EUROPEAN COMMISSION
Programme «LIFE+2007»

Developing Local Plans for Climate Change Mitigation by 2020

(CLIM-LOCAL2020)

LIFE07 ENV/GR/000282

ACTION 1

Local Inventory Report for GHG Emissions

Executive Summary

ES.1 Background and scope

Climate change is already happening and represents one of the greatest environmental, social and economic threats facing the planet. Observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level constitute clear evidence of the warming of the climate system. Most of the warming that has occurred over the last 50 years is very likely to have been caused by human activities.

The Kyoto Protocol, entered into force on 16 February 2005, represents a first step for addressing and combating climate change as it defines legally binding commitments of the developed countries to reduce, individually or jointly, emissions of 6 greenhouse gases (CO_2, CH_4, N_2O, HFC, PFC and SF_6) by more than 5% in the period 2008 to 2012, below their 1990 level. Currently, negotiations are in progress regarding future commitments for the period after 2012.

In this context, European Union is committed to reducing its overall emissions to at least 20% below 1990 levels by 2020, and is ready to scale up this reduction to as much as 30% under a new global climate change agreement when other developed countries make comparable efforts. To this end, a legislative package on energy and climate change (named "20-20-20 by 2020") has been put in place. Three key targets are set by this legislation package:

- A reduction of at least 20% in greenhouse gases (GHG) emissions by 2020 - rising to a more ambitious reduction of 30% in the event of an international agreement.
- An improvement of energy efficiency by 20% in 2020 compared to a baseline scenario.
- A 20% share of Renewable Energy Sources (RES) in the European Union's final energy consumption by 2020.

It is clear that these decisions have put in place a new framework for both the European and the Greek market by creating a favourable investment environment for RES and energy-saving technologies. This is of particular importance, especially under current circumstances of economic crisis and recession. In this general policy context, the assessment of the potential of large GHG emissions reductions after 2012 together with the associated policies and measures are mainly focused on national and/or EU level.

On the contrary, local authorities in many cases remain passive, waiting to see first what will be the new national reduction targets. This prevents undertaking a number of actions at local level in due time, while on the other hand a number of decisions affecting future GHG emissions are taken at present establishing local infrastructures with a long lifetime, which will not be altered soon once created. The assumption that local communities will move forward once a new national target is set and appropriate policies decided at central level are introduced/ reinforced, ignores the fact that a large number of measures presupposes the participation of local communities for an efficient implementation (e.g. energy conservation in buildings) or at least their consensus (e.g. exploitation of wind energy at a large scale).

The benefits of an active participation of local communities to the climate change mitigation effort are multifold as:

- Local economy will be strengthened
- Living conditions and quality of life will be improved
- There will be positive effects on employment at local level

At the same time, local authorities are faced with a lack of systematic approaches, methodologies and tools which can assist them in investigating, assessing and realizing their local potential with respect to GHG emissions reductions. Although some tools may exist at national level, these require several adjustments so that they can be used at local scale.

The objectives of CLIM-LOCAL2020 are to:

1. Develop a systematic approach and appropriate tools which will enable local authorities to substantially reduce GHG emissions in their region with the aim to contribute in keeping the global temperature increase below the threshold of 2 ^{o}C in order to achieve the ultimate objective of UNFCCC as stated in its Article 2.
2. Develop appropriate monitoring and assessment activities related to GHG emissions reduction at local level, which can serve as a guide to other interested municipalities in Greece and the rest of the EU.
3. Clearly identify the interface between local authorities and central administration with respect to climate change mitigation and the main barriers imposed at local level when taking measures for reducing GHG emissions.
4. Promote awareness, provide training and disseminate of information on climate change and its mitigation, which is necessary for the active participation of citizens and local stakeholders in any mitigation effort.
5. Initiate GHG emission reductions at local level within a 10-15 years horizon and with the active participation of citizens.

Action 1 of the CLIM-LOCAL2020 project (entitled *Calculation of present local GHG emissions*) aims at the calculation of present GHG emissions generated from stationary and mobile emission sources operating in the administrative area of the Municipality of Volos, as well as from neighbouring areas that form part of the greater Volos area. Emissions will be disaggregated by greenhouse gas and emission source. Figures will derive from the application of the IPCC (Intergovernmental Panel on Climate Change) methodologies for the compilation of greenhouse gases emission inventories, in combination with complementary methodologies (where necessary) for further disaggregating emissions per sub-sector/use. Emission figures will be calculated for the most recent year for which there are available input data.

ES.2 Energy balance for the greater Volos area

Energy production and use represent a major source of greenhouse gases (GHG) and other gases emissions. Therefore, estimates of energy production and use are absolutely necessary for the compilation of an emissions inventory. However, the availability of such data at local level is limited. Therefore, the formulation of a local energy balance is necessary as the energy sector generates the major part of GHG and other gases emissions. To this end, a bottom-up approach has been developed. The application of this approach aims on the estimation of fuel consumption figures on the basis of which emissions are estimated.

This approach starts from calculating energy requirements of each energy consuming activity, in terms of useful energy. To this end, data both at local / regional and central level were collected. At central level, all available bottom-up data on the consumption of fuels and electricity as well as on non-energy parameters (e.g. agricultural areas, number of buildings, etc.) at the Volos region were collected. At local level, the collection of energy data target competent municipal divisions, local fuel suppliers and large consumers. Energy and non-energy data were fed in simulation models developed for the estimation of total energy consumption from the different end-use activities defined. Final energy demand results on the basis of the mix of end-use technologies used to satisfy the estimated energy needs.

The year 2007 was selected as the base year for the formulation of the energy balance of the greater Volos area, which is presented in **Table ES.1**.

