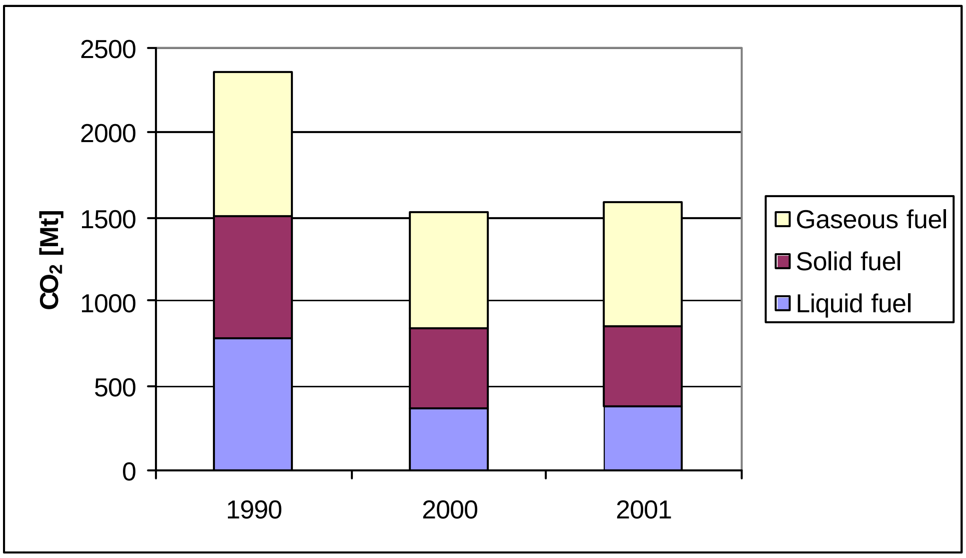

Figure 2. CO_2 emissions in Russia by types of fuels (CENEf, 2004).

Landfills are also a significant source of greenhouse gas emissions. Precise estimates of the amounts of methane forming at Russia's landfills do not exist. Nozhevnikova and Lebedev (1995) have nevertheless estimated that the amount of methane released annually at Russia's landfills is between 700 – 1300 Mm^3, i.e., 500 – 900 thousand tonnes. Converted into carbon dioxide-equivalent tonnes, this corresponds to approximately 10.5 - 19 million tonnes of carbon dioxide emissions. Although the proportion of the methane emissions at the landfills is, compared to overall greenhouse gas emissions, rather low, their reduction at large landfills could even be highly profitable. As individual targets, landfills can be very significant sites indeed for the implementation of climate-related projects.

3 GHG emission reduction potentials in energy production

The bulk of Russia's greenhouse gas emissions are generated as a result of the exploitation of fossil fuels in energy production. In this chapter, the volume of energy production is clarified as well as the current technical status of power and heating plants utilizing fuels in the Leningrad and St Petersburg regions. On the basis of this information, the possibilities of reducing greenhouse gas emissions are assessed in the processes concerned.

In clarifying potential reduction methods with respect to greenhouse gas emissions, it should be noted especially at the present time that plans are currently in the works for wide-scale renewal projects specific to boiler houses, district heating systems and heat transfer networks in the St Petersburg and Leningrad regions. These types of plans are also part of the programmes of many other municipalities. In particular, the replacements of district heating pipes, as well as natural gas substitution at boiler houses have high current interest.

3.1 Energy production in the regions of Leningrad Oblast and St Petersburg

In the region of Leningrad Oblast and St Petersburg, the facilities of innumerable business enterprises as well as municipal and State-owned plants are in operation which produces electricity and heat for the region. In the entire region, a total of 10 merged electrical and heating production facilities (CHP) are operational, as well as a few industrial CHP power plants and over a thousand district heating facilities, not to mention one nuclear power plant whose generated energy is incorporated not only in the production of energy but in district heating as well.

The electric production facilities incorporating fuels in the region of St Petersburg, which are all CHP plants (see Table 3), are in the ownership of the St Petersburg Generating Company. This company is one of the four which came into being when JSC Lenenergo was unbundled in October 2005. In the region of St Petersburg, district heating is produced not only by these CHP plants but also in the boilers owned by enterprises, public bureaus and the municipality. One substantial heat producer is St Petersburg's fuel and energy group, "GUP TEK SPb", with a total of about 560 boiler houses under its auspices boasting over 2500 boilers (GUP TEK SPb, 2005). In addition, about 220 boiler houses belong to various institutions and offices (FRESCO 2005). The heating production capacity for the St Petersburg region is approximately 34600 Gcal/h (~ 40200 MW), and the heating requirement is, at its peak, about 25000 Gcal/h (~29000 MW). In Fig. 3 following, the heating production capacities and load of the St Petersburg region are presented.

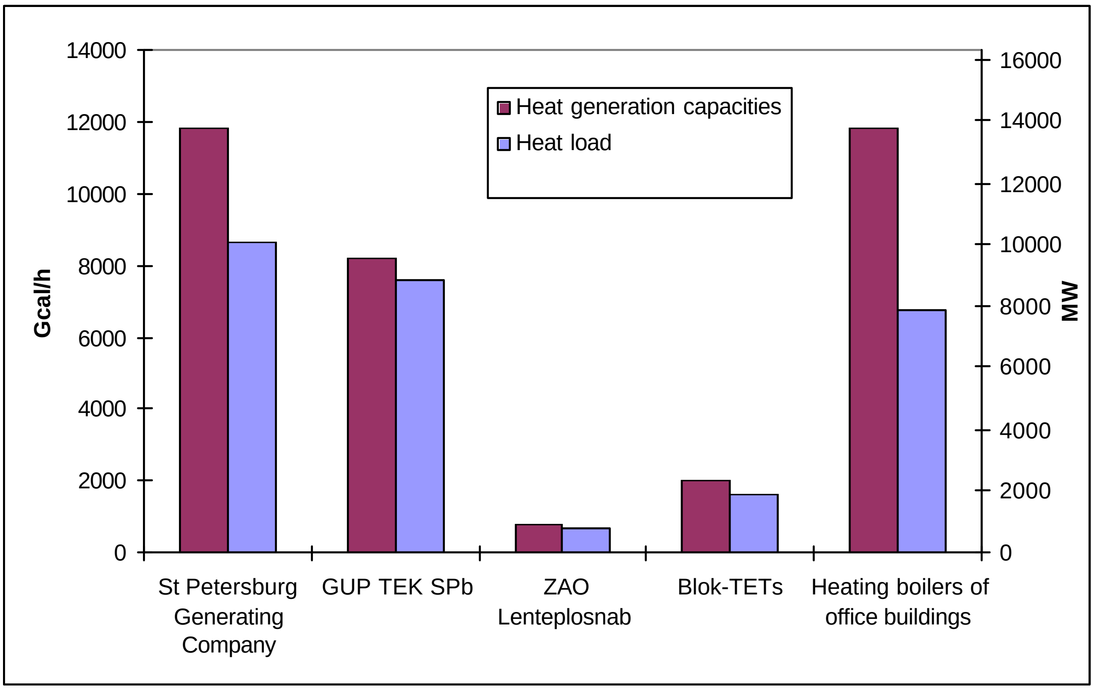

Figure 3. Heat generation capacities and load in St Petersburg (FRESCO 2005).

Of the electricity produced in the Leningrad Oblast region, the bulk is generated in the Sosnovy Bor nuclear power plant as well as in one of the CHP plants (CHPP-19) in the city of Kirishi. Also electricity is produced by hydro power stations (Svir', Narva and Vuoksi rivers). District heating production takes place in boilers owned by small companies and the municipality. In the region of Leningrad, 536 municipality-owned boiler houses as well as 148 boiler houses owned by various institutions are currently operational, also accommodating the requirements of the municipal economy (FRESCO 2005, p. 16). Large boiler houses in excess of 10 MW in the Leningrad region are found only in the cities of Vyborg, Gatchina and Kingisepp. The electrical generation capacities of the regions of St Petersburg and Leningrad according to owner group have been collated in Table 1.

Table 1. Power generation capacity in the St Petersburg and Leningrad regions in 2001

	St Petersburg, [MW]	**Leningrad Oblast, [MW]**
Total capacity, including:	2 940	7 127
• under ownership of RAO UES	450	
• Wholesale Generation Company - 5		2 100
• under the State (nuclear power plant of Sosnovy Bor)		4 000
• under the Petersburg Generation Company (Lenenergo) as a part of Territorial Generation Company - 1 (TGC 1)	2 410	649
• independent	80	378

Table 2. Heat generation capacity in the Leningrad region in 2001 (Zakrzhevsky 2005).

Heat capacities:	**Gcal/hour**
• CHPP and boiler houses belonging to Petersburg Generation Company	1 420
• Industrial producers including the nuclear power plant	5 500
• Municipal boiler houses	5 110
Total	**12 630** ***(14 686 MW)***

The table includes the proportion of heat produced by the St Petersburg Generating Company.

In both the St Petersburg and Leningrad regions, over half of the district heating generated is produced in boiler houses, but of the entire energy production-related fuel use, the greater share is expended in the power plant boilers for CHP generation.

The distribution of the use of fuels observes the national distribution in both the St Petersburg and Leningrad regions. The share of natural gas in fuels utilized is clearly large, after which the most considerable are oil and the fuels refined from the same, as well as coal. The fuel distributions presented in Fig. 4 are based on statistical data from the year 2000.

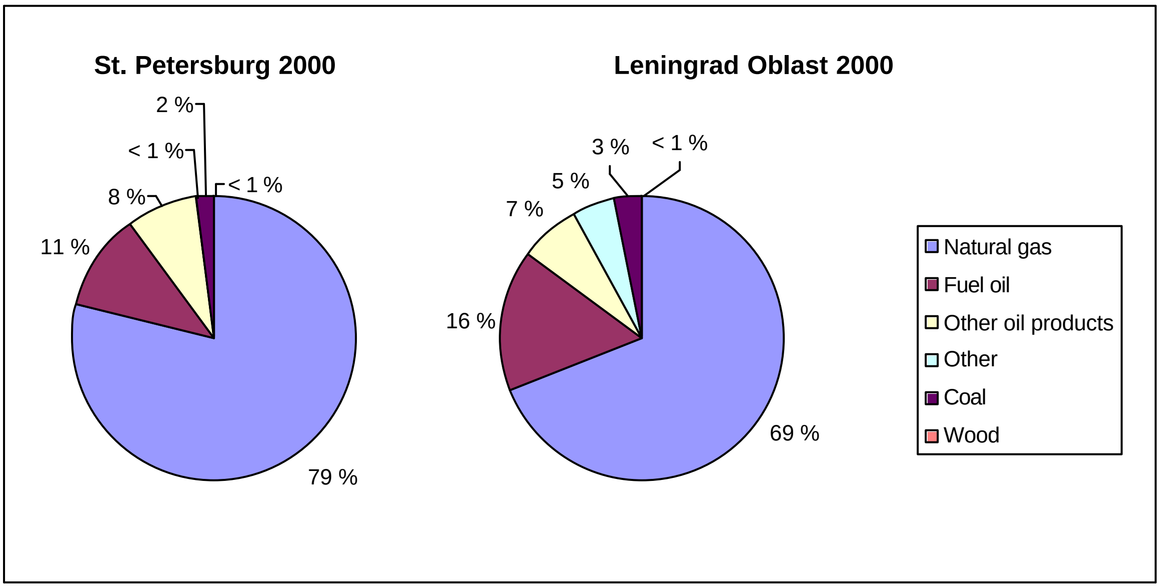

Figure 4. Fuel balance of the Leningrad region (Center for Strategic Studies 2002).

3.2 CHP

Eight CHP steam power plants are located in the St Petersburg region, which are all formerly Lenenergo-owned and nowadays belong to the St Petersburg Generating Company, as a part of TGC-1. In addition, two CHP plants are situated in the region of Leningrad. One is the city of Kirovski-based GRES-8 (State Regional Power Plant) and the other one, GRES-19, is located in the city of Kirishi. The technical specifications of the CHP plants are set forward in Table 3 and the geographical locations are in Fig. 5.

5.7% of Russia's total electrical production was generated in 1999 in Northwest Russia. Of this share, 32.9% was produced from fuels and the rest by hydro- and nuclear power. The share of electricity generated by combined production in Russia is about 30%.

Table 3. CHP plants respective to St Petersburg Generation Company (Lenenergo 2003)

	Electricity generating capacity, MW	Heat generating capacity, Gcal/h (MW)	Fuel specific consumption		Output 2003	
			For electrical production, kg/ MWh	For heat production, kg/Gcal	Electricity, million MWh	Heat, million Gcal
Central CHPP	78.5	1 409 (1 640)	396.8	147.2	0,431	2,820
CHPP-5	64	1 222 (1 420)	396.8	154.1	0,228	2,604
CHPP-7	85	1 084 (1 260)	-	-	0,483	2,124
CHPP-14	330	1 773 (2 060)	340.7	145.4	1,037	2,256
CHPP-15	291	1 814 (2 110)	324.1	130.0	1,367	3,667
CHPP-17	255	1 060 (1 230)	323.5	126.5	0,972	1,451
CHPP-21	500	1 188 (1 380)	282.6	121.7	1,995	3,648
CHPP-22	800	2 250 (2 620)	259.3	137.6	3,051	4,202
GRES-8	192	185 (215)	464.0	154.1	0,267	0,320
GRES-19	2 100	1 234 (1 440)	340.4	145.4	3,584*	2,926*

* Data: 2001 (Lenenergo Annual Report 2001).

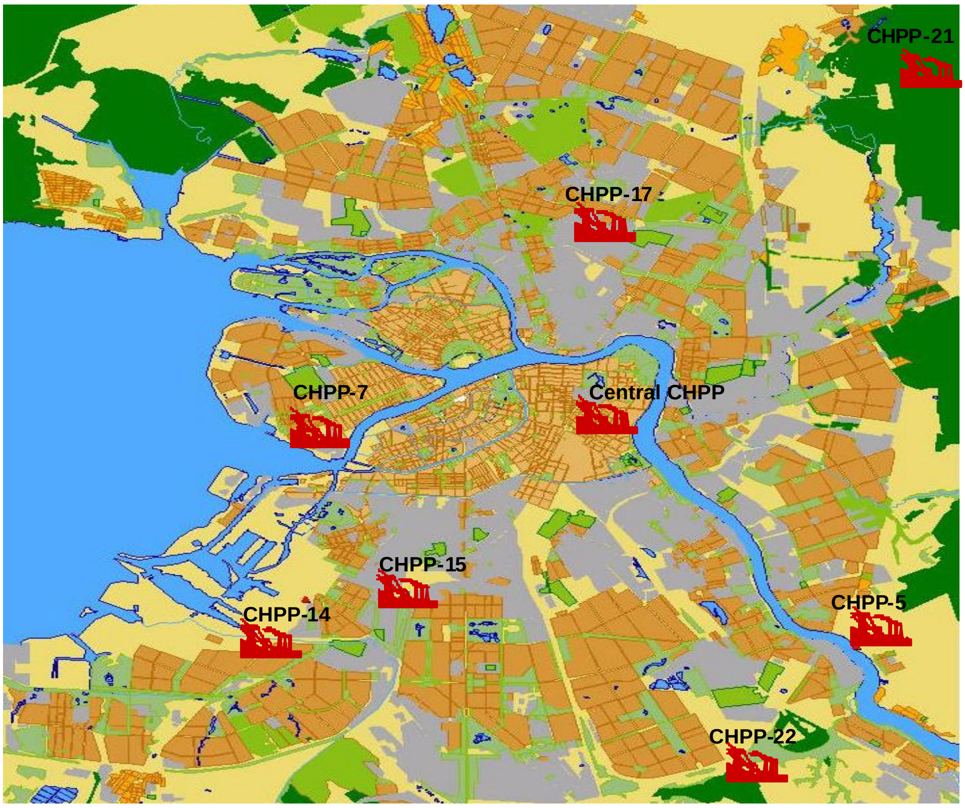

Figure 5. Locations of the CHP plants in St Petersburg.

The electrical and heat production quantities in 2003 at CHP power plants were in accordance with those presented in Fig. 6. It can be noted from the Figure that in some of the power plants concerned, the amount of generated heat is not very large compared to electrical production (with steam power processes in pure CHP production, 1 part of electricity to 4 parts heat is optimally obtained). From the Figure, one may conclude that in these plants part of the steam is driven in the turbines until condensation occurs, at which point overall efficiency remains considerably smaller than in pure CHP production (> 90 %).

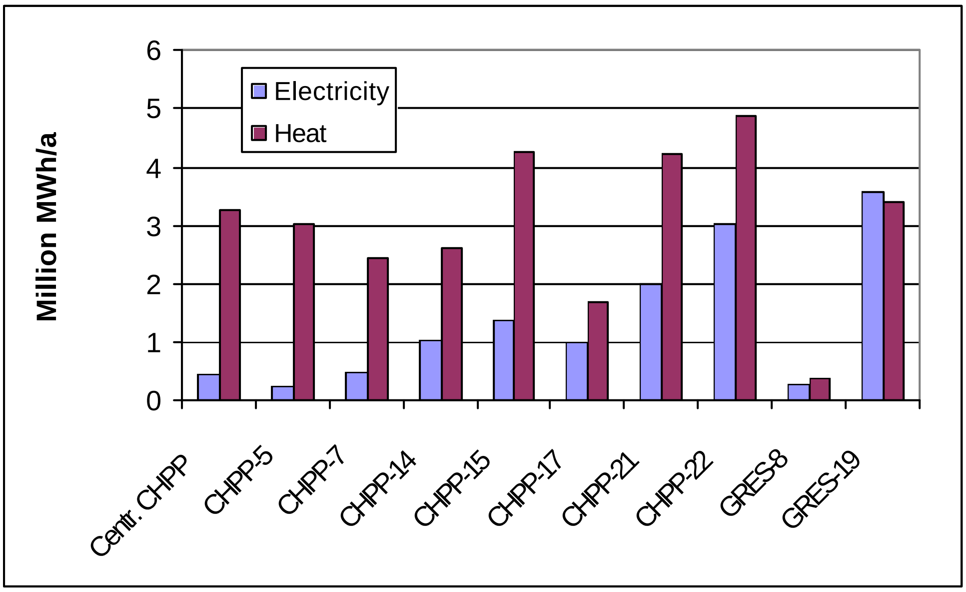

Figure 6. Electricity and heat produced in Lenenergo's CHP plants in 2003.

All ten CHP power plants located in the region use natural gas as the main fuel. In Fig. 7, the fuel distribution of Lenenergo's nine power plants in 2003 is presented (Lenenergo 2003). In addition to natural gas, oil (mazut) is utilized as an auxiliary fuel, as well as small quantities of coal as an extra fuel at the CHPP-14 and GRES-8 plants.

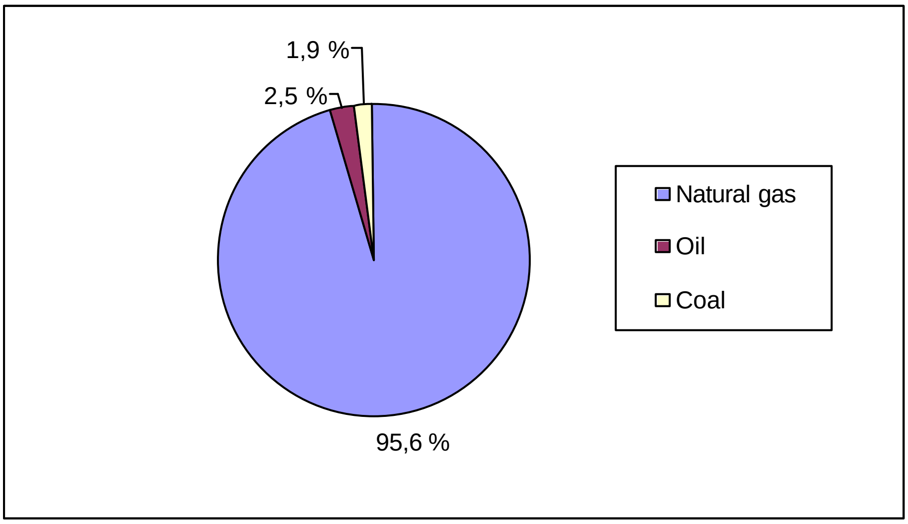

Figure 7. Fuel structure of Lenenergo's CHP plants in 2003.

The total consumption of fuel in a year, overall efficiency and carbon dioxide emissions at the CHP plants have been calculated for Table 4, utilizing the information in Table 3 as the initial data. The use of coal in the calculations are targeted in the CHPP-14 and GRES-8 plants as well as the use of fuel oil evenly distributed amongst all the plants mentioned, which only impacts carbon dioxide emissions.

Table 4. Fuel consumption, efficiency and CO2-emissions of CHP plants in 2003.

	Fuel consumption [kt]	**Overall efficiency**	**Most recent turbine installation**	**CO_2 –emissions [kt]**
Central CHPP	586.1	46 %	1950	1 632
CHPP-5	491.7	48 %	1929	1 369
CHPP-7	445.6	48 %	1964	1 241
CHPP-14	681.3	39 %	1962	2 119
CHPP-15	919.8	44 %	2000	2 561
CHPP-17	498.0	38 %	1969	1 387
CHPP-21	1007.7	45 %	1983	2 807
CHPP-22	1369.3	42 %	1998	3 814
GRES-8	173.2	27 %	1958	539
GRES-19	1645.4	31 %	1979	4 582
	Average	**40.2 %**	**Sum**	**22 051**

In CHPP 5 plan there will be new gas-turbine operating in the end of May (2006). Capacity of this gas turbine is 180 MW. In Northwest CHHP plan there will be new gas-turbine operating December (2006). Capacity of this gas-turbine is 450 MW for electricity and 300 MW for heat. Efficiency of these turbines is estimated to be about 52%.

The overall efficiency of the above-presented plants is substantially lower than what should be the case in CHP production (typically > 90 %). The overall efficiency ratings presented in the Table depict the average during one year of operation. In Fig. 6 previously, it was noted that part of the steam is condensed in the CHP plants concerned when there is a wish to produce more electricity relative to heat. In this connection, heat energy goes more to waste, reducing overall efficiency. The preservation of electrical production and improvement in total efficiency would thereby require raising the heat load (a broader district heating area, more process heat). This often requires changes to the infrastructure. On the basis of this data, it is difficult to assess with respect to energy how economical power plants are in reality. Nevertheless, when it is known that the technology in use is quite old (see, e.g., the latest installation years respective to the turbines in Table 4), it is certain that significant reforms can be made to the energy economy of these plants.

The combined overall efficiency of the St Petersburg and Leningrad CHP plants, emphasizing the amount of fuel utilized, is slightly above 40% on average. The annual CO_2 emission reduction attainable by improving the average efficiency of all CHP plants is estimated in Fig. 8. For example, in the event that the total efficiency could be raised from approx. 40% to 60%, the carbon dioxide emissions would be diminished by over 7 million tonnes a year, since the current emissions are, according to calculation, about 22 million tonnes in total. In addition to reducing emissions, raising the overall efficiency to 60% would reduce fuel acquisition costs by approximately €84 M per year. How substantial the improvement in overall efficiency realistically attainable by means of these various measures has not, however, been clarified in this work.

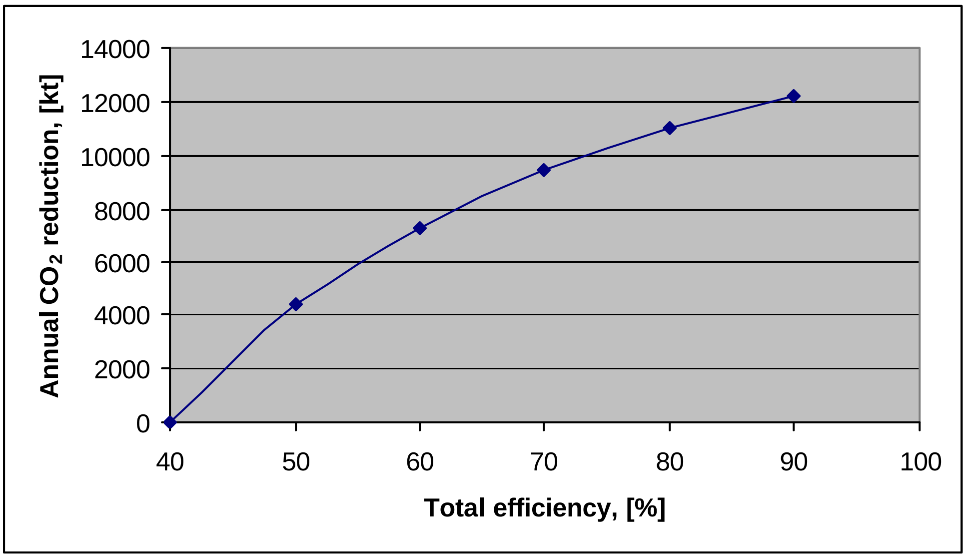

Figure 8. Efficiency-related CO_2 reduction potential of CHP plants in the regions of St Petersburg and Leningrad.

3.3 Boiler houses

In the region of Leningrad, there are approximately 617 heating boilers in total, of which those that are municipal come to 536. The municipal boilers generated a total of 7.19 million Gcal (8.36 TWh) of heat in 2003 and 7.27 million Gcal (8.98 TWh) in 2004. Correspondingly, heat in industrial boilers and those respective to bureaus was generated at 4.2 million Gcal (4.89 TWh) in 2003, and 3.9 million Gcal (4.53 TWh) in 2004. The production capacities of individual boiler houses are not known, but in the region of Leningrad boiler houses of over 10 MW are found only in the cities of Vyborg, Gatchina and Kingisepp (Zakrzhevsky 2005).

With respect to the boiler houses in the St Petersburg area, most data is available in regard to the plants belonging to the significant heat producer, GUP TEK SPb. The total calculated heating production capacity of the same was, at the beginning of 2005, 9263 Gcal/h (10773 MW), and the amount of heating generated annually is about 15 million Gcal, i.e., 17.4 TWh (GUP TEK SPb, 2005). In the boiler houses respective to this governmental facility, what is in use is primarily DKVR, DE and Gm-type steam boilers (about 300 in total) as well as PTVM and KVGM-type water boilers (about 70 in total), which have been in use for 15 – 30 years (FRESCO 2005). The largest proportion of the boilers would require basic renovation due to their age and wear. With respect to the base of boiler houses in general, the smallest boiler houses are generally poorer in condition, since most maintenance is reserved for the CHP plants and the largest boiler houses.

Table 5. Average efficiencies of boiler houses in the Leningrad region (Zakrzhevsky 2005).

Fuel	**Efficiency 2002 [%]**	**Efficiency 2003 [%]**	**Efficiency 2004 [%]**
Natural gas	89	87	88
Wooden chips	83	75	67
Fired wood	49	49	45
Mazut	73	75	76
Peat	36	39	42
Coal	59	59	60
Shale oil	69	63	69
Shale	54	62	58
Diesel	82	84	88

In Appendix 1 the overall efficiency of boiler houses operating in various areas of Leningrad is shown by reference to fuel.

The most usual fuels in municipal heating boilers are mineral coal, natural gas and oil (mazut). In the list below, the total number and proportion of various municipal boiler houses (534 altogether) using fuels in the region of Leningrad in 2001 have been categorized (Zakrzhevsky 2005).

Municipal boiler houses in the Leningrad region in 2001:

- 249 coal 46.6 % of the total
- 129 natural gas 24.2 %
- 103 black oil (mazut) 19.3 %
- 14 electrical boilers 2.6 %
- 13 peat 2.4 %
- 12 wood fuel 2.2 %
- 8 shale oil 1.5 %
- 4 diesel oil 0.8 %
- 2 slate (bituminous) 0.4 %.

The amounts of fuels used in municipal boiler houses in the Leningrad region are presented in Table 6. On the basis of the annual consumption of fuels, the energy obtained from these as well as the carbon dioxide emissions formed have been calculated.

Table 6. Structure of the consumption of fuels by municipal boiler houses in Leningrad 2002 and evaluation of CO_2 emissions.

Fuel	**Fuel mass*** **Mt/a**	**Fuel energy million Gcal/a, (TWh/a)**	**CO_2 kt/a**
Natural gas	461.3	5.45 (6.34)	1 279.5
Fuel oil (mazut)	190.9	1.90 (2.21)	615.1
Coal	144.8	0.64 (0.74)	254.5
Wood	26.2	0.12 (0.14)	0.0
Peat	53.0	0.15 (0.17)	65.8
Shale oil	9.3	0.09 (0.10)	27.9
Diesel	2.0	0.02 (0.02)	6.2
Shale	10.1	0.02 (0.02)	9.2
Sum	**897.6**	**8.38 (9.75)**	**2 258.3**

* Source: Zakrzhevsky, 2005.

Most carbon dioxide emissions in Leningrad's municipal boilers are formed from the use of natural gas, fuel oil and coal.

In the region of Leningrad, a programme is currently in progress whose goal is to renew the production of energy in order to achieve better energy economy. In the region's 530 municipal boiler houses, reviews have already been carried out for the implementation of the programme. In 2004, 41 boiler houses were renewed, as a consequence of which the overall efficiency of the boiler equipment rose on average from 30 – 40% to 90%. Of the district boiler houses, 24 have been transferred to natural gas and five are beginning to incorporate biofuels. Fuel costs alone have dropped by 100 million rubles (€ 2.9 M). The consumption of fuel oil has declined by 25 000 tonnes and coal by 20 000 tonnes (FRESCO 2005).

From the perspective of carbon dioxide emissions, a reduction in the consumption of 25 000 tonnes means a reduction of approximately 80 000 tonnes in carbon dioxide emissions; and correspondingly, a 20 000 tonne decrease in coal consumption represents a cut in carbon dioxide emissions of about 35 000 tonnes. It must, however, be noted that part of the decrease in the use of fuel oil and coal has been brought about by switching the fuel to natural gas: the carbon dioxide emissions produced through burning the latter further shrink the reductions in carbon dioxide emissions presented above.