Table ES.1 Energy balance for the greater Volos area in 2007 (in toe)

	Industry	Road transportation	Residential	Tertiary	Public lighting	Primary	Final Consumption
Electricity	71,009	89	16,764	10,201	683	870	99,615
Solid fuels	286,514						286,514
LPG	21		356	74			450
Diesel	52	13,374	19,079	6,082		4,411	42,997
Heavy fuel oil	12,542					739	13,281
Gasoline		20,494					20,494
Natural gas	26,059		17,386	3,111			46,555
Biomass			9,519				9,519
Solar energy			1,626				1,626
Total	396,197	33,956	64,730	19,468	683	6,019	521,052

The main findings of the analysis can be summarized as follows:

- Total final consumption is estimated at 521 ktoe, 73.7% of which concerns major industrial activities (i.e installations participating in the EU-ETS). The residential sector accounts for 12.4% of total final consumption, while road transportation (as defined in the context of the present analysis) and tertiary sector account for 6.5% and 3.7% respectively. Public lighting and primary sector account for about 1.3% of total final consumption, while the rest 2.3% concerns energy consumption in rest industry including the municipal enterprise for water supply and wastewater treatment. This distribution of final energy consumption per sector is in line with the socio-economic profile of the greater Volos area, in which industrial activity represents a key sector.

- The consumption of solid fuels (and petroleum coke) represents 55% of final consumption. This amount of consumption refers exclusively to the industrial sector and more specifically to cement and lime production installations.
- A significant penetration is estimated for natural gas, the consumption of which accounts for 9% of total final consumption. Industry is the major natural gas consumer (about 26 ktoe) while the residential sector with a total consumption of 17 ktoe (mainly space heating) is the second largest consumer of natural gas. As a result of natural gas penetration the LPG consumption is limited.
- The use of RES in final consumption (biomass and solar) accounts for 2% of final consumption. About 85% of RES consumption concerns biomass consumption for space heating.

Energy consumption in the greater Volos area is dominated by the energy consumption of industrial installations participating in the EU-ETS. It should be mentioned that the share of industrial energy consumption to total final energy consumption at national level is 21% for 2007. A totally different allocation of energy consumption per sector and fuel is obtained by excluding energy consumption of EU-ETS installations from the analysis. The resulting allocation with the residential sector being the major energy consumer, followed by road transportation and a more balanced contribution of the various energy forms to total energy consumption is more representative for an urban area such as the greater Volos area.

ES.3 Emissions inventory for the greater Volos area

Emission inventories represent a core element of international agreements (e.g. United Nations Framework Convention on Climate Change, Kyoto Protocol, Convention on Long Range Transboundary Air Pollution, etc.) as well as environmental legislation of the European Union (e.g. Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, Emissions Trading Directive, etc.). Significant guidance has been developed in the context of these international environmental agreements so as to facilitate reporting and provide necessary assistance for the estimation of the emissions controlled.

This guidance provides the basis for the compilation of the emissions inventory for the greater Volos area taking into consideration local circumstances. In this context the boundaries set for the analysis include, to the extent possible, the stationary and mobile emission sources operating in the administrative area of the Municipality of Volos, as well as in neighbouring municipalities that form the greater Volos area:

- Energy use, including electricity consumption, in the residential and commercial sector, municipal infrastructures and buildings, rest tertiary sector activities, transport, agriculture and industry. Mobile combustion includes urban passenger transportation of local population, the activity of the vehicle fleet of the municipal authorities, inshore fishing by vessels of 19 hp or less, agricultural machinery and the machinery of the port of Volos.
- Industrial processes, including the use of F-gases especially for refrigeration and air-conditioning.
- Solvents
- Agriculture
- Waste management (both solid waste and wastewater treatment).

Specific attention was paid in order to quantify all emission sources on which municipal authorities have direct control. Emissions estimates from the above-mentioned sectors refer to all greenhouse gases (CO_2, CH_4, N_2O, F-gases), as well as basic air pollutants (PM10, NOx, SO_2, NMVOC). Emissions estimates include also the indirect emissions attributed to electricity consumption. The reporting year for the emissions inventory is 2007.

Calculation of greenhouse gases emissions is mainly based on IPCC guidelines, while the EMEP/CORINAIR methodology is mainly used for the estimation of non-GHG emissions. Additionally, the indirect emission factors for electricity consumption derive from the latest national GHG emissions inventory.

Table ES.2 provides an overview of GHG and other gases emissions per sector for the greater Volos area.

Table ES.2a GHG emissions per sector in the greater Volos area for 2007

	CO_2 (t)	CH_4 (t)	N_2O (t)	F-gases (t CO_2 eq)	GHG (t CO_2 eq)
Stationary combustion	2401174.63	41.31	186.38	-	2459819.26
Of which, EU-ETS installations	*1916387.08*	*22.18*	*179.53*	-	*1972505.79*
Mobile combustion	117455.41	55.05	11.66	-	122227.38
Industrial processes	1863806.62	4.50	-	414.28	1864315.41
Of which, EU-ETS installations	*1863806.62*	*4.50*	-	*0.00*	*1863901.12*
Solvents	1338.28	-	-	-	1338.28
Agriculture	-	411.23	46.14	-	22940.51
Waste	-	4502.38	13.87	-	98851.08
Total	4382179.79	5014.44	258.04	414.28	4569491.91
Total excluding EU-ETS installations	603581.24	4987.78	78.54	414.28	733084.99

Table ES.2b Other gases emissions per sector in the greater Volos area for 2007

	NOx (t)	SO2 (t)	NMVOC (t)	PM10 (t)
Stationary combustion	8203.95	8183.24	522.81	858.73
Of which, EU-ETS installations	*7126.44*	*5754.76*	*96.50*	*388.01*
Mobile combustion	1081.76	76.34	344.96	43.22
Industrial processes	90.00	58.50	40.50	799.32
Of which, EU-ETS installations	*90.00*	*58.50*	*40.50*	*799.32*
Solvents	-		429.39	-
Agriculture	1.05	-	-	-
Waste	-	-	-	-
Total	9376.77	8318.09	1337.66	1702.78
Total excluding EU-ETS installations	2164.49	2515.75	1200.84	516.35

- Total GHG emissions at the greater Volos area for 2007 are estimated at 4569.49 kt, representing 3.5% of total GHG emissions at national level (excluding Land Use, Land Use Change and Forestry, LULUCF).
- Stationary combustion is the major source of CO_2, N_2O, GHG and other gases emissions, followed by Industrial processes in the case of CO_2 and PM10 emissions. CH_4 emissions from Waste account for about 90% of total CH_4 emissions in the greater Volos area, while Agriculture accounts for 8% and 18% of total CH_4 and N_2O emissions respectively.
- Emissions estimates are clearly dominated (in the cases of GHG and PM10 emissions) by industrial installations participating in the EU-ETS as indicated by the high share of industrial processes (cement, lime and steel production) to total GHG emissions (about 40% compared to 7% at national level).