As an example, we shall examine a boiler house in which renewal raising overall efficiency was implemented as well as fuel substitution in some instances. In each case, values in accordance with Table 5 were utilized for the overall efficiency of the boiler prior to renovation, and afterwards 90% overall efficiency. Let us assume that the peak-load operating hours is, on the basis of the heating season, about 4000 hours a year. In Table 7 following, the results of some sample calculations for a few varied alternatives are set forward. The carbon dioxide emission reduction that must be achieved in a year is reported as tonnes per one megawatt of thermal power (the thermal power generated by the boiler).

Table 7. Impacts of improvements to efficiency and fuel substitution on CO_2 emissions.

Fuel	**Efficiency [%]**	**Annual CO_2 reduction, [t_{CO2}/MW]***
Coal	60 → 90	758
Mazut	75 → 90	248
Coal → natural gas	60 → 90	1 373
Coal → wood	60 → 90	2 270
Mazut → natural gas	75 → 90	587
Mazut → wood	75 → 90	1 485

* when the peak-load operating hours of the boiler is 4000 h/a.

Mere renovation of the boiler house to raise overall efficiency is, from the perspective of carbon dioxide emissions, most profitable in boiler houses utilizing coal. If total efficiency can be raised by 30%, this sort of renovation is more effective than the modification of a similarly sized oil boiler into natural gas use. Multiple emission reductions by reference to the overall efficiency can be realized when a fossil fuel is switched to a biofuel. In switching to a biofuel, the overall efficiency from the perspective of the carbon dioxide emissions is no longer important, but the total efficiency of profitability still exerts impact via fuel acquisition costs. The conversion of a coal boiler into natural gas use also achieves significant emission reductions.

3.4 Bioenergy and its production possibilities in the Leningrad Oblast region

Due to Northwest Russia's extensive forest resources, the area's biofuel potential is very great. The wood waste produced as a by-product of modern wood processing has, already in itself, regionally significant biofuel potential. In Table 8, the amount of wood waste arising as a by-product of wood processing is presented, as well as an estimate of the carbon dioxide reduction potential thereby gained.

Table 8. Biofuel resources in Northwest Russia (Sammut 2002)

	Biofuel resources		**CO_2 emission reduction potential**
	Million m^3	TWh	Mt CO_2
Archangelsk	12.4	15.0	9
Karelia	3.3	3.9	2.4
Komi	15.7	19.0	11.7
Murmansk	0.8	0.9	0.5
Vologda	3.3	3.9	2.4
Total	**35.4**	**42.7**	**25.6**

According to a second estimate, the wood waste energy potential from Northwest Russia's saw and pulp and paper industries is 45 – 50 TWh/a (39 – 43 million Gcal), which would be possible to exploit advantageously in the area's various regions. The Leningrad Oblast Forest Committee has estimated that approximately 250 000 m^3 of wood waste is produced in the region of Leningrad Oblast annually (12% from processed wood), of which 30–50% remains non-exploited (OECD/IEA, 2003).

The consumption of wood fuels in the municipal boiler houses of the Leningrad region in 2002 was 67.71 thousand m^3, which represents a share of 1.49% from heat energy production. The same year, the amount of heat generated by wood fuels was 66 000 Gcal (~77 GWh). It has been estimated that the proportion of wood in municipal boiler houses would be 7% in 2010 and 10% in 2020. A list has been compiled regarding the conversion of the existent facilities from fossil to wood fuels, according to which a switch of fuels would be feasible during the next ten years (Zakrzhevsky 2005).

Small and mid-sized class boiler houses have already been converted in Russia to use biomass. The Russian Federation has financed several projects benefiting from renewable energy sources from the State budget within the context of the national "Energy Efficient Economy" programme. Among others, two projects are respective to these in which boiler houses were modified in the region of Leningrad to make use of local fuel. The costs of these projects came to 3.9 million rubles. The repayment period with modifications of this kind is typically 3 – 5 years. The regions showing the most potential for this type of market are Leningrad, Karelia, Vologda, Novgorod, Primorie and Khabarovsk (OECD/IEA, 2003).

Some of the most profitable targets for a switch in fuels are the coal and heavy fuel oil-based (mazut) boilers. In addition, the price of fuel oil in Russia has risen close to Western levels, thereby improving the competitive edge of wood fuel. The exchange in fuel performed in the Leningrad area has demonstrated that switching coal to wood fuel diminishes heating costs to 45% and fuel oil to wood to 28%. This report is based on price levels in 2001, so the savings with current rates are even greater (OPET 2005).

Carbon dioxide emissions can be significantly reduced in individual boiler houses by renovating the boiler so that it can use biofuel. In Table 7, examples of CO_2 reductions in fuel exchange from coal and heavy fuel oil to wood fuel are shown. According to the examples, by converting coal-produced megawatt heat power to biofuel, it is possible to achieve a decrease of approximately 2300 t_{CO2}/MW CO_2 (peak-load operating hours 4000 h/a) on a yearly level.

The reduction potential pertaining to carbon dioxide emissions on the part of biofuels can be estimated on the basis of the boiler house reserve in the Leningrad region. Some Danish specialists have compiled a list of Leningrad region boiler houses where it would be possible to implement a change in fuel to biofuel in the production of district heating. This list, in which 37 facilities are collated, is presented in Appendix 2. The boiler houses concerned currently use, as their main source of fuel, mineral coal. The total power of these boiler houses using coal as the type of fuel is about 120 Gcal/h (140 MW). If all these boiler houses were renovated to use wood fuels, and their average peak use period is 3000 h/a, i.e., a little over 3 months annually, the reduction in carbon dioxide emissions would be 208 000 tonnes/a. The value of the emission rights achieved would thereby be 4.16 million euros per year at a rate of €20 per CO_2-tonne.

3.5 Deficiencies in the engineering of power and heating plants

In a large proportion of Russia's power and heating plants, old or otherwise deficient engineering is in use, owing to which the overall efficiency of many facilities remains low, thereby weakening profitability and increasing emissions. For instance, there is a large number of small boiler houses (over 2000) under the auspices of GUP TEK SPb which are equipped with cast-iron boilers. Many of these function with mineral coal in the absence of fuel-process mechanization and automation, and their total efficiency is about 50 – 60%.

In many Russian power plants and boiler houses, certain deficiencies appear, by reason of which their overall efficiency remains low. Russian-made boilers, turbo-generators and accessory-based control systems are typically low-standard both in condition and technically. An automation system is one of the most important factors from the perspective of efficient operation. Currently, control is manually handled in many facilities. The monitoring and adjustment of equipment is frequently implemented in both CHP facilities and in boiler houses by telephone directly from headquarters. Typically, the amount of thermal energy fed into the district heating network is measured only by reference to the CHP facilities. Measurement and process follow-up systems are still used only minimally. Production is usually monitored afterwards on the basis of reports from the heat production units (Power Economics 1998).

The most usual deficiencies in Russian boiler houses which would be relieved by improving overall efficiency have been collected in the following list. In addition, measures are mentioned therein which would favourably impact total efficiency (procedures after the arrow):

- Air leaks in the boiler lead to an overly substantial amount of air, which increase dissipation → repair of the boiler and combustion gas ducts as well as control of combustion gas oxygen concentration
- Combustion air control on the basis of oxygen measurement of combustion gases
- Control and data collection system for automatic process
- Chemical boiler water preparation to reduce the leaks caused by corrosion in the piping

- Obsolete burner engineering → Renewal of burners in natural gas, oil and coal dust boilers in order to improve combustion efficiency (and at the same time diminish emissions)
- Poor-quality fuels weaken combustion and cause contamination → a more developed/new combustion technology is required which will permit fluctuations in the quality of the fuel; the switching of poor-quality fossil fuels to biofuels
- Heat is not efficiently recovered → an increase in the heat delivery surface and to keep heat delivery surfaces clean
- Faults in maintaining the cleaning of heat delivery surfaces → an increase in chimney-sweeping systems or updating
- Preheaters for combustion air and boiler water
- Due to transfer network systems, thermal load is not optimal; therefore, the boiler operates at partial load, weakening overall efficiency.

3.6 Potential reduction targets for greenhouse gas emissions in energy production

CHP production occupies a significant role in energy production in the regions of Leningrad and St Petersburg. Of the electrical generation based on the use of fuels, the share of CHP is almost 100%, and with respect to heat production, slightly less than half is produced in CHP facilities. The use of fuels in the area's CHP stations is based in excess of 95% on natural gas, so its share in diminishing carbon dioxide emissions cannot actually be increased. The technology in use is nevertheless quite old in many of the facilities, both in regard to CHP production and the boiler houses. Through technical improvements, it would be possible to improve the reduction of carbon dioxide emissions considerably.

One of the problems respective to CHP stations is the lack of thermal load. From the perspective of energy economy, it would be advantageous if there were sufficient thermal load to CHP stations, so that part of the steam would not have to be condensed in accordance with requirement. This aspect is stressed particularly when thermal energy is generated in the boiler houses for the district heating network.

With respect to boiler houses, part of the greatest reduction potential in carbon dioxide emissions includes, in particular, boiler houses using solid fuels, as the worst heat production-related overall efficiency is found in facilities incorporating peat, slate and coal. In terms of the total, the region of Leningrad has the most coal-burning boiler houses, but the amount of thermal energy produced is nonetheless significantly smaller than, for example , the amount of energy produced with natural gas or oil. The stations utilizing coal as a fuel are, in fact, smaller by average in their unit size and, additionally, the total efficiency of these facilities is low. The second smallest are the diesel-operated boiler houses, but these are quite minimal in number (only 4). Through renovation projects on the functional boiler houses and the switching of fuels to natural gas, it would be feasible to obtain as many as 2000 – 3000 tonnes of carbon dioxide emission reductions per megawatt capacity annually (when the peak usage period is about 4000 h/a). From the perspective of carbon dioxide emissions, switching to neutral biofuel may correspondingly mean a decrease of about 4000 tonnes of CO_2 per MW in, for instance, mineral coal use replacement.

With respect to the more potential boiler houses, CO_2 emission reduction targets include, from the perspective of their large number and poor overall efficiency, coal boilers; peat boilers by reference to their poorer total efficiency on average; and—owing to their easier implementation of fuel replacement—oil boilers. In Table 9 following, calculated examples of achieved benefits generated per energy unit with regard to increases in total efficiency and exchange of fuels are presented.

Table 9. Effects of efficiency improvements and fuel change on CO_2 emissions and costs.

Fuel	**Efficiency [%]**	**CO_2 reduction, [t_{CO2}/GWh]**	**Emission allowances [k€/GWh]**	**Fuel cost savings [k€/GWh]**
Coal	60 → 90	190	1.9	3.2
Mazut	75 → 90	62	0.6	1.9
Coal → natural gas	60 → 90	343	3.4	6.9
Coal → wood	60 → 90	568	5.7	?
Mazut → natural gas	75 → 90	147	1.5	8.7
Mazut → wood	75 → 90	371	3.7	

Prices utilized: coal rate 1000 RUR/t, natural gas rate 1100 RUR/t, fuel oil rate 3300 RUR/t and rate of emission allowance €10 /t_{CO2}.

4 GHG emission reduction potentials in energy transfer and distribution

The significance of energy transfer in cutting down CO_2 emissions is connected via overall efficiency with the fuel use requirement-related production of electricity and district heating as well as distribution. In this chapter, the volume of transferable energy flows and current technical situation of the transfer networks in the areas of Leningrad and St Petersburg shall be examined. On the foundation of this data, the impact of energy savings on the formation of greenhouse gas emissions in the production of fuel-based energy shall be evaluated.

4.1 District heating

In Russia, district heating is in a highly prominent position both economically and politically. Russia's thermal requirement is fulfilled almost 70% by district heating production. The first district heating network was built in Leningrad (now St Petersburg), USSR, 1924. Currently, the total length of Russia's district heating network as a whole is estimated as reaching approximately 257 000 km. Of this, about 25 000 km is made up of main transfer lines and 232 000 km of distribution pipes (CENEf 2005).

The length of the heat transmission network in the St Petersburg area is about 6000 km. GUP TEK SPb owns 5497 km of the transmission network and St Petersburg Generating Company 333 km. The amount of thermal energy transferred in the district heating transmission network of the City of St Petersburg is approximately 50 million Gcal (~ 58 TWh) per year.

4.1.1 District heating transfer engineering in Russia

In the Soviet system, the State produced and provided heat for users. In this sort of system, there was no need to measure the amount of thermal energy received by the individual consumer. For this reason, calculations based on real heat consumption are still rare today. The control of transferable district heating functions in Russia on the basis that the amount of water leaving the boiler house is maintained at a stable rate and its temperature level is adjusted by changing the amount of heat supplied between 70 – 130 °C. In this kind of system, only one boiler house can be connected to the district heating transfer network at a time, owing to which parts of the large district heating network must be isolated from each other during the heating season (Power Economics 1998).

Typically, a few combined electrical and boiler houses (CHP) as well as several hundreds of rather small boiler houses are connected with the large district heating networks in Russia. The district heating network is divided up into smaller networks which can be differentiated from other networks by valves. During the period of peak consumption, this kind of separate disconnected network section can be supplied with heat by only one boiler house. Larger CHP stations are also operated as independent parts of their own district heating network in accordance with their own consumption. During periods of smaller heating consumption, parts of the district heating network separated from each other can be combined by opening the valves separating them, whereupon heat can be generated at the CHP plant for a wider area (Power Economics 1998).

In the district heating system, water generally leaves from the electricity and heat production stations at an unnecessarily high temperature of about 180 ^{o}C, though the maximum required temperature in district heating network is normally in the region of 130 - 135 ^{o}C. This aspect also worsens the total efficiency of energy production and transfer. In theory, the temperature level of the water conducted through the district heating network would be sufficient at about 100 ^{o}C. The district heating network in the heat production facilities is connected directly to the boiler's water circulation system without heat exchanger. The circulation water temperature is controlled manually by means of mixing loops (Olkinuora 2004).

A comprehensive district heating network heat distribution system is made up of a transference section as well as primary and secondary distribution. A typical district heating network comprises paired hot water feed and return pipes. These are situated in a concrete duct or above the ground. The pipes are insulated in the main with mineral wool. The lifetime of these sorts of pipes is only 10 – 15 years, which is 1.5 – 2 times less than in Finland (Power Economics 1998). Only large cities can afford to use polyurethane foam-insulated district heating pipes. For instance, 5% of Moscow's district heating pipe network is insulated with polyurethane.

The transfer system is composed of a main pipe line which comes from the main boiler house (a CHP or boiler house). Generally speaking, the heat transfer line is branched off by degrees into the primary distribution system. The primary distribution system consists of feeding pipelines going from the transfer section to the substations. A substation can be either a central or block-specific substation. The transfer section and primary distribution system together make up a primary network. The feeding pipes which leave from the central substation, accommodating several buildings, compose the secondary distribution system (Olkinuora 2004).

The hot process water is generally readied group substations (CTP = Central Heat Point). The secondary network is customarily a three or four-pipe system. If distribution covers large numbers of buildings, the length of the secondary system grows very large, sometimes even larger than the primary system. In Northwest Russia, a substantial number of the substations are built into single buildings, but nevertheless without steering and control equipment (Olkinuora 2004).

The pumps installed in the heat production facilities circulate heating water in the primary network, and the block-specific substations pump water into the secondary network. At various parts of the network, there are booster stations balancing out pressure losses. Pumps are utilized at varying speeds. Control is of the manual blade angle controlling. Cavitation hinders controlling (Olkinuora 2004).