- Indirect emissions associated with electricity consumption in all sectors represent a significant part of total emissions as they account for 22% of total GHG emissions, 28% of total NOx emissions, 84% of total SO_2 emissions, 8% of total NMVOC emissions and 34% of total PM10 emissions.

- If both indirect emissions from electricity consumption and emissions from installations participating in the EU-ETS are excluded from totals, then GHG emissions are estimated at 395.5 kt (about 12 times lower compared with the total figure presented in Table 4.2a). In this case, the contribution of the various sectors to total GHG emissions (**Figure ES.1**) is totally different compared to the one presented in Table ES.2a.

  Stationary combustion is still the major contributor to total GHG emissions but its share is reduced to 40%. The share of emissions from mobile combustion increased to 28% of total emissions, while the Waste sector accounts for 25% of the total. On the contrary, the contribution of industrial processes and solvents use is minor (about 0.4% of the total) as in this case only GHG emissions from Solvents use and F-gases emissions are considered.

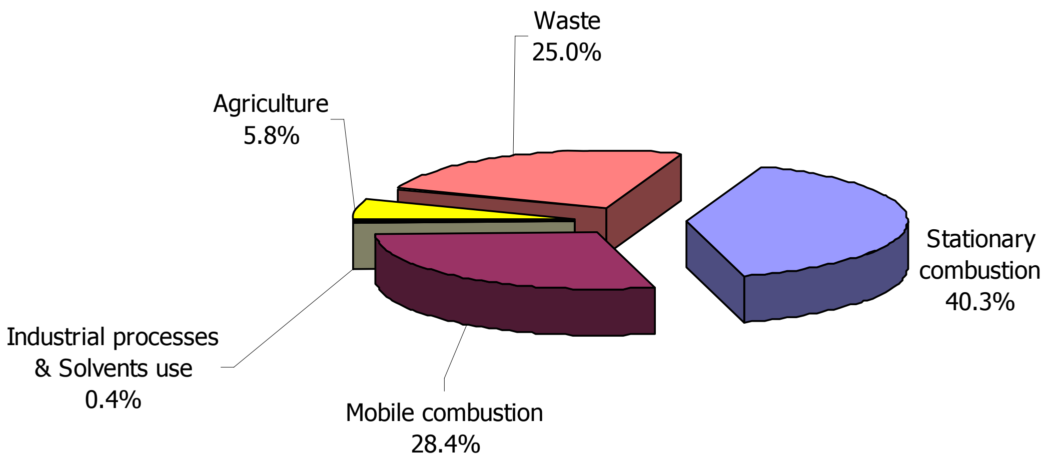

Figure ES.1 Total GHG emissions in the greater Volos area for 2007 (excluding indirect emissions and emissions from EU-ETS installations)

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1 Introduction

1.1 General policy context

In response to the emerging evidence that climate change could have a major global impact, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on 9 May 1992 and was opened for signature in Rio de Janeiro in June 1992.

Recognizing early on the need for an effective instrument to provide confidence in addressing the climate change challenge, the parties at third meeting of the Conference of the Parties (COP) to the Convention, held in Kyoto (1-11 December 1997), finalised negotiations related to the establishment of such a legal instrument, the Kyoto Protocol on Climate Change. The Protocol calls for legally binding commitments of the developed countries to reduce, individually or jointly, emissions of 6 greenhouse gases (CO_2, CH_4, N_2O, HFC, PFC and SF_6) by more than 5% in the period 2008 to 2012, below their 1990 level. The European Union (EU) and its Associated Counties agreed to a -8% reduction of their emissions by 2008 – 2012 compared to 1990 levels. The Kyoto Protocol entered into force on 16 February 2005, after its ratification from 141 Parties including developed countries with a contribution of more than 55% to global CO_2 emissions in 1990. Currently, negotiations are in progress regarding future commitments for the period after 2012.

With the negotiations being in progress, the European Commission (EC) announced in January 2008 a legislative package on energy and climate change (named "20-20-20 by 2020"), aiming to materialize the decisions of the March 2007 Summit of the EU and to adopt and implement effective policies for tackling global warming. This package sets a series of ambitious legally binding targets on greenhouse gas (GHG) emissions reduction, renewable energy sources (RES) penetration, and energy efficiency promotion. The package also seeks to promote the development and safe use of carbon capture and storage (CCS), a suite of technologies that allows the carbon dioxide emitted by industrial processes to be captured and stored underground where it cannot contribute to global warming. On December 2008, the European Parliament adopted the legislative package on energy and climate change.

More specific, three key targets are set by the European Council (Commission of the European Communities, 2008):

- A reduction of at least 20% in greenhouse gases (GHG) emissions by 2020 - rising to a more ambitious reduction of 30% in the event of an international agreement.
- An improvement of energy efficiency by 20% in 2020 compared to a baseline scenario.
- A 20% share of Renewable Energy Sources (RES) in the European Union's final energy consumption by 2020.

At the heart of this legislative package is the amendment of the Directive 2003/87/EC on emissions trading, aiming to strengthen, expand and improve the functioning of the European Union emission trading system (EU-ETS) in the 3rd trading period 2013-2020. GHG emissions from the sectors covered by the system will be cut by 21% by 2020 compared with levels in 2005.

Furthermore, the EC's legislative package comprises a draft Directive relating to the sharing of efforts to meet the Community's independent GHG emissions reduction commitment in sectors not covered by the EU-ETS (such as transport, buildings, services, smaller industrial installations, agriculture and waste). Emissions from sectors not included in the EU-ETS will be cut by 10% from 2005 levels by 2020 at an EU-level. Each Member State will contribute to this effort according to its relative wealth, with national emission targets ranging from -20% for richer Member States to +20% for poorer ones. In this context Greece has the commitment to reduce its GHG emissions from the sectors not included in the EU-ETS by 4% in 2020 as regards 2005 levels.

Additionally, the Commission acknowledging that "energy efficiency is a crucial part of the puzzle" proposed a target of 20% energy conservation by 2020 compared to a baseline scenario. Boosting investment in energy efficiency and new technologies contributes to a secure energy supply by helping at the same time the creation of new jobs, the economic growth and the enhancement of competitiveness.

An increase in the use of RES also figures prominently in the package with the Commission requiring 20% use of energy from RES such as wind power, solar power and geothermal heat in the final energy consumption. Today, the share of renewable energy in the European final energy consumption amounts to 8.5% and so an increase of 11.5% is needed on average to accomplish the target.

It is clear that these decisions have put in place a new framework for both the European and the Greek market by creating a favourable investment environment for RES and energy-saving technologies. This is of particular importance, especially under current circumstances of economic crisis and recession.

1.2 Scope of Action 1

In the general policy context described in the previous paragraph, the assessment of the potential of large GHG emissions reductions after 2012 is mainly focused on national and/or EU level. There is significant emphasis on new reduction technologies such as carbon capture and storage which can reduce significantly CO_2 emissions (although their environmental implications are not yet fully known and at present there are only a few, mostly pilot scale, installations across Europe), but these technologies are usually associated with large industrial emitters or oil pumping activities and leave out the residential and commercial sectors, transportation, agriculture and waste management issues.

Since the discussion on what needs to be done with respect to climate change mitigation after 2012 and by what actions and means ambitious GHG emissions reduction targets can be achieved is underway, local authorities in many cases remain passive, waiting to see first what will be the new national reduction targets. This prevents undertaking a number of actions at local level in due time, while on the other hand a number of decisions affecting future GHG emissions are taken at present establishing local infrastructures with a long lifetime, which will not be altered soon once created. The assumption that local communities will move forward once a new national target is set and appropriate policies decided at central level are introduced/ reinforced, ignores the fact that a large number of measures presupposes the participation of local communities for an efficient implementation (e.g. energy conservation in buildings) or at least their consensus (e.g. exploitation of wind energy at a large scale).

The benefits of an active participation of local communities to the climate change mitigation effort are multifold as:

- Local economy will be strengthened
- Living conditions and quality of life will be improved
- There will be positive effects on employment at local level

Local authorities are faced with a lack of systematic approaches, methodologies and tools which can assist them in investigating, assessing and realizing their local potential with respect to GHG emissions reductions. Although some tools may exist at national level, these require several adjustments so that they can be used at local scale.

The objectives of CLIM-LOCAL2020 are to:

1. Develop a systematic approach and appropriate tools which will enable local authorities to substantially reduce GHG emissions in their region with the aim to contribute in keeping the global temperature increase below the threshold of 2 ^{o}C in order to achieve the ultimate objective of UNFCCC as stated in its Article 2.
2. Develop appropriate monitoring and assessment activities related to GHG emissions reduction at local level, which can serve as a guide to other interested municipalities in Greece and the rest of the EU.
3. Clearly identify the interface between local authorities and central administration with respect to climate change mitigation and the main barriers imposed at local level when taking measures for reducing GHG emissions.
4. Promote awareness, provide training and disseminate of information on climate change and its mitigation, which is necessary for the active participation of citizens and local stakeholders in any mitigation effort.
5. Initiate GHG emission reductions at local level within a 10-15 years horizon and with the active participation of citizens.

Action 1 of the CLIM-LOCAL2020 project (entitled *Calculation of present local GHG emissions*) aims at the calculation of present GHG emissions generated from stationary and mobile emission sources operating in the administrative area of the Municipality of Volos, as well as from neighbouring areas that form part of the greater Volos area. Emissions will be disaggregated by greenhouse gas and emission source. Figures will derive from the application of the IPCC (Intergovernmental Panel on Climate Change) methodologies for the compilation of greenhouse gases emission inventories, in combination with complementary methodologies (where necessary) for further disaggregating emissions per sub-sector/use. Emission figures will be calculated for the most recent year for which there are available input data.

The emissions inventory developed, together with the emissions projections (Action 2), will provide the basis for the identification of possible policies and measures to be defined at local level as well as the quantification of their expected effect.

1.3 Outline of the report

The present report covering deliverable product "**Local inventory for GHG emissions"** is structured as follows:

Chapter 2 provides a short description of the demographic, economic and energy profile of the greater Volos area according to official statistics.

In **Chapter 3** the energy balance developed for the greater Volos area is briefly presented.

The greenhouses gases and other gases emissions inventory for the greater Volos area is presented in **Chapter 4**, where the methodologies selected and applied and the results obtained per sector and source category are described.

Key concluding remarks are addressed in **Chapter 5**.

2 Overview of the greater Volos area

A short description of the demographic, economic and energy profile of the greater Volos area according to official statistics is presented. Emphasis is given in identifying those parameters that are expected to affect energy system development over time.

2.1 Population

The greater Volos area includes the municipalities of Volos, Nea Ionia and Esonia. The municipality of Volos is the capital of Magnesia Prefecture, with a population of 82,439 according to the National Population Census of 2001 (**Table 2.1**). The population of Nea Ionia and Esonia was 31,929 and 3,031 respectively. The greater Volos area collectively accounts for about 57% of the population of the Magnesia Prefecture. The population of the greater Volos area increased by 7.6% between the population census of 1991 and 2001, while the population increase at the level of prefecture was about 4.3%, indicating a population move towards the greater Volos area.

Table 2.1 Real population in the greater Volos area according to the National Population Census of 1991 and 2001

	Magnesia Prefecture	Greater Volos area	Volos	Nea Ionia	Esonia
1991 Census	198,434	109,107	77,192	29,018	2,897
2001 Census	206,995	117,399	82,439	31,929	3,031
Total change	4.3%	7.6%	6.8%	10.0%	4.6%

The age distribution of population (**Table 2.2**), according to the National Census results, reveals that population in Greece is getting older. The ageing of the population, as depicted in the ratio of older people (65+) to young people (0 – 14), is more intense at national level compared to the greater Volos area. This ratio is estimated 0.96 for the greater Volos area and 1.1 for Magnesia Prefecture and Greece. However, in the greater Volos area the share of population with ages 25 – 64 is higher than the share of population with ages less than 25 indicating a risk of population ageing.