In Russia, it is typical that district heating distribution is operational for only part of the year. Heating is initiated when the average temperature during a certain period has dropped below the defined threshold value (8 – 10 °C) and is similarly terminated when a return above the threshold value has occurred. It is generally the case that heating lasts from October to April. During the summer, only hot process water is supplied, during which there is also a maintenance interim lasting 2 – 8 weeks (Olkinuora 2004). Customarily, control of the district boiler house takes place directly from the headquarters, from which only the information as when to start and end the heating season or the need to operate at partial load is derived (Power Economics 1998).

Residential dwellers are unable to control the amount of heating themselves to fit the temperature outside. For this reason, the temperature of the flat is commonly controlled by opening a window. During the Soviet era, energy was regarded as a fringe benefit whose consumption was not even measured. The heating requirement was roughly calculated on the basis of the surface area of the flats to be heated. Indeed, the specific heat consumption of buildings in Russia is about triple the level of the Western nations (Power Economics 1998).

4.1.2 Condition and overall efficiency of district boiler houses and the transfer network

The largest proportion of CHP facilities, boiler houses and district heating piping systems which are functional at this time were constructed or rehabilitated after the war. It has been possible to do basic repairs and improvements to them, but because of the aged technology and minimal maintenance, their efficiency frequently remains very low by comparison to the West. The greatest attention in upkeep is focused on the large CHP plants and boiler houses, so that the smallest boiler houses are generally in poorer condition (Power Economics 1998). (For more on the proportion of energy production by boiler houses, see Chapter 3.)

Of the problems found in the district heating network, the largest is corrosion, which occurs on both the outer surfaces and inside the pipes. External corrosion is often due to wet pipe system insulation, which is not allowed to dry due to the installation method. In some cases the leaks are so massive that the production of extra water fails to generate enough new water for the district heating network. In this case, it is necessary to use untreated raw water, which causes corrosion to the inside of the pipes. This results in a vicious circle in which the leaks caused by corrosion further increase while the condition of the piping deteriorates rapidly (Power Economics 1998).

The average degeneration of the district heating transfer pipes is estimated to be 55 - 65% and in some cities almost 100% (CENEf 2005). In the networks owned by the municipalities, the number of instances of damage has grown five-fold during the last ten years. In 2000, 200 instances of damage per 100 km occurred in these heat transfer networks (FRESCO 2005). The general value of district heating transfer network failure density in Russia is 0.6 – 4 failures per kilometre annually (Bashmakov 2004). In the Leningrad region's city of Kirish, the failure density is 0.63, in Vyborg 0.9 and in Kingisepp 0.98 faults per kilometre annually (FRESCO 2005).

In practice, the repair of heat pipes requires the replacement of the corroded part. The smallest leaks are filled either by welding the site or by installing a steel collar on the leakage site. On a yearly basis, 2% of the piping is replaced, whereas the requirement for replacement on the basis of condition would actually be 5 – 8 % (Bashmakov 2004).

In the pipelines from the district boiler house, there is poor insulation all the way to the usage site. Heat losses are typically 3 – 5 times greater than in Western Europe. Exact data on the losses occurring in transfer is unavailable, due to deficiencies in the measurement systems. There are, however, several estimates in existence on transfer losses performed by various parties. In Table 10, estimates of transfer losses have been collated from various sources. Among others, assessment by Russian specialists on heat losses places the estimate at 20 – 30% (OECD/IEA 2002). In their view, Russia's official statistical values are much smaller than the actual level, since part of the heat losses are entered as consumption, or faulty measurements lead to excessively minimal values.

Table 10. Estimates of losses in district heating systems.

Losses	**Additional info**	**Source of information**
15 – 16 %	This figure does not include "physical" heat losses of hot water going through the leaks	CENEf, 2005
20 – 30 %	Total losses	OECD/IEA, 2002, p. 217
10 – 15 % 30 %	Losses through hot water leaks Total losses	FRESCO, 2005, p. 16
16.35 % 15.4 % up to 30 %	Normative losses in 2002 Normative losses in 2003 Estimate of real losses	The Committee for Energy Complex and Utility and Housing Economy (Zakrzhevsky 2005)

The losses of the magnitude presented above in district heating transfer consume whatever benefits obtained by CHP production. In practice, almost all the fuel savings by reference to separate production are lost at the moment in the heat transfer and distribution network (CENEf 2005).

With respect to losses in the Leningrad region's better district heating systems, the following list exists which is based on data gathered by "The Committee for Energy Complex and Utility and Housing Economy" for the years 2003 and 2004 (Zakrzhevsky 2005):

- Tosno area: 10.3 – 7.3%
- Volkhov area: 9.5 – 8.3%
- Lodeinoe Pole area: 13.2 – 7.4%
- Kuznechnoe village: 7.1 – 8.6%
- Tikhvin area: 8.0 – 9.3%
- Sertolovo village: ? – 6.5%
- Kirishi area: 10.6 – 10.4%.

The main reasons for substantial heating and water losses in the district heating network are:

- excessively high transfer temperature use (the water generally leaves the combined electrical and heat production facilities at a temperature that is needlessly high: about 180 ^{o}C)
- the lack of up-to-date thermal and water-block insulation

- manual flow controls by throttle valves and blade angle adjustments → district heating pumps should be equipped with revolution-speed control systems
- the low corrosion resistance of the steel district heating pipes causes leaks
- weak active and passive corrosion protection in district heating pipes
- abundant usage of valves and limiters in the pipelines promotes corrosion (on average, there are 25 valves along a distance of one kilometre)
- the circulating water is unsuitable in quality, resulting in corrosion inside the pipes
- inadequate testing and deficient pressure control methods
- inadequate pressure shock protection strains the pipe systems
- the lack of modern diagnostics methods and equipment
- up-to-date repair methods are lacking.

4.1.3 Examples of district heating transfer network-related improvement projects

1. Example

As the first example, a district heating transfer network in poor condition on which basic renovations are being performed is examined on a theoretical basis. As a result of the repair, heat transfer losses decline from 30 % to 10 %. Let us assume that the heat power delivered to users is, during the period of the most substantial consumption, 5 MW, and during the peak usage period 4000 h/a. In Table 11 following, improvement project impact on the consumption of fuel is presented, as well as the benefits achieved through the same when heat is generated with coal as the fuel or in a boiler house that incorporates natural gas. In addition, a case is included in this review in which a change in fuel has been implemented at the boiler house in addition to the renovation of the district heating transfer network.

Table 11. Theoretical example of district heating network renovation effects on CO_2 reduction and operating costs when losses decrease from 30% to 10% and the heating power supplied is 5 MW.

Fuel and efficiency	**Reduction of fuel consumption, [t/a]**	**CO_2 reduction, [t/a]**	**Fuel cost savings, [€/a]**	**Value of achieved emission allowances, [€/a]**
Coal-fed boiler house (efficiency = 60 %)	2 050	3 604	59 600	36 000
Natural gas-fed boiler house (efficiency = 90 %)	508	1 401	22 500	14 000
Fuel change from coal to natural gas (efficiency = 60 → 90 %)		11 313	189 100	113 100

Prices utilized: coal rate 1000 RUR/t, natural gas rate 1100 RUR/t, rate of emission allowance €10/t_{CO2}.

Other benefits achieved by improvement in the heat transfer network are:

- repair/maintenance expenditure reduction
- a decrease in water preparation costs with the decline in the number of leaks.

2. Example

In the region of Murmansk, basic renovations are being implemented on a district heating system which, according to the plans, should be complete in 2008. A goal in the project is to improve the overall efficiency of the boilers in the boiler house and reduce heat losses in the heat transfer network. The cost estimate of the project is 30 million euros. The measures being realized are:

- the replacement of district heating transfer pipes in poor condition by modern heat transfer pipes
- the updating of the boilers with control and automation systems
- the replacement of several boiler houses by one that is centralized
- the substitution of small, low-efficiency coal boilers by natural gas boilers
- installation of measurement and control systems.

According to the calculations by GreenStream Network Ltd, it would be possible to improve the system with the measures under way to such an extent that the carbon dioxide emissions produced would decrease by 65 000 tonnes. During the 2008 – 2012 period, this would mean about 1.5 million euros of income through the sale of emission rights if the rate for the same is, on average, €5 / tonne during the interim concerned (GreenStream Network 2005).

4.1.4 Greenhouse gas emission reduction potentials with respect to the district heating transfer and distribution network

The carbon dioxide emission reduction potential respective to the district heating transfer system in the St Petersburg region can be assessed by presuming that there is the potential to diminish losses to a level of 10% in transfer losses of 30% on average, which corresponds to typical district heating transfer losses in Finland. The amount of heat supplied from St Petersburg's heat production facilities to the district heating networks is currently about 50 million Gcal/a (~58 TWh/a): thus, reduction of transfer losses to the extent described above would decrease the requirement for energy production by 11 million Gcal/a (~13 TWh/a). Taking the distribution in the use of fuels in the St Petersburg region into account, the need for various fuels would diminish as a result of the reduction in losses in keeping with the estimates presented in Table 12.

Table 12. CO_2-reduction potential respective to St Petersburg district heating network.

Fuel (share of usage in St Petersburg)	**Reduction of heat production, [million Gcal/a]**	**Reduction of fuel consumption, [t/a]**	**CO_2 reduction, [kt/a]**	**Fuel cost savings, [M€/a]**	**Value of ERUs, [M€/a]**
Natural gas (79 %)	8.7	820 000	2 260	26	23
Oil (19 %)	2.1	290 000	920	28	9
Coal (2 %)	0.2	80 000	140	2	1
Total	**11**	**1 190 000**	**3 320**	**56**	**33**

Prices utilized: coal rate 1000 RUR/t, natural gas rate 1100 RUR/t, fuel oil rate 3300 RUR/t and rate of emission allowance 10 €/t_{CO2} (Source of fuel prices: Lenenrgo).

4.1.5 CO_2-emission reduction potentials achievable by lowering district heating consumption

In this section, there is an assessment of how much carbon dioxide emission decline when district heating consumption is successfully decreased due to, for instance, an energy savings project. It is presumed in the estimate that lowering energy consumption will reduce, by the same ratio, all use of fuels incorporated in district heat production in the various districts of St Petersburg and that district heating transfer- and distribution losses are, on average, 30 %.

In Table 12, it is readily proposed that the generation of an amount of energy of 11 million Gcal in district boiler houses corresponds to 3 320 kt of carbon dioxide emissions. Of this 11 million Gcal, 7.7 million Gcal can be supplied to the site of usage, taking losses of 30% into consideration. On this basis, it can be calculated that the delivery of one Gcal of heat energy to the site of usage results in about 430 kg of carbon dioxide emissions (370 kg_{CO2}/MWh).

The district heating savings-related CO_2 emission reduction potentials in this report shall be subsequently assessed by utilizing the calculated value above.

4.2 Transmission of electricity

The transmission of electricity networks in the regions of Leningrad and St Petersburg are primarily under the control of Lenenergo's decentralized "Leningrad Regional Power Network Company". Of the electricity used in the region, 99% is transmitted by this company's network. The length of its transmission lines is 38 600 km, and the length of the underground transmission cables is 15 000 km. The amount of electrical energy transmitted via this company's electrical networks in recent years has been approximately 21 million Gcal/a (25 TWh/a).

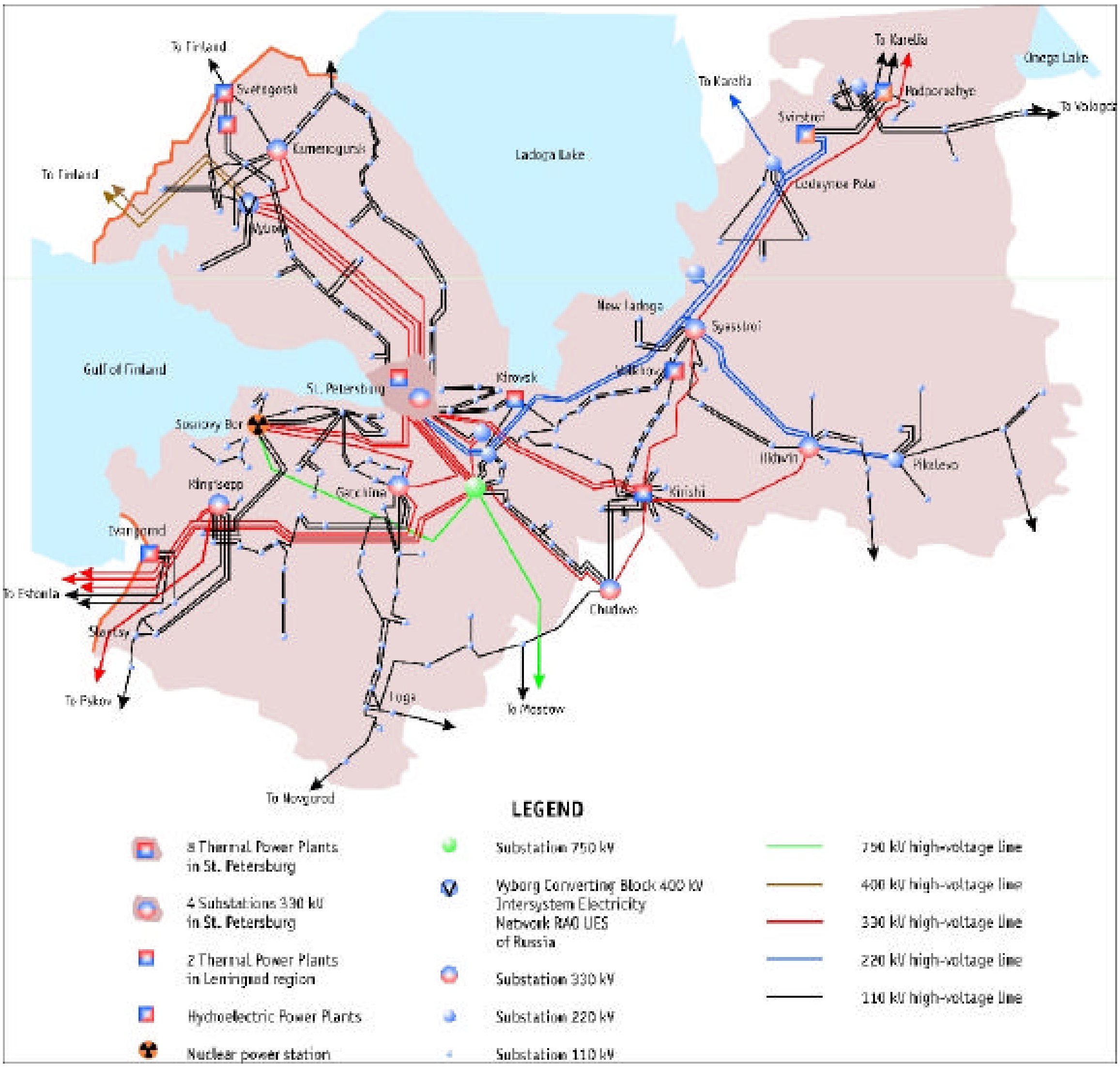

Figure 9. Electrical transmission lines: Leningrad Regional Power Network Company.