Table 2.2 Age distribution of population in the greater Volos area according to the National Census of 2001

	0-14	15-24	25-39	40-54	55-64	65-79	>80
Greece	0.152	0.143	0.229	0.200	0.110	0.137	0.030
Thessalia Region	0.156	0.135	0.208	0.197	0.122	0.148	0.033
Magnesia Prefecture	0.154	0.144	0.215	0.201	0.116	0.139	0.031
Greater Volos area	0.162	0.148	0.219	0.208	0.107	0.128	0.028
Volos	0.155	0.141	0.220	0.212	0.109	0.132	0.031
Nea Ionia	0.178	0.165	0.216	0.198	0.103	0.119	0.022
Esonia	0.176	0.152	0.208	0.207	0.110	0.122	0.025

2.2 Economic profile

The Gross Value Added (GVA) during the period 2000 – 2006 increased by 26% for the Magnesia Prefecture (from 2,002 million € to 2,525 million €, at 2000 constant prices). The contribution of regional GVA to the formation of GVA at national level has remained almost constant (it varies from 1.62% to 1.80%) over the period 2000 – 2006. The economic development in the Magnesia Prefecture (as depicted in the GDP per capita indicator) is below national average over the period 2000 – 2006 (**Figure 2.1**) but a convergence trend is recorded.

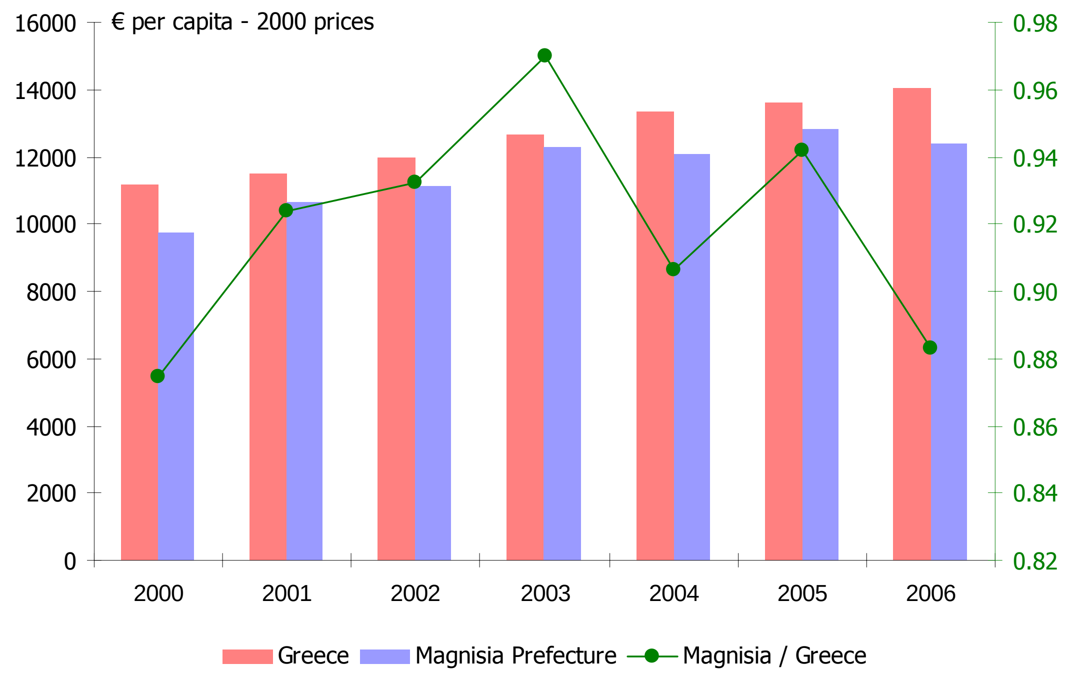


Figure 2.1 Gross Value Added per capita (at constant 2000 prices) over the period 2000 – 2006 for Greece and the Magnesia Prefecture

Macroeconomic data at the level of municipality do not exist. However, the available information at the level of prefecture and its comparison to national level data gives an indication of the socio-economic characteristics of the Magnesia Prefecture and the greater Volos area. **Table 2.3** presents the structure of GVA at national level and at Magnesia Prefecture. The main difference observed concerns the contribution of the secondary sector which in the case of Magnesia Prefecture (a) is higher compared to the contribution of the sector at national level and (b) presents an upward trend for the period 2000 – 2006.

Table 2.3 Structure of Gross Value Added in Greece and in Magnesia Prefecture for the period 2000 - 2006

	2000	2001	2002	2003	2004	2005	2006
	Magnesia Prefecture						
Primary sector	9.1%	6.3%	6.7%	7.2%	5.6%	6.0%	5.0%
Secondary sector	31.6%	39.9%	39.0%	42.2%	40.8%	42.8%	42.9%
Tertiary sector	59.3%	53.9%	54.3%	50.6%	53.6%	51.2%	52.2%
	Greece						
Primary sector	6.6%	6.3%	5.8%	5.2%	5.1%	5.1%	4.0%
Secondary sector	21.0%	22.0%	19.3%	19.9%	19.7%	21.2%	21.7%
Tertiary sector	72.5%	71.7%	74.9%	75.0%	75.2%	73.7%	74.3%

Figure 2.2 presents an overview of the employment structure per sector of economic activity according to the National Population Census of 2001. The qualitative characteristics of the distribution per sector presented in this figure are expected to continue to be valid.

- Employment in the primary sector is minor for the greater Volos area as it accounts for less than 3% of total employment. According to the results of the Agricultural – Livestock Census 2000, 16% of the agricultural holdings of the Prefecture, accounting for 10% of the agricultural land, belong in the greater Volos area.
- Employment in the secondary sector in the greater Volos area is similar to the one for the Magnesia Prefecture and for Greece. It should be noted that in the greater Volos area two industrial areas, of a total area of 448 Ha, are sited.