4.2.1 Condition of electrical transmission network and transmission efficiency

The technology used in the transmission of electricity in Russia is beginning to age, due to which transmission losses have continuously been increasing. In Table 13, the age and planned remaining operational period of RAO UE's electrical networks on average in Russia as a whole are presented.

Table 13. Average age of RAO UES's electrical fixed assets in 1999 (OECD/IEA 2002).

	Age [years]	**Planned service life**	**Remaining**
Electrical transmission	24 – 40	40	0 – 16
Electrical distribution	22 – 40	40	0 – 18

Typical losses in the transmission of electricity in Russia are about 15%. In Finland, correspondingly, electrical transmission and distribution losses are, on average, 4%. Substantial electrical transmission-related losses in Russia derive from the poor condition of the technology utilized, in addition to the illegal use of electricity (Zakrzhevsky 2005). In Table 14, the development of electrical transmission losses during the last few years is shown.

Table 14. Losses in electrical transmission in Russia (Bashmakov 2004).

	1990	**1995**	**1999**
Electrical losses: ratio to final use	10.2%	13.4%	15.9%

4.2.2 Greenhouse gas emission reduction potentials connected with the transmission of electricity

By improving the transmission efficiency of electricity, the achievable emission reduction potential can be estimated by the same principle as previously assessed with regard to district heating transfer. What is problematic in this assessment, however, is the fact that Northwest Russia's fuel-based generation of electricity occurs almost exclusively by means of CHP technology, which is generally run in accordance with the heating requirement, the electricity being a by-product. This being the case, it is not advantageous to lower production in the CHP stations even if electrical consumption is thereby decreased: rather, reduction in electrical generation can be directed towards other modes of production. Electricity in the regions of St Petersburg and Leningrad is generated by means of CHP production employing natural gas, in addition to nuclear- and hydropower.

In lowering electrical consumption, typically it is the costliest share of production based on production costs that is limited first. On this basis, coal condensing power is, with respect to production costs, the mode of production which would affect electrical consumption in Russia as well. On the other hand, in the region of Northwest Russia there is actually no real coal condensing power -based electrical generation. As a result of Russia's electrical stock market and the special features of the transmission networks, it is possible that reduction in electrical production may be steered into other "more economical" modes of production. Because of this, the CO_2 reduction potential related to electrical transmission is assessed in this report by two different options, so that the feasible saving in electricity lowers, as a whole, the requirement for electrical production in both coal-based and natural gas-based condensing power plants.

We may estimate the CO_2 emission reduction potential of the electrical transmission network in the St Petersburg and Leningrad region by presuming that, at average 16% transmission losses, there is potential to reduce losses to the level of 4%, which corresponds to typical electrical transmission losses in Finland. It is known that the transmittable amount of electricity is currently about 21.5 million Gcal/a (25 TWh/a) via the electrical transmission and distribution networks of the ”Leningrad Regional Power Network Company”, so that reducing transmission losses to the degree described above would lower the need for electrical generation by approximately 3.2 million Gcal/a.

From the development of condensing electricity generated by coal, carbon dioxide is typically produced at approximately 950 – 1200 g CO_2/kWh, depending on the efficiency of the power plant (35 – 28%). On this basis, it is possible to estimate that a potential reduction in electrical production of 3.2 million Gcal/a (3,7 TWh/a) would mean a CO_2 reduction potential of about 4 million tonnes.

On the other hand, the development of condensing electricity generated by natural gas gives rise to carbon dioxide at about 600 – 700 g CO_2/kWh with the efficiency of the power plant at 35 – 30%. On this basis, it may be estimated that a potential 3.2 million Gcal/a reduction in the generation of electricity would mean a reduction potential of about 2.5 million tonnes of CO_2.

According to this estimate, the CO_2 reduction potential obtained by reducing electrical transmission losses is in the region of 2.5 – 4 million tonnes annually.

5 GHG emission reduction potentials in energy usage

5.1 Background to the efficiency of Russia's energy use

In Russia, energy intensiveness is considerably higher in the consumption of energy than in the Western nations. The reason for this lies in the economic structure of Russia itself, in which the predominant industry rests in energy-intensive fields such as the processing of raw materials, the construction of large machines and the manufacture of building materials. The primary foundation for high energy intensiveness is systematic inefficiency in energy consumption in all sectors. This in turn is the result of low energy prices, insufficient measurement and supervision, the absence of market controls in reducing costs and the lack of production-based goal orientation in the monopolistic fuel and energy supply systems.

Energy consumption is impacted by the fact that fuel is cheap and prices subsidized. The motor vehicle fleet is also highly consumptive. Not even the marketing of low fuel consumption exists.

The market economy has increased knowledge in regard to the use of energy in heating buildings, leading to energy-saving investments where construction ownership relationships are clear. (In Russia, it is frequently difficult to determine whether the consumer is actually a building or a resident, owing to unclear ownership relations.)

The overall potential for Russia's energy savings was assessed at approximately 500 Mtoe in 1995. This meant about 40% of total energy consumption. Russia's governmental power company (RAO EES) estimated that a saving of 20% realized as respective to electrical and thermal energy in energy consumption would reduce the need for new production capacity 5 – 6 percent. As electricity, the saving concerned would correspond to approximately 20 TWh and, as heat, about 167 500 TJ (FRESCO 2005).

With regard to potential savings, the industrial as well as fuel and energy sector would be capable of realizing about 50%. The primary reason for energy wastage rests in the technical standard solutions applied during the Soviet decades from the 1950s to the 1970s in the planning of companies and buildings. A secondary reason is the inappropriate use of energy, which is entrenched as a habit and is something which does not affect the profit of firms as such. This has led to a dynamic increase in production-related energy consumption. According to specialists, Russia's gross national product-based energy intensiveness is 2.3 times that of the EU countries. During the last twenty years, this intensiveness has declined in the world as a whole by 18% and, in the developing nations, by 21 – 27%. By means of certain technical procedures, Russia's GNP-based energy intensiveness could be reduced by 38 – 47%. This corresponds to primary energy savings of 380 – 460 Mtoe. The related savings potential is 35 – 37% in industry, in the fuel and energy field almost one-third, and in the municipal economy 25 – 27% (FRESCO 2005).

Russia has concentrated district heating in use, and support-related fees totalling approximately 40% of local budgets are paid to the State energy companies (FRESCO 2005).

The lack of energy meters (with the exception of electricity) in use by private consumers as well as, in many instances, associations, results in a situation in which energy is billed according to the terms of the suppliers. In the planning of real estate and in energy invoicing, energy consumption norms are applied which are based on concentrated energy production and overall usage, and the necessary basic consumption by consumers is forgotten. The energy losses in excess of the guidelines are also added to energy bills, in addition to the losses incurred by inappropriate transfer.

The profitability of energy-saving measures is dependent on the local energy rate price primarily applied to each individual property. From the perspective of the public sector, city or state, the matter is not so directly resolvable. Public finances invariably incur losses when they are wasted somewhere. Extra domestic consumption makes it claim on available export proceeds from energy: by this token, the price rate of energy in the State-level calculations should use the world market price. In Russia's case, the price difference between the world market price and the local tariff may be multiple: utilizing the local price level could destroy the profitability of virtually any energy-saving measure.

In the economic calculations, the most important criterion is the repayment period, which depends on the amount of investment and savings. The price rate for energy-saving measures should take note of the extra expense which emerges between the repair method and the energy savings measure. In the event that the lifespan costs of the various alternatives are examined, the profitability of the energy savings procedures increases. The amount of savings depends on the building's starting situation in addition to the extent of the repair measures required. Through energy auditing, it is possible to clarify the actual starting situation.

5.2 Public property and private residences

The suggested indoor temperature for residential buildings is 18 °C. Temperatures in dwellings vary greatly, however. During the winter, a temperature deficit appears, and the temperature may be substantially below the recommended value. Conversely, overheating in spring and autumn is common due to the absence of temperature control possibilities.

Many buildings in Russia waste energy. Elemental construction is not high-quality, and cracks are frequently found between elements. The sealing in the wall and window casing as well as between the window frame and casing is also inadequate. Moreover, there are defects in the weather strip. As a result of these deficiencies, draughts occur as well as drops in the indoor temperature. Moreover, changes emerge in the pressure ratios from one residential space region to another, hindering ventilation functions.

Water consumption per dwelling is large compared to the statistics in Western countries. Taps leak, so temperature is lost along with the waste water. In one month, a tap or WC valve that leaks at a dense rate can incur about 2 m^3 of extra water consumption, and with more sustained leakage this can be as much as 5 – 20 m^3 (Planora Oy 2001). In addition to points of leakage, reasons for substantial water consumption are:

- a substantial flow rate respective to the lower floors of blocks of flats, owing to high pressure,
- dishwashers and washing machines are not in use.

Flat-specific meters for temperature and electricity in residences are also missing. In some blocks of flats there is some kind of maintenance charge which also covers energy. Energy charges are based on a one-time payment sum and/or calculated values.

The City of Pskov, for example, is experiencing an energy shortage. The dwellings are without heating, and warm water is available for only three months of the year. Various procedures apply to the various standards of housing. Substitute heating is frequently provided by gas. The energy shortage is caused by the energy quotas: these are too low (the city has grown, but the quotas have not). There is an effort during the winter to manage with the quotas and in the summer to save. The interruptions in the heating supply have led to a situation in which electrically heated boilers are purchased for homes. It would make more sense to produce the energy concerned concentratedly in district boiler houses.

Residences are privatized. Everyone has been given a home and everyone looks after only his/her own dwelling. Joint responsibility is not practised. Nevertheless, the administration of the housing companies is such that it hinders reforms. For instance, it is not possible for individuals to obtain thermostats. By resolution of the city government, it could be conceivable to assign thermostats to all. Ownership and administrative arrangements occupy a key position in the reform measures.

The starting point for repairs is normally the poor condition of structures or unsatisfactory living conditions, which are linked in turn with the substantial consumption of energy. An increase in knowledge about the impact of consumption on costs would be an important factor controlling consumption. Up-to-date information on property-related energy and water consumption is produced by the relevant monitoring and follow-up. By these means, the deviations in consumption caused by equipment and operational technology-based faults are noted, through which it is possible to react to them quickly and the deviations in consumption thereby caused avoided.

The amount of energy required to heat buildings in Russia is 3 – 4 times that compared to the Finnish standard. The large-sized public buildings, such as the schools and hospitals, offer a good target group for the implementation of energy savings and carbon dioxide emissions-related reduction measures. Already at one location, great savings have been achieved for a large-sized site. The owner of public real estate is the municipality or the city, with respect to which the decision to make corrective decisions is simpler. Participation of the city or region in JI projects in association with the Kyoto agreement could also be easier to realize, since such projects are easier to link with the energy-saving goals of the Russian State. The problem is more that of money.

For instance, the U-value (the overall heat transfer coefficient) of outer walls in buildings constructed during the 1950s till the 1970s with Soviet era elemental engineering has been measured at 1.0 – 2.4 W/m^2K. The external 100 mm additional heat insulation and aerating facade lining could be improved to conform to the U-value figures 0.2 – 0.5 W/m^2K. In this case, the result of the energy-economizing repair procedure in one year would be about 90 – 230 kWh/m^2 of the wall surface when the total number of temperature days is approximately 5000 (Planora Oy 2001).

On an annual level, 90 – 230 kWh/m^2 of energy savings would mean a reduction in carbon dioxide emissions achieved by district heating respective to the region of the wall surface, 33 – 85 kg_{CO2}/m^2.

In aspiring towards high energy-saving figures, the external casing of the building with good heat insulation has substantial significance. First it should be in condition and investments should subsequently be initiated in energy conservation-based indoor renovations (air conditioning, thermal reduction systems, measures intended to decrease the use of hot process water). Good heating insulation in the external casing of a structure also plays a central role in increasing residential comfort. A poorly insulated outer wall of a building keeps the temperature inside the wall low, and this is also felt—due to the effect of radiation—at a greater distance inside the flat. In the event that energy savings-related measures are initiated from the systems inside the building, the benefit thereby obtained is minimal. Raising the indoor temperature only increases the heat flow proceeding through the external casing, and does not improve residential comfort close to the wall. It would be possible by resorting to well-insulated external casing to reduce the temperature of the housing by 2 – 3 degrees without it having a negative effect on living comfort (Planora Oy 2001).

For example, if the U-value of the outer walls is changed from the starting value of 1.5 W/m^2K to the after-repair value of 0.3 W/m^2K by means of extra thermal insulation, and the surface of the building's outer wall is 2 500 m^2, in one year the savings in energy will be approximately 360 000 kWh (Planora Oy 2001). When it is acknowledged that the use of district heating incurs, on average, 370 kg_{CO2} of emissions per MWh (see Chapter ***4.1.5***), it can be estimated that the saving concerned would reduce carbon dioxide emissions by 133 tonnes in one year.

Generally, the surface area of the wall is approximately 70% of the combined facade and window surface. The energy savings potential in Russia of the outer wall is approximately 70 – 80%. By multiplying the energy-saving potential of the outer wall by the surface region proportion of 0.7, we achieve a calculated energy saving of 49 – 56%. With respect to windows, we correspondingly obtain a savings potential of only about 12%.

5.2.1 Examples of Norwegian realization with respect to renovation measures on public real estate

The Norwegians have implemented, among other things, projects in Northwest Russia in which the energy efficiency of buildings has been clarified. For the most part, the projects have concerned public properties such as schools, hospitals and children's nurseries, which are owned by the municipalities. Among other things, the measurement and monitoring of energy consumption has been incorporated in use. It has been possible in this manner to adjust the room temperature to the optimal level and, additionally, the air indoors has improved. By means of various improvements, it has been possible to achieve a 25% reduction on average in energy consumption. In the following Table, the renovation measures taken are presented in addition to their typical repayment schedules (Grytsenko N., Teigen Ø., 2005).

Table 15. Repayment periods for energy-saving improvements (Grytsenko N., Teigen Ø. 2005).

Potential improvement	Average repayment period (years)
Development and implementation of operation, maintenance routines and energy monitoring	1.5 – 2
Renovation and sealing of the windows	3 – 4
Installation of the new substation with automatic controls	3 – 4
Thermal insulation of pipelines and valves	4 – 5
Installation of thermostatic valves	5 - 6
Hydraulic balancing of the heating system	5 - 6

Favourable results have also been accomplished by the mere installation of meters in buildings. In this respect, invoicing occurs in accordance with consumption rather than by norms. In many cases of this kind, the repayment period is under one year.

The energy consumption of buildings in Russia is, generally speaking, approximately ¼ of all energy consumption. The largest part of energy is used in heating rooms. A considerably smaller proportion is used for illumination, machines, equipment and hot process water. The energy-related efficiency of buildings is quite low in Russia, even if climatic factors are taken into account. The energy requirement of Russian buildings per floor-based square metre is approximately double by reference to Nordic structures. With respect to the energy consumption of buildings, the energy-saving potential is in the order of 40 – 45% (Grytsenko N., Teigen Ø. 2005).

In surveying the energy consumption of buildings, the targets under inspection are:

- Building walls, roof, floor and windows
- Heating system
- Automatic ventilation system
- Process water
- Automatic control systems
- Illumination
- Installations in kitchen and washing facilities

- Insulation (does it work as intended?)