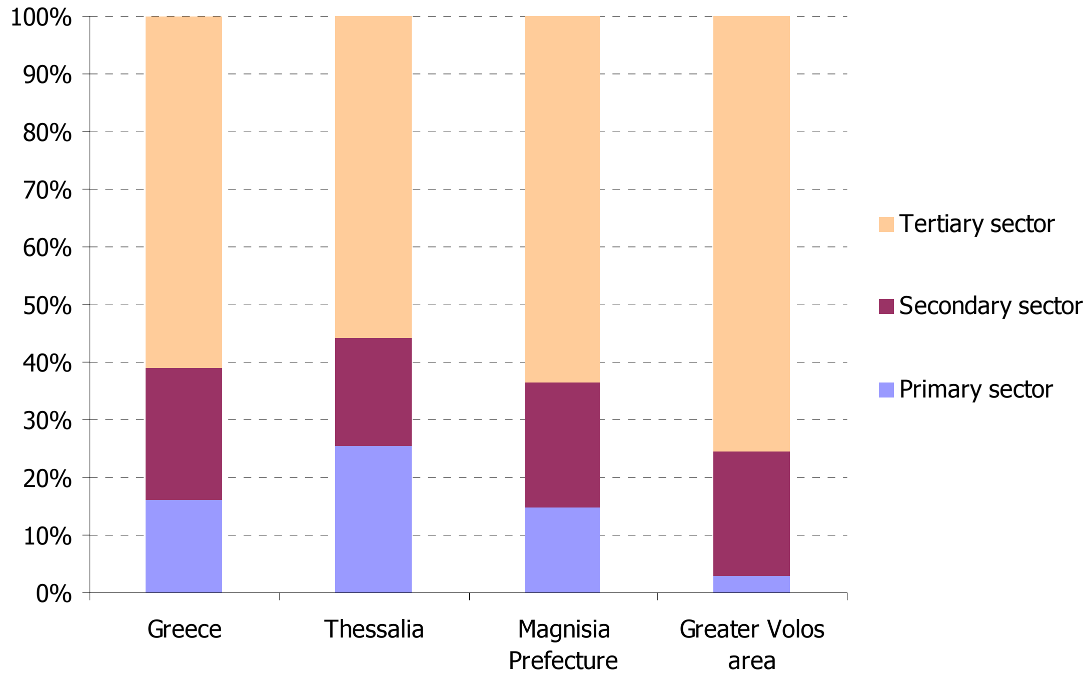


Figure 2.2 **Structure of employment per sector of economic activity according to the National Population Census of 2001**

2.3 Energy demand

The data presented in the paragraphs 2.3.1 – 2.3.3 concern the Magnesia Prefecture (electricity and liquid fuels consumption) and the Thessalia Region (natural gas) as more disaggregated data and information are not available. The development of disaggregated energy consumption estimates is discussed in Chapter 3.

2.3.1 Electricity demand

Electricity demand in Magnesia Prefecture increased by 105% from 1995 (1132.6 GWh) to 2007 (2322.7 GWh), at an annual average rate of 6.2% (for the period 1995 – 2007). The main increase was experienced in the commercial sector and industry (about 144% and 123% respectively – **Figure 2.3**). Industry is the highest consumer of electricity accounting for 70% (in 2007) of total electricity consumption, a share that is significantly higher compared to the one at national level (28% at 2006). Such deviations are attributed to differences in the economy profile at national and regional level and especially in the high contribution of industry in local economy and consequently in electricity consumption.

Residential electricity consumption per capita is slightly lower compared to national average (1,525 kWh/cap and 1,605 kWh/cap in 2007 respectively).

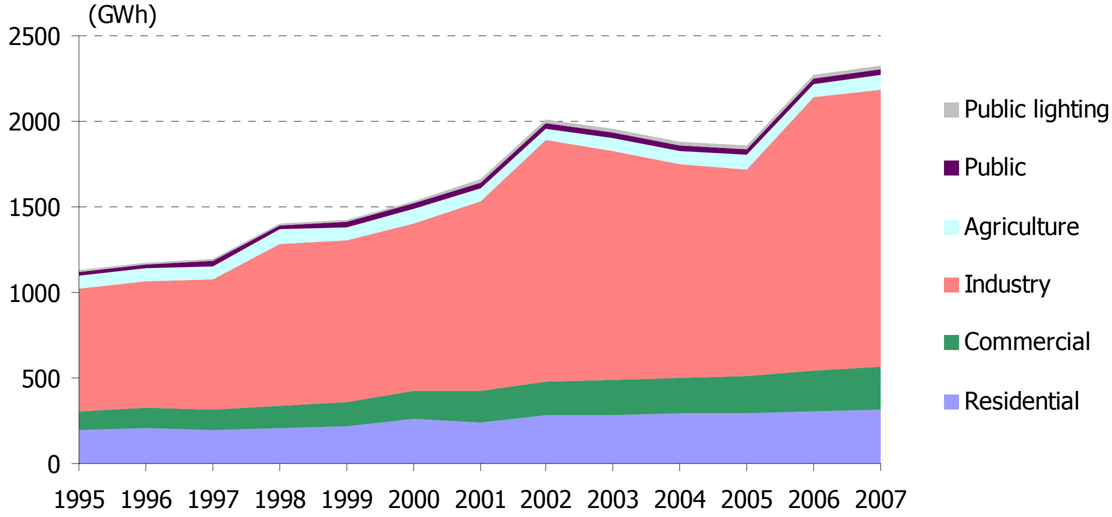


Figure 2.3 Sectoral distribution of electricity consumption in Magnesia Prefecture (in GWh) for the period 1995 – 2007

2.3.2 Liquid fuels

Information regarding fuels consumption at regional level is limited and refers only to total consumption (i.e. without any sectoral disaggregation) of key liquid fuels (heating and transport diesel, heavy fuel oil and gasoline). Data (provided by the Ministry for Development) refer to sales of liquid fuels excluding large consumers such as the Public Power Corporation and maritime transport.

Table 2.4 provides an overview of the available consumption data of liquid fuels in Magnesia Prefecture.