Each building has its own special features, and at each site the most important points for improvement particular to the location concerned must be pinpointed in order to achieve the most significant energy savings.

Example 1:

The target is a house whose basal region for heating is 2300 m². In Table 1, the potential renovation measures, related investment costs, energy saved as a result of the procedures, repayment schedule for the investments concerned and reduction in carbon dioxide emissions are presented (Grytsenko N., Teigen Ø. 2005).

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Table 16. Effects of energy-saving improvements on a 2 300 m^2 building.

Potential improvement	**Investment [USD]**	**Net savings**		**Repayment period [years]**	**CO_2 reduction [kg/a]**
		[kWh/a]	**[USD/a]**		
Energy-saving showers	400	2 300	200	2.0	851
Operation and maintenance manuals	15 000	81 000	7 100	2.1	29 970
Sealing: windows	10 000	80 000	8 000	1.3	29 600
Insulation of roof	12 500	17 800	1 800	6.9	6 586
Pipes and valves: insulation	9 500	17 700	1 800	5.3	6 549
Balancing heating system and thermostatic valves	22 500	53 800	5 400	4.2	19 906
Ventilation air system and heat recovery	25 000	37 000	3 200	7.8	13 690
Automatic control system	20 000	38 000	3 300	6.1	14 060
Total	**114 900**	**327 600**	**30 800**	**3.7**	**121 212**

For the determination of CO_2 emissions, the coefficient of 0.37 kg CO_2/kWh has been used.

When it is known that the utilization of district heating results in emissions at 370 kg_{CO2} per MWh on average (see Chapter **4.1.5**), it may be calculated that the energy-saving concerned would diminish carbon dioxide emissions by 121 tonnes in one year.

In determining the consumption preceding the renovation measures, it is possible to make use of three alternative methods: based on measurements, according to norms, or the basic level as calculated. The last-mentioned is the one most utilized. Its usage eliminates those cases in which the room temperature in the initial situation is so low in the winter as to be non-usable: thus it would also look as if negative savings will be obtained through repairs.

Example 2: (Grytsenko N., Teigen Ø. 2005)
Hospital (Apatity Hospital Block 2). In Table 3 following, the renovation measures are presented as well as the savings thereby obtained.

Table 17. Energy audit of Apatity Hospital Block No 2.

Potential improvement	**Invest-ment [€]**	**Net savings**		**Repayment period [years]**	**CO_2 reduction [kg/a]**
		[kWh/a]	**[€/a]**		
Operation and maintenance routines	2 160	78 400	1 064	2,0	29 008
Pipes and valves: insulation	3 520	97 160	1 320	2,7	35 949
Hot water supply system optimization	8 176	85 070	2 672	3,1	31 476
Radiator thermostatic valves	7 232	110 920	1 512	4,8	41 040
Ventilation air heat recovery	10 688	141 360	1 920	5,6	52 303
Windows: quality improvement	20 000	187 230	2 544	7,9	69 275
Heating: sub-central modernization	27 336	233 940	3 184	8,6	86 558
Total	**79 110**	**934 080**	**14 216**	**5,6**	**345 610**

For the determination of CO_2 emissions, the coefficient of 0.37 kg CO_2/kWh has been used.

The total calculated energy saving from the various sectors is 934 080 kWh/year, which corresponds to 30% of the energy consumption determined by calculation of the existing energy consumption prior to renovations. The energy saving concerned shall reduce carbon dioxide emissions by approximately 346 tonnes annually.

Example 3:
School no. 3 Petrozavodsk, whose floor-based surface region is 5 306 m^2, was built in 1976. In Table 18 as follows, the renovation measures as completed and the savings obtained thereby are presented.

Table 18. Energy audit of School No. 4 in Petrozavocsk.

	Investment, [€]	Net saving		Repayment period [years]	CO_2 reduction [kg/a]
		[kWh/a]	[€/a]		
Insulation of pipes in the basement, balancing heating system	2 400	59 500	752	3.2	22 015
Heating: sub-central upgrading	13 200	178 000	2 248	5.9	65 860
Sealing: windows	6 480	137 000	1 732	3.7	50 690
Reconstruction of heat-insulated roof insulation features	5 440	91 000	1 152	4.7	33 670
Renovation of greenhouse	1 120	25 000	316	3.5	9 250
Total	**28 640**	**490 500**	**6 200**	**4.6**	**181 485**
Installation of cold water meter	160			0.3	

For the determination of CO_2 emissions, the coefficient of 0.37 kg CO_2/kWh has been used.

By means of the measures presented in the Table, energy savings as calculated of about 25% are achieved, together with a carbon dioxide emission reduction of 181 tonnes.

The ”Energy Efficiency in Northwest Russia” project implemented by the Norwegians had over 250 buildings as its target for examination. A total of 24 cases were selected as targets for improvements. Through the measures implemented, an average energy saving of 25% was attained, and the average repayment period for the selected procedures was 2.4 years.

5.2.2 Blocks of flats from the Soviet period: heat and water consumption in blocks of flats

As a form of collaboration between the Ministries of the Environment of Finland and Estonia, the heat and water consumption in blocks of flats built during the Soviet era has been examined (Aro et al. 1999). The blocks of flats included in the survey are standard blocks, i.e., 5 – 16 storey elemental or brick buildings situated in various parts of Estonia. The sample represents approximately 8% of these structures. A large number of these buildings are equipped with an energy-wasting district heating ejector connection link. In the following Table, construction year impact on specific heating consumption is presented.

Table 19. Impact of construction year on specific heat consumption in buildings.

Year of construction	**Specific consumption kWh/m^2,a (1997)**	**Measured buildings**
1960 - 1964	281	16
1965 - 1969	261	47
1970 - 1974	270	27
1975 - 1979	289	30
1980 - 1984	300	35
1985 - 1989	287	27
1990 - 1994	267	3

On the basis of the Table, it can be stated that the greatest specific consumption with respect to the houses under examination are in the houses built at the end of the 1970s and during the 1980s. Of these, the majority were equipped with a district heating ejector connection link. In addition, the 14 – 16 storey tower blocks in the study, which consume a considerable amount of energy, were built during the same time periods.

In the Soviet Union, a district heating link referred to as an ejector was generally in use. It is a direct connection in which water from the district heating network circulates the residential housing radiator network. In the ejector section, the cooler water returning from the building's heating network is mixed with the warmer district heating network's incoming water. The temperature of the water going into the building could be adjusted individually in accordance with the structure's heating requirement. The weakness of the link, however, has been the fact that the mixing ratio of the ejector has been constant. The adjustment of the radiator network in the building is therefore based on the temperature of the incoming water from the district heating network. During the frost season, the ejector connection link has functioned satisfactorily, but during spring and autumn the general result is over-heating. The district heating water temperature must stay sufficiently high due to the fabrication of hot process water. Turning off the heating connection completely in spring and autumn has not emerged as an option, so it has been necessary to relieve overheating through opening the windows. Additional detriment has been caused by corrosion in the radiators and in the piping of the housing, due to the poor quality of the district heating water.

By renewing the district heating sub-distribution unit, it is possible to improve the adjustment of heating over that of the past. Automatic regulation of the heating system's outgoing water temperature in accordance with the outdoor temperature enables stable room temperatures no matter what the weather. The prerequisite is that the adjustment curve is set correctly and the residential building's heating network is balanced. According to the research, renewal of the sub-distribution unit would appear to reduce heating consumption by approximately 10%. The result of renovating the sub-distribution unit would be functional hot water circulation, which also decreases the consumption of process water, because the unnecessary running of water while waiting for it to warm is eliminated.

In renovating the heating network, line control valves are often installed into the network, which enable the balancing of the heating network. As a result, the room temperatures in a building are integrated, and it is not necessary for the entire building to be heated in accordance with the coldest rooms. By installing pre-adjustable thermostat-equipped radiator valves, balancing is even better achieved. In addition, they interrupt the heating of the room when the temperature rises too high. Through renovation of the heating network, it is possible to reduce heating consumption by approximately 7% (Aro et al. 1999).

Sealing windows decreases uncontrolled leakage ventilation in a building. In the blocks of flats constructed during the Soviet era, ventilation is generally based on natural air draught. In sealing and renewing windows, attention should be given to not allowing ventilation amounts to remain too small. By window sealing and replacement, an approximate 9% reduction in heating consumption is achieved.

It is possible to position extra thermal insulation on the walls and in the roof. In one of the Soviet-era blocks of flats, the following renovation measures were carried out: renovation in the district heating sub-distribution unit as well as in the heating network and process water piping, and extra thermal insulation in the walls and roof. Through the combined effect of these repair measures, a reduction in heating consumption of approximately 27% was achieved.

It is advisable with extra thermal insulation to start from the ends. Windows are found at these locations more rarely, and are thereby relatively easy to insulate. End flats are typically the coldest ones in the building and, due to the same, the temperature of the water going into the heating network must be kept high, making the residences situated in the middle of the structure too warm. Through this procedure, the residential comfort of end-flats also improves.

Terijoki Hospital no. 41: energy economy clarification and renovation-related productivity

The Planora consultancy office has completed the Terijoki Hospital energy economy clarification for the winter of 2000 – 2001. As the main inspection-related target, energy-saving renovation to the building's external casing was selected. The report has been financed by the Ministry of the Environment and Rautaruukki PLC.

The hospital's old section was built by Finns and has operated as a garrison hospital. It was expanded later by using Soviet era concrete elemental engineering. The hospital is linked up with the local district heating network. Roughly assessed, approximately 25% of the building's external casing repair-related costs would, according to the report, be feasible to finance by means of the commercial emission trade.

Altogether, potential means to achieve energy savings on the consumption side in private and public real estate are:

- The measurement systems for heat consumption should be installed for every consumer, and in the future invoicing should be based on actual consumption (by regional resolution)
- The straight injector connection links for heating rooms should be replaced with an indirect connection (heat transmission), and building-specific automatic systems should be installed
- Open circulation at the point of hot process water should be modified by means of a closed cycle
- A one-pipe system based on series connections inside the buildings should be replaced with a parallel coupling-connected dual pipe system
- The radiator should be equipped with thermostat valves
- Renovations should be carried out to structures.

5.3 Industry

The most important reason for the energy-intensiveness of Russian industry is found in the industrial production structure already prior to economic reforms and technical underdevelopment in the industrial fields. The machine base is aged, the apparatus is worn and the engineering utilized has remained non-advanced. There are also subjective causes which affect energy consumption, the elimination of which does not require large investments. These are, among other things, the wasteful use of energy, the failure to observe laws respective to energy savings (particularly applicable to the monitoring and control of the consumption of fuel and sources of energy) and the underdevelopment of management mechanisms.

In the region of Leningrad, industrial plants consume about 35% of the primary energy used in the area. They make up the largest group of concentratedly generated electrical and thermal energy users. Large consumers include the region's equipment manufacturing, shipbuilding, chemical and petrochemical industries as well as those in wood processing and food production. In connection with many mechanical engineering-based industrial facilities, there are also energy-dominant metal factories, which utilize energy primarily in the form of natural gas and electricity. The proportion of the region's overall use of industrial energy by mechanical engineering and equipment manufacture is about 30%.

There are more extensive financing possibilities and great energy savings-related potentials in industry. The weak aspect concerns the inefficiency in the control of energy consumption and an underdeveloped energy management system. The problem in industry is the inappropriate use of energy. Over 40% of energy resources are utilized in a non-economical manner and fail to obtain decent margins.

The reasons for wastage in industrial energy can be divided into these main categories as follows:

- energy losses occurring within the plant's internal energy distribution systems (energy consumption, heat consumption, use of water)
- energy losses arising in production processes which are connected with the formation of material flows inapplicable to practical application (combustion gases, steam losses, waste water)
- energy losses caused by the aging of machinery and equipment.

Losses incurred within the plant's internal energy distribution systems can mostly be eliminated by means of the enterprise's own resources. With respect to larger renovations, greater investments are required, whereupon the repayment periods for such measures are longer. The improvement achieved by investment on energy efficiency is typically so considerable that the repayment periods remain reasonable even for large renovations. In the following Table, a few examples have been gathered of the measures implemented in industry together with their key ratios.

Table 20. Energy-saving investments for industry (GreenStream Network 2005 & FRESCO 2005)

Measure	**Industrial field**	**Realized improvement**	**Investment [USD]**	**Repayment period [years]**
Substitute-purchased heat for own heat production	Metal industry	Annual heat energy costs reduced by 82%	546 000	4.4
Installation of boiler and steam turbine in order to own electrical production	Food processing industry	Low-cost electrical production	1 250 000	1.6
Installation of steam turbines in existing boiler plant for CHP production	Pulp and paper industry	Reduced electricity and heat costs	2 860 000	1.6
Installation of CHP unit in order to produce own-use electricity and heat	Wood industry	Reduced electrical costs	2 700 000	2.7

According to expert estimates, the following types of solutions are amongst the most effective in the various technical means of saving energy:

- the establishment of monitoring, summarizing, analysis and a flexible control system for fuel and energy consumption at the various stages of the production processes and in all factory departments and services which safeguard basic production as well as, in similar manner, the equipage of substantial consumption targets with control and measurement devices
- the installation of electrical energy consumption measurement equipment (savings in electrical energy yearly 25 000 kWh/measurement device and repayment period < 1 year)
- the usage of measurement and control equipment for verifying the efficiency of energy consumption with regard to the most important fuel and energy resources (reduction in energy consumption 2.5 – 3.5% and repayment period 1 – 1.5 years)
- the commissioning of local energy management and surveillance systems in addition to automatic controlling systems and, simultaneously, rehabilitation of the company's energy economy (energy consumption would decline 5 – 8%, repayment period = 1 year)

For all in fields of industry using compressed air, an applicable energy-savings measure could be the installation of a low-power additional compressor at the compressor station, or replacement of the former unit with one that is lower in power. Considerable loss of compressed air occurs during quiet workshifts and on free days. This procedure would afford the possibility to reduce energy consumption during these periods by 10 – 15%. The degree of economic suitability depends on the power of the machinery at the compressor station and, at particular locations, the actual method of using the compressed air.

The control of lighting to occur according to stages in factory departments has also proven to be effective. When lighting power is 20 – 30 kW, energy consumption declines by 4 000 kWh in a year, which is 8 – 10% of energy consumption in the distribution networks.

In industrial energy consumption, the heating and ventilation systems in the production areas also have pivotal significance. These systems are substantial consumers of energy, and their impact on the production plant-based fuel and energy balance as well as on the company's energy-savings potential is large. The proportion of heat consumption from ventilation systems and air-heating in a firm's overall energy consumption vary in terms of energy intensiveness, depending on the field of industry, as follows:

- iron industry and colour metallurgy, chemical industry 5 – 10%
- light industry (textiles, ready-made clothing and shoe industry), food industry 15 – 20%
- mechanical engineering industry, metal working, electrical engineering, equipment industry 20 – 25%
- heavy mechanical engineering industry, shipbuilding 50 – 60%

The substantial consumption of thermal energy in the heating and ventilation of industrial plants derives from the need for considerable ventilation in production facilities. In this sector, it would be feasible to achieve savings in energy through the following measures:

- by reducing the amount of ventilated air (incoming and exhaust air) per product unit
- by utilizing secondary thermal and energy sources to heat the incoming air
- by utilizing the warmth of exhaust air to heat the incoming air
- by rebuilding the ventilation system and incorporating new technical solutions (e.g., by incorporating infrared gas radiation, as a result of which it would be possible to save 80% of the energy employed compared to traditional convection systems).

The consumption of industrial energy in the St Petersburg region and the reduction potentials of energy consumption were surveyed during the spring of 2004. The survey was prepared by the specialists of the Kontakt research centre. The potentials obtained as a whole for industry are presented in Table 21 following, with the carbon dioxide reduction potentials calculated on the same basis in Table 22.

Table 21. Energy consumption and energy-saving potential of industrial production in the St Petersburg region (FRESCO 2005).

Energy consumption			**Energy-saving potential**					
Electricity (1000 MWh)	Natural Gas (million m^3)	Energy (1000 toe)	Electricity (1000 MWh)		Natural gas (million m^3)		Energy (1000 toe)	
			min	max	min	max	min	max
6 169	3 684	6 303,3	438	811	379	603	582	966

Table 22. CO_2 reduction potential of industrial activity in the St Petersburg region.

	CO_2 reduction potential [kt]	**Energy purchase cost savings [M€/a]**	**Value of achieved emission allowances [M€/a]**
Electricity use	360 – 668*	13.0 – 24.1	3.6 – 6.7
Natural gas use	757 – 1204	8.9 – 14.1	7.6 – 12
Total	**1 117 – 1 872**	**21.9 – 38.2**	**11.2 – 18.7**

Prices utilized: natural gas rate 1100 RUR/t, electrical rate 1010 RUR/MWh, and rate of emission allowance € 10/t_{CO2}. * = Specific CO_2 emissions of electrical production in Russia, estimated to 700 g/kWh .

The fields of industry consuming the most energy are the iron industry, colour metallurgy, the chemistry and petrochemical industries and construction. This being the case, these are also potential targets for energy-efficient investment projects. The significance of energy efficiency has grown in Russia as the price of energy has risen and it has become necessary to lower production costs. The efficiency of fuel and energy use can be increased by two routes:

- through the aid of technical production processes and the modernization of companies' infrastructure, which require considerable investments and a long repayment period;
- by renewing energy-saving systems at the industrial plant on a stage-by-stage basis, it is feasible to recover the investments made during a reasonable interim and in preparation for rationalization in the energy economy.

Regardless of what method is used, it is appropriate for each industrial enterprise to develop a total programme for fuel and energy savings.

6 GHG emission reduction potentials in waste management

In this chapter, the quantities of waste as well as the potential of landfills on the basis of the current state of waste management as possible reduction targets for greenhouse gas emissions in the regions of St Petersburg and Leningrad are examined.

6.1 Current status of waste management in the region of St Petersburg and Leningrad Oblast

The general area of St Petersburg and Leningrad is one of Russia's most densely inhabited and most industrialized, which is also visible in the amount of waste generated. In the region of St Petersburg, inhabitants number approximately 4.6 million and in that of Leningrad Oblast the total is approximately 1.6 million. Though the population in the general area has been declining for years, the quantity of wastes has been increasing vigorously.

In the region of St Petersburg, over 5 million m^3 of community waste is produced yearly, of which 75% is derived from households (Florinskaya et al. 2002). In Fig. 10, the development of community waste in the St Petersburg region is presented on a ratio to the number of inhabitants.

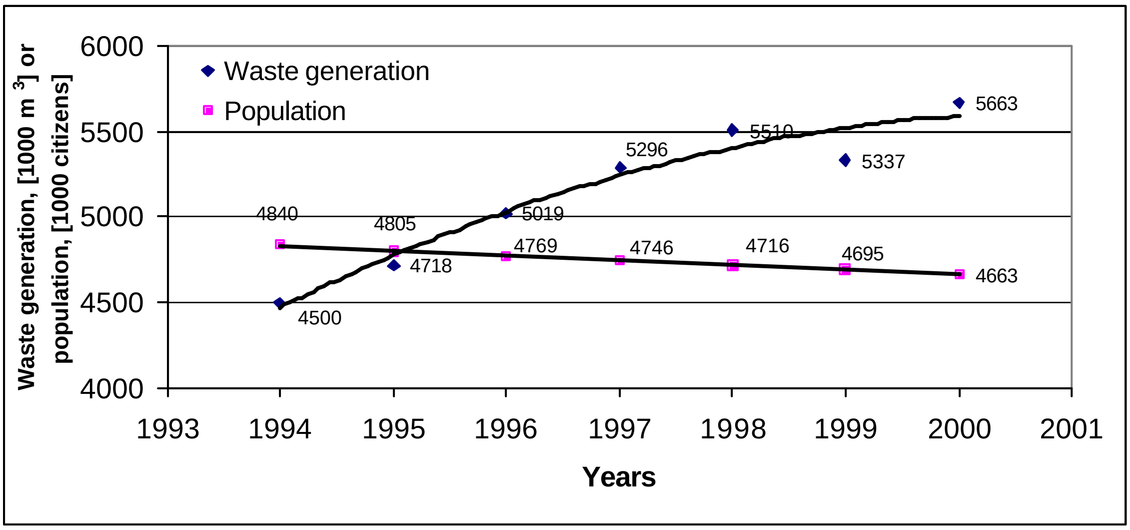

Figure 10. Change in population and amount of waste, 1994 – 2000 (Florinskaya et al. 2002).

There is no exact data available on the waste generated in the region of Leningrad Oblast. In the St Petersburg region, it is known that waste is generated per person to the amount of approximately 1.2 m^3/a. If it is presumed that the same relative quantity of community waste is produced in the region of Leningrad annually, the result is that the amount of waste generated is altogether approximately 2 million m^3/a.

Waste management in Russia is based for the most part on landfilling. Over 70% of the wastes generated in the region of St Petersburg are delivered directly to the landfills, and in the region of Leningrad Oblast, these wastes are to all intents and purposes relegated in full to the landfills. With regard to St Petersburg's wastes, slightly under 30% are processed in two composting plants, which include metal separation and drum-composting. Part of the waste handled in these facilities still ends up in the landfills.

In the region of St Petersburg and Leningrad Oblast, hundreds of landfills can be found, of which only a few are official. The lack of an adequate refuse collection and transportation system leads to circumstances in which a large part of waste materials is taken to unofficial, 'illegal' dumping grounds which are generally small. According to the Department of Natural Resources of the Northwest Region, there is a total of about 75 official landfills and approximately 1000 illegal dumping areas of various sizes (Pedersen & Holse 2003) in the St Petersburg and Leningrad regions.

According to a second assessment which is based on Russia's Statistics Committee data, there are 17 special landfills, 124 official landfills and 93 illegal dumping grounds in the region of Leningrad, to which a total of 4.3 million m^3 of refuse are conveyed yearly. Moreover, local industrial plants have 15 'muddy' landfills, 6 based on ash, 174 on sludge and 27 landfills for various sorts of industrial wastes (Prioda 2005). Part of the waste at landfills in the Leningrad region is conveyed there from the St Petersburg region.

In Russia, waste disposal sites are typically filled by means of a layer-filling technique, which must be taken into account in assessing landfill gas formation and planning its accumulation. In layer-filling, the landfill is filled throughout its entire surface area, so that the thickness of the refuse layer grows more slowly than a modern landfill which is constructed in sections landfill. Also, covering of the landfill occurs only when the site is closed for good.

6.2 The region's most important landfills and an assessment of their greenhouse gas reduction potential

The accumulation of landfills gases is most economically profitable at large landfills where the most methane is formed. Due to this, the largest landfills in the region of Leningrad and St Petersburg have been adopted as a target for examination. The greatest proportions of wastes produced in the region are located at a few main landfills which clearly offer more potential with regard to the collection of gas. In section 6.2.3, methane production showing this trend is presented for these landfills, assessed through calculations by utilizing the so-called 'mass balance' method.

Over the long term, the amount of landfill gas formed can also be reduced by sorting organically degradable materials separately to the collection of waste placed in the landfills. This affects both small and large landfills in terms of their gas generation. In section 6.2.1, the impact achieved by the sorting of waste on greenhouse gas emissions is described.

6.2.1 Impact of waste sorting on the formation of methane emissions at landfills

Approximately 80% of degradable organic carbon (DOC) delivered to St Petersburg's dumping grounds arrive in conjunction with organic kitchen waste, paper and wood. By sorting these waste components separately, it shall be possible in the future to diminish the landfill gas emissions formed. It depends on the conditions at the dumping ground as to how much the organically degradable components become landfill gas. On the basis of equation 2 in Appendix 3, it is possible to roughly reckon that:

- the breakdown of one tonne of kitchen waste forms ~ 40 kg of methane
- one tonne of wood waste decomposition forms ~ 80 kg of methane
- one tonne of paper waste decomposition forms ~ 100 kg of methane.

The estimate made in 2003 by the Committee for Environmental Protection of the City of St Petersburg with regard to the waste material distribution formed is found in Table 23. The organic coal proportions containing the typical various waste components have been added to the Table.

Table 23. Waste components in Russia

Component	% by mass		
	Household waste	**Commercial waste**	**DOC***
Food	26.0	11.1	16
Paper	14.8	37.7	40
Wood	9.3	9.3	30
Metal	8.1	1.7	0
Textiles	8.5	6.1	40
Glass	10.9	6.1	0
Leather	1.8	1.4	16
Stony	6.8	7.0	0
Plastics	11.1	14.9	0
Other	2.4	4.1	0

* DOC = Degradable Organic Carbon. Source (Tuhkanen 2001).

As an example, on theoretical grounds one may examine the impact of paper recycling on the methane emissions formed in the regions of St Petersburg and Leningrad. In this general area, community waste makes up a total of over 7 million m^3 annually, which expressed as mass is approximately 1.4 million tonnes. If the share of paper amongst this mass is 15%, this adds up to 210 000 tonnes of paper. Let us presume that the share of 10% (21 000 tonnes) of the paper waste generated can be added to the sphere of recycling. This would mean a reduction of 2 100 tonnes of methane emissions, i.e., approximately 44 000 tonnes of carbon dioxide emissions at dumps. Though it must be noted that the sorting, transport and processing of paper also cause carbon dioxide emissions, this share remains considerably smaller than the figures mentioned above.

On the basis of Table 23, paper is the most significant organic element which brings about the formation of methane at dumps in the area. In addition, its *in situ* sorting is simple, and sorted paper has value as a raw material for recycled paper. This being the case, paper waste is the waste component with the greatest potential from a reductive point of view with regard to landfill gases. The next most important is the sorting of wood and biowaste for processing.

6.2.2 Method used to assess methane emissions at landfills

There is very little detailed information available about the landfills situated in Russia with regard to waste placement history and composition, due in part to the lack of measurements and statistical practice on waste brought to such landfills. This being the case, the amount of methane formation is impossible to precisely ascertain. Assessments indicating the trend, however, can be calculated by means of, for example, the mass balance method used in this examination. On the other hand, the express goal of this study is to provide a rough picture of the circumstances, on which basis those targets can be chosen which have interest from the perspective of deeper examination.

By means of the mass balance method mentioned above, it is possible to calculate the rough values yearly of the amounts of methane composed at landfills with quite minimal source data and suppositions. In this model, the principle is that the methane arising from the decomposition of waste placed at a landfill during one year is released from the landfill the same year. In reality, methane is gradually freed from waste decomposition over the course of dozens of years. In examining the results, it must indeed be taken into account that the methane quantities provided by the model may deviate from reality by as much as 50% (IPCC 2000). If there is a wish to model the volume of methane formed more reliably—e.g., through the FOD (First Order Decay, see Appendix 3) method recommended by IPCC, the following source data must first be known with regard to each landfill:

- the amount of relegated waste on a separate basis for each year of operation
- the composition of the relegated waste (relative proportions of materials)
- the time in which the waste decomposes by half its original mass
- depth of the landfill
- the filling method of the waste disposal site as well as its structures.

6.2.3 Estimates of methane emissions at the most important landfills

Some of the most important landfills in the regions of St Petersburg and Leningrad in addition to information about amounts of waste placed there during a specific year have been collated in Table 24. With respect to these landfills, there is also an awareness of how large the proportion of landfilled waste originates either from the community or from industry. On the basis of this information, the quantity of methane as a mass released from dumps in one year has been calculatedly assessed. Due to the general character of the model, it must be noted that the amounts of methane thus estimated may deviate from reality by even 50%. For the purpose of examining the reduction potential of greenhouse gases, the quantity of methane is also converted into CO_2 –equivalent tonnes by employing the coefficient 21 t_{CO2}/t_{CH4} for the methane. The equations utilized in the modelling as well as the presumed coefficients are presented in Appendix 3.

Table 24. Placement of wastes in the largest landfills of Leningrad and St Petersburg and estimates of methane formation at the same (Florinskaya et al. 2002, Zakrzhevsky 2005).

LANDFILL	**Year**	**Municipal waste/Industrial waste, [%]**	**Waste, [1000m^3/a]**	**Waste, [t/a]**	**CH_4 formation, [t/a]**	**CO_2 equal, [t/a]**
City of St Petersburg						
Volkhonka (SWL-1)	2000	~100/~0	1 786	357 200	18 570	390 000
Samarka (SWL-2)	2000	75/25	214	42 800	1 960	41 000
Novoselky (SWL-3)	2000	~100/~0	1 802	360 400	18 740	393 600
Vsevolozhsk district						
Lepsari	2003	63/37	616,2	123 240	5 250	110 300
Vuoly-Eco	2004	25/75	170	34 000	1 120	23 600
Rostechno-complex	2002	-	26,6	5 320	210	4 400
Gatchina district						
Novy Svet-Eko	2004	-	914,1	182 820	7 190	151 000
Ecomonitoring	2004	-	116	23 200	910	19 200
Lomonosov district						
KPO-plant	2004	-	339,4	67 880	2 670	56 100
Tosno district						
Spetstrans-Kungolovo	2004	-	1,2	240	9	200
					?	1189400

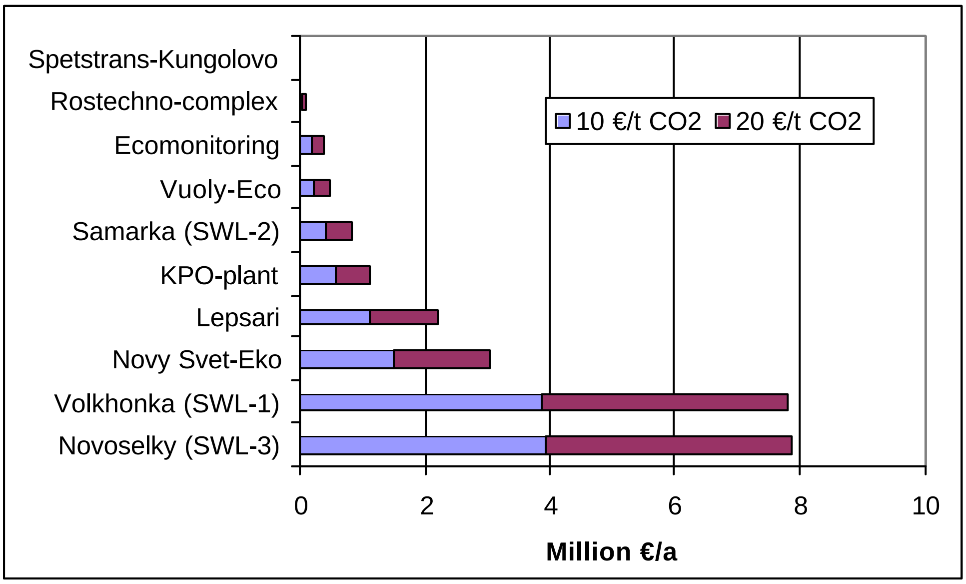

Figure 11. Potential of landfills for achieving emission rights by accumulating and eliminating generated methane.