- With the exception of heavy fuel oil, sales of liquid fuels have increased significantly during the period 1995 – 2007. Sales of transport diesel presented the highest increase (59% for the period 1995 – 2007) followed by gasoline (49%) and heating diesel (46%).
- The sales of gasoline and transport diesel include sales to vehicles passing through and refueling within the boundaries of the Magnesia Prefecture. On the contrary, sales of heating diesel and heavy fuel oil are representative of the consumption in the Magnesia Prefecture.
- The consumption of heavy fuel oil presents a declining trend since 2002 when it reached a peak of 38,870 t. The decrease is more intense since 2004 due to the gradual penetration of natural gas.

Table 2.4 Sales of liquid fuels (in t) in Magnesia Prefecture for the period 1995 – 2004

Year	Gasoline	Heating diesel	Transport diesel	Heavy fuel oil
1995	48336	48085	37325	29790
1996	48321	61702	36847	33323
1997	47045	56756	39873	36141
1998	50984	63599	46876	29364
1999	55459	64763	48873	22707
2000	55598	70408	46939	28777
2001	58005	57137	48147	37750
2002	63053	76400	53940	38870
2003	67340	93421	54816	34372
2004	66562	78106	54922	36371
2005	58745	73127	50065	26981
2006	68200	80555	56475	27354
2007	72026	70135	59491	16248

2.3.3 Natural gas

The introduction of natural gas in the local energy system started at the end of the 90s, with industrial installations being the first consumers. According to the Natural Gas Supply Corporation (responsible for natural gas supply in the greater areas of Volos and Larissa) the length of the transmission network in use reaches (for both areas in the first semester of 2009) 579 km[1]. **Table 2.5** provides an overview of the contracts already signed up to 28.02.2009.

Table 2.5 Signed contracts for natural gas use from 2001 up to 28.02.2009

Cooking and hot water	186
Autonomous heating	30326
Central heating	4622
Small commercial users	1359
Large commercial users and small industries	66
Industry	41

[1] http://www.epathessalia.gr/index.php?lang=el&rm=1&mn=34

According to the Operational Programme 2007 – 2010 of the Municipality of Volos[2] (approved by the Municipal Council at 16.04.2008), about 20,000 dwellings, most of the public buildings (e.g. hospital, university, schools, municipal buildings etc.) in the greater Volos area are already connected to natural gas transmission network, while most of the large industrial consumers are located in the greater Volos area.

2.4 Building stock

Energy consumption in buildings is related (excluding installed equipment capacity) to the age, size and use of a building. According to the National Buildings Census (2000/1) the total number of buildings in the greater Volos area is 32,989, the majority of which (28,733) serves the residential needs of households.

Table 2.6 Number of buildings per use in the greater Volos area according the National Buildings Census of 2000/1

Year	Volos	Nea Ionia	Esonia	Total
Residential	19264	8244	1225	28733
Churches	38	13	15	66
Hotels	26	1	2	29
Industrial	91	143	186	420
Schools	98	26	8	132
Offices - Trade	1097	262	59	1418
Parking	7	1	0	8
Hospitals	13	0	0	13
Other	1263	482	425	2170
Total	21897	9172	1920	32989

The building stock is rather old as about 74% of the total number of buildings was constructed before 1980 and therefore high heat losses are expected since the mandatory implementation of the insulation code was introduced in Greece at 1980. At the same time, the significant construction activity should be noted as for the period 2001 – 2006 a total of 11,000 dwellings have been constructed.

[2] http://www.volos-city.gr/default.aspx?id=24713&nt=18&lang=1

2.5 Road transportation

Economic development and improved living standards have a significant effect on the ownership of passenger cars. At national level, the number of passenger cars in 1994 was almost 10 times higher compared to the number of passenger cars in 1970, while similar trends are also observed for the number of trucks, buses and motorcycles.

For the time period 1998 – 2007, the number of passenger cars, trucks and motorcycles in Magnesia Prefectures increased continuously. In 2007, the number of passenger cars was 65,200 presenting a total increase (compared to 1998) of 68%. The high growth rates of vehicles fleet is a common feature at both national and local level. Car ownership (**Figure 2.4**) in Magnesia Prefecture (32 cars per 100 inhabitants for 2007) corresponds to an average of 75% of car ownership at national level (43 cars per 100 inhabitants for 2007).

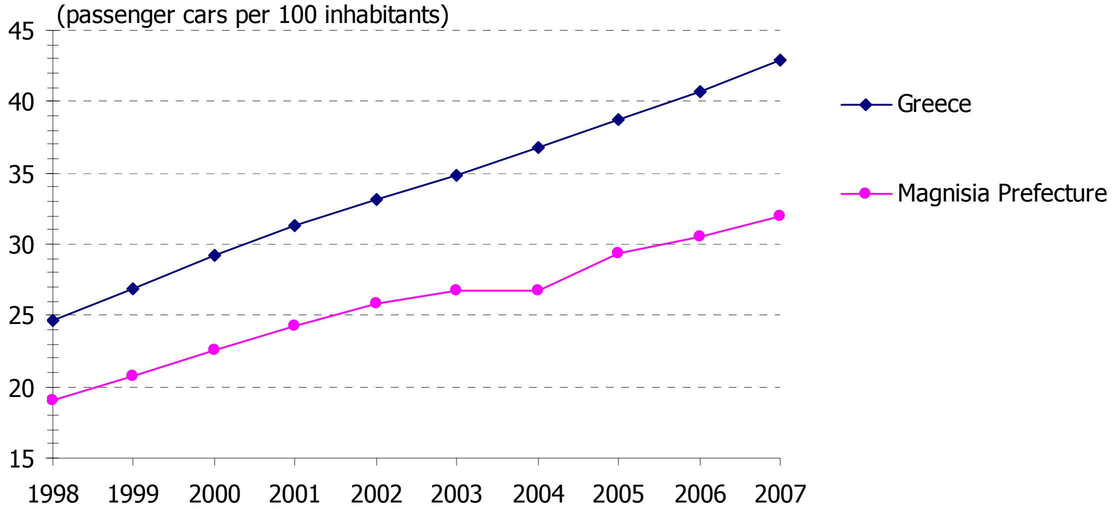


Figure 2.4 Passenger car ownership for the period 1998 – 2007

3 Energy balance of the greater Volos area

3.1 Methodology for the development of the energy balance

The official energy data published yearly by the Ministry for Development refer to the national level only. In order to calculate the present GHG emissions at local level, geographically disaggregated energy data are required. Therefore, the formulation of a local energy balance is necessary as the energy sector generates the major part of GHG and other gases emissions.

The formulation of local energy balances can not rely on the standard procedure followed at national level. The degree of detail required to estimate energy demand can not be drawn from conventional statistical data on energy consumption since those data are only partially available (especially for fuels consumption) even at regional level. Therefore, a bottom-up approach has been developed. The application of this approach aims on the estimation of fuel consumption figures on the basis of which emissions are estimated.

This approach starts from calculating energy requirements of each energy consuming activity, in terms of useful energy. To this end, data both at local / regional and central level were collected. At central level, all available bottom-up data on the consumption of fuels and electricity as well as on non-energy parameters (e.g. agricultural areas, number of buildings, etc.) at the Volos region were collected. At local level, the collection of energy data target competent municipal divisions, local fuel suppliers and large consumers. Energy and non-energy data were fed in simulation models developed for the estimation of total energy consumption from the different end-use activities defined. Final energy demand results on the basis of the mix of end-use technologies used to satisfy the estimated energy needs.

3.1.1 Energy demand disaggregation

The first step towards the formulation of the energy balance is the disaggregation of the basic demand sectors into different sub-sectors and end-use activities. The end-use activities defined within a demand sector should correspond to the whole of the energy demand assigned to that sector. Moreover, the defined sub-sectors and end-use activities should reflect (a) economic/social needs and (b) consumer behaviour of the local population. **Figure 3.1** presents the disaggregation adopted for the greater Volos area. In relation to transportation, the analysis deals only with:

- Road transportation of local population within the boundaries of the greater Volos area.
- The activity of the vehicles' fleet operated by local authorities (e.g. solid waste collection, technical service, etc.).
- The equipment / machinery operated at the port of Volos as energy issues related to maritime transport are addressed outside the boundaries of the Volos area.
- Heavy duty vehicles passing through the greater Volos area, covering the needs of local population and goods transportation to and from the two industrial areas operating within the boundaries of the area.

On the contrary, vehicles passing through Volos, even if refueling within the boundaries of the greater Volos area, are not considered in the analysis.

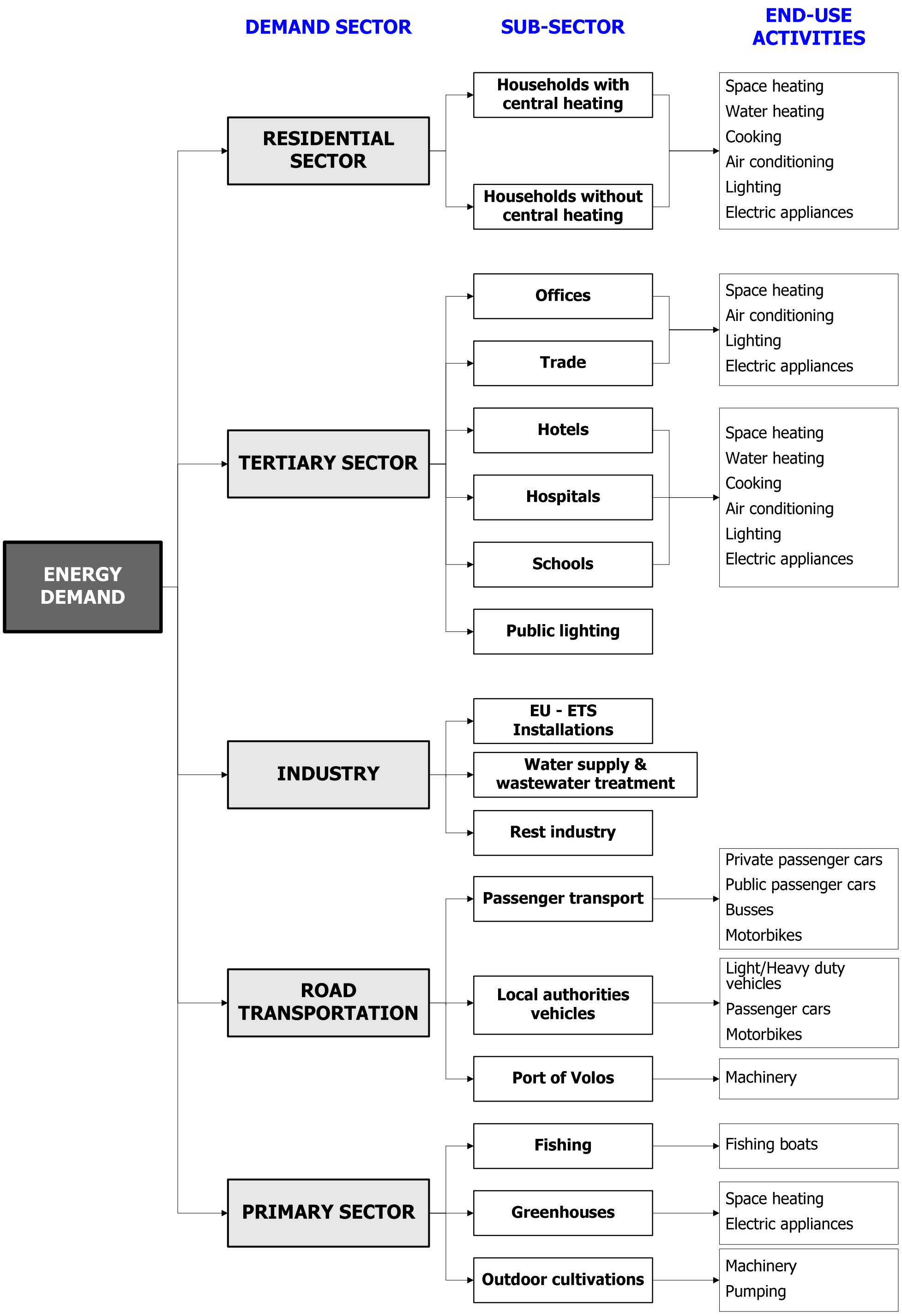


Figure 3.1 Energy demand disaggregation for the greater Volos area

3.1.2 Estimation of energy demand / consumption

The estimation of energy