On the basis of the calculations in the previous Table, Fig. 11 presents the most significant value of methane generated yearly at landfills in the St Petersburg and Leningrad regions as converted into emission rights, presuming that the rate per carbon dioxide tonne is either €10/t or €20/t. During 2005, the value of emission rights has risen approximately €7.5 to the level of approximately €20, reaching a maximum of €28/t_{CO2}. Conversely, the contract rate for emission reduction units may come to 3-10 €/t_{CO2} (GreenStream Network 2005) in the JI projects, in which landfill gas collection systems could be realized. In practice, not all the methane at landfills can be retrieved even using the best collection systems, particularly if the filling of the refuse dump is in progress. A utility function of approximately 90% is achieved in the collection of methane at a covered landfill.

By using the methane formed at landfills to replace fossil fuels, it would be possible to achieve more than 21 emission reduction units per methane tonne. If the amount of energy (50 GJ/t) contained in one tonne of methane were to replace other fuels by the same amount of energy, it would be possible to obtain, per one tonne of methane, the following:

- in replacing natural gas ~ 23.8 emission reduction units
- in replacing oil ~ 24.9 emission reduction units
- in replacing coal ~ 25,7 emission reduction units.

Landfills represent one of the easiest targets for obtaining greenhouse gas emission reductions. The technology is in existence and tested in practice. At the large dumps, reasonable repayment periods can be anticipated, especially if emission reduction units can be utilized in the improvement of project profitability.

Analyses for the evaluation of the profitabilities of projects should be carried out quickly on all landfills within the immediate vicinity of Russia. The collection and eradication of landfill gas may already be profitable through the value of the emission reduction units thereby achieved. Still better profitability is accomplished if the gas is beneficially exploited in the production of energy. Russia shall not have any obligations on the way with respect to waste disposal sites for some time. There are estimates that Russia’s waste disposal sites will be sold rather soon beyond Russia’s borders, so Finland should be wary of the matter (Hämeenkoski, 2005). It would be sensible to ensure the right to the Finns to the landfills by contractual agreement.

7 Conclusions

Russia's carbon dioxide emissions as a whole are, on an annual level, about 1500 Mt. This is primarily the result of using fossil fuels. The usage proportion of fuels utilized in energy production and traffic of Russia's carbon dioxide emissions in 2001 was over 70% (see Fig. 1). In addition to this, the carbon dioxide emissions formed in industry are, for the most part, derived from the use of fossil fuels. In particular, the energy production of the regions of St Petersburg and Leningrad is strongly weighted towards fossil fuels, of which natural gas and coal are employed the most.

The greatest potential for diminishing greenhouse gas emissions is clearly found in the procedures connected with reducing the utilization of fossil fuels along the entire energy maintenance chain of energy production, right up to its transfer and actual use. It is important that improvements are made throughout the entire energy maintenance chain, so that the improvement or usefulness achieved is not forfeited as losses at other stages or as a consequence of the inappropriate employment of energy.

It is peculiar to energy production in the regions of St Petersburg and Leningrad that energy is generated at large CHP power plants incorporating natural gas in addition to smaller boiler houses mainly employing fossil fuels. The conversion of the CHP plants to accommodate biofuels is not feasible in practice, so their emission reduction potential is linked with measures which will raise their operating efficiency. Russian-made steam boilers typically exhibit numerous technical deficiencies, the improvement of which could raise the operating efficiency of the facilities. In the boiler houses, on the other hand, the replacement of the fuel with one that is wood-derived or with natural gas would enable the reduction of emissions in a manner that is economically profitable. Renewable technology combined with fuel replacement would also elevate operating efficiency. Fuel replacement projects are of high current interest, as this procedure in some boiler houses has already been performed, and in several facilities it is being planned. The most potential targets for switching fuels are the boilers incorporating solid fossil fuels.

Due to forest reserves, for instance, the biofuel potential of Northwest Russia is substantial. The energy potential of wood waste alone in Northwest Russia's sawmills as well as its pulp and paper industry is over 40 – 50 TWh/a.

Energy transfer losses in Russia are about triple that of Finland's level both with respect to district heating and electrical transfer. The district heating networks are aged and in poor condition. Losses occur because of insufficient insulation and water leaks. Over half of the transfer pipes have deteriorated and the number of leaks has multiplied during the last few years. It has been calculated in this report that delivery of one Gcal of thermal energy to the site of use results in an average of about 430 kg of carbon dioxide emissions. By renovating transfer networks by, e.g., correcting those faults and omissions mentioned in section 4.1.2 so that 30% of the transfer losses decline to 10%, carbon dioxide emission can be brought down to the level of 334 kg_{CO2}/GCal.

Russia's gross domestic product-related energy intensiveness is 2.3 times that of the EU nations. In the region of Leningrad, the industrial plants consume about 35% of primary energy utilized there. They compose, as users, the largest group of intensively generated electrical and heat energy. The problem of industry is its inappropriate use of energy. Over 40% of energy resources are applied in an uneconomical manner. Energy-saving potentials are highly dependent on the field of industry concerned. Consumption of industrial energy in the St Petersburg region and energy consumption-related reduction potentials were surveyed in spring 2004 by the specialists of the Kontakt research centre. According to the same, it would be feasible by means of various measures to achieve 582 – 966 ktoe of energy savings, which corresponds to a decrease of 1 117 – 1 872 kt of carbon dioxide emissions.

The share of methane emissions respective to landfills compared to overall greenhouse gas emissions is rather low, but as individual targets the landfills can be highly significant for the implementation of climate-related projects. In addition, reducing emissions at the large could be quite profitable indeed and easy to realize, by reason of which interest towards them is on the rise.

In Table 25 following, estimates of CO_2 emissions in this report in terms of their reduction potentials have been gathered. Not all points in the Table describe maximum potential; rather, they are examples of certain CO_2 emission reductions achieved by certain measures. In the Table, the value of the reduction units potentially achieved at a rate of 10 €/t_{CO2} as well as savings with respect to certain measures from reducing the use of fuels are estimated.

Table 25. Summary of CO_2 reduction potentials estimated in this report.

Objects	**Measures**	**CO_2 reduction potential, [kt/a]**	**Achieved emission allowances, [M€/a]**	**Other savings, [M€/a]**	**More info**
CHP	Increase in total efficiency of CHP plants (10 plants) of St Petersburg and Leningrad from 40% to 60%.	7300	73	84 (Natural gas)	Figure 8
Municipal heating plants in the Leningrad region	Total energy produced by heating plants in region: ~9 TWh/a, CO_2 emissions ~2 258 kt/a. CO_2 reductions could be achieved by changing fuel and increasing efficiency.	No estimate	No estimate	No estimate	Section 3.3
Wood waste utilization in energy production	Utilization of all wood waste formed in region (42.7 TWh)	25 600	256	No estimate	Section 3.4, Table 8
Fuel change from coal to biofuel in 37 coal fed heating plants	Changing from coal to biofuel (installed heat power 140 MW)	208	2	No estimate	Section 3.4
District heating	Reducing losses 30% → 10% (St Petersburg region)	3 320	33	56 (fuels)	Table 12
Electricity transfer	Decreasing losses 16% → 4% (St Petersburg and Leningrad regions)	2500 – 4000	40	No estimate	Section 4.2.2
Industrial energy consumption	Based on estimate of energy-saving potential made by Kontakt research centre	1117 – 1872	11 – 19	22 – 38 (Natural gas)	Table 22
Landfills	Methane collection and flaring in 10 biggest landfills	1 190	12	No estimate	Table 24, Figure 11
Paper recycling	Improving paper recycling rate by 10% in order to reduce CH_4 emission formation in landfills (St Petersburg and Leningrad regions)	44		No estimate	Section 6.2.1

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APPENDIX 1 (Zakrzhevsky 2005)

Efficiency of boiler-houses operating with gas (in 2003 and 2004):

- Novaya Ladoga town: 72.97 - 92.49 %
- Sosnovy Bor: no info - 92.45 %
- Schlisselburg: 90.65 - 91.60 %
- Vsevolozhsk district: 89.54 - 90.91 %
- Sertolovo settlement: 90.95 - 90.67 %
- Kingisepp district: 89.0 - 90.0 %
- Lomonosov district: 89.72 - 90.15 %
- Gatchina city: 87.41 - 89.98 %
- Vyborg district: 89.8 - 89.65 %
- Lodeinoe pole district: 92.60 - 89.54 %

Efficiency of boiler-houses operating with mazut (in 2003 and 2004):

- Tikhvin district: 92.17 - 89.29 %
- Vsevolozhsk district: 86.35 - 83.43 %
- Kuznechnoe settlement: 79.99 - 83.16 %
- Lodeinoe Pole:district: 89.51 - 84.15 %
- Novaia Ladoga town: 77.69 - 85.71 %
- Vyborg district: 78.76 - 80.86 %.

Efficiency of boiler-houses operating with coal (in 2003 and 2004):

- Vsevolozhsk district: 69.51 - 76.72 %
- Volkhov town: 50.01 - 73.21 %
- Tosno district: 58.43 - 68.42 %
- Lodeinoe Pole:district: 68.59 - 68.09 %

Efficiency of boiler-houses operating with wooden chips (in 2003 and 2004):

- Industrial boiler-houses: 79.46 - 79.46 %
- Tosno district: 84.18 - 73.06 %
- Tikhvin district: 70.64 - 59.37 %.

Efficiency of boiler-houses operating with peat (in 2003 and 2004):

- Vyborg district: 49.29 - 58.44 %
- Boksitogorsk district: 27.18 - 46.25 %
- Tosno district: no info - 38.54 %
- Luga district: no info - 35.00 %.

APPENDIX 2 – List of potential boiler-houses for conversion to biofuels. (Planora Oy)

Number	Name and location of boiler house	Planned capacity for boiler plant [Gcal/h]	Type of boiler	Number of boilers	Fuel
1	Boksitogorski district				
	- Podborov	1,7	self-made	6	coal
2	Volosovski district				
	- Bolshaia Vruda	3,5	E-1/9, welded water-tube boiler	2	coal
	- Kursk	2,2	welded water-tube boiler	3	mazut/coal
	- Ostrogovitsy	1,2	welded water-tube boiler	6	mazut/coal
	- Lesozavod	1,8	welded water-tube boiler	4	coal/mazut
3	Vsevolozhsk district				
	- Rappolovo	5,0	KVTS-1	1	coal
	- Lesnoje	5,2	KVZ-2/115M	2	mazut
			DKVr-4,5	3	coal
	- Toksovo	6,0	EP-2,5	2	mazut
			E- 1/9	4	
	- Kuivozi	1,72	KVT- 1,1 /95	2	coal
4	Viborskiy district				
	- Vozroshdenije	4,5	KVTU-1	4	coal
			NR-18	4	coal
	- Tarasova	3,6	Bratsk -1	4	coal
	- Baryshevo	2,4	Tula-3	0	coal
	- Kondratjevo	2,8	Luga	4	coal
5	Gatsina district				
	- Semrino	3,2	NR-18	2	coal
			Luga	2	coal
6	Kirovskiy district				
	- Maluksa	4,5	DKVr -2,5/13	3	coal
	- Shum	4,5	welded	5	coal
	- Suhoe	1,0	Tula	4	coal
7	Lodeinopolskiy district				
	- Alehovshina	4,8	Luga- 1,5	6	coal
	- Jarovshina	2,6	Bratsk -1	1	coal
			KVTU-1	2	coal
8	Lomonosovskiy district				
	- Gora Valday	5,0	Tula -3	3	coal
			NIISTU	2	coal
	- Lesopitomnik	0,8	Universal-6	2	coal

9	Luga district				
	- Poshap	3,9	Luga	8	coal
	- Skreblovo	5,0	Luga	6	coal
	- Mezhozernyi	4,5	Luga	3	coal
			NR-18	2	coal
			Tula -3	2	coal
	- Volodarsky	3,6	Luga	5	coal
			NR-18	1	coal
	- Sabo	1,2	Luga	4	coal
	- Voloshovo	1,0	Bratsk -1	3	coal
10	Priozaersk district				
	- Razdolje	4,0	NR-18	10	coal
	- Krivko	7,3	NR-18	3	coal
			Bratsk	5	coal
	- Gromovoje	4,5	Bratsk	5	coal
			NR-18	4	coal
			Luga	1	coal
	- Romashky	4,0	NR-18	6	coal
			DZK-0,63	3	coal
	- Snegiryovka	9,0	DKVr-4/13	2	coal
			KE-6,5/14	1	coal
11	Tihvinskiy district				
	- Shugozero	7,2	KE-6,5/14	2	slate coal
	- Tsaritsyno Ozero	3,5	Luga	4	coal
			Welded	3	coal
	- Berjozovik number 2	2,2	Welded	5	coal
	- Gorka	6,5	Luga-Lotos	6	coal
	- Gankovo	5,0	Bratsk	6	coal

APPENDIX 3 - Landfill gas modeling equations

Equations of the mass-balance model (IPCC 2000):

$$CH_4 \text{ generated in a year} \left[Gg/a \right] = M(x) \cdot L_0(x), \quad (1)$$

where $M(x)$ = waste acceptance to landfill in year x, [Gg/a]

$L_0(x)$ = methane generation potential, [Gg_{CH4}/Gg_{waste}].

$$L_0(x) = MCF(x) \cdot DOC(x) \cdot DOC_F \cdot F \cdot 16/12 \quad (2)$$

where $MCF(x)$ = methane correction factor in year x (fraction)

$DOC(x)$ = degradable organic carbon in year x (fraction), [Gg_C/Gg_{waste}]

DOC_F = fraction of DOC dissimilated[1)]

F = fraction by volume of CH_4 in landfill gas

16/12 = conversion from C to CH_4.

1) = DOC_F is an estimate of the fraction of carbon that is ultimately degraded and released from solid waste landfill, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in landfill.

Equation of the first order decay (FOD) model (IPCC 2000):

$$CH_4 \text{ generated in a year} \left[Gg/a \right] = \sum_{x=t_0}^{t} \left[\left(A \cdot k \cdot M(x) \cdot L_0(x) \right) \cdot e^{-k(t-x)} \right], \quad (3)$$

where t = year of inventory

t_0 = starting year of calculation

A = $(1 - e^{-k})/k$; normalization factor which corrects the summation

k = ($k = \ln 2/t_{½}$) methane generation rate constant, [1/a]

$t_{½}$ = the time taken for the DOC in waste to decay to half its initial mass, [a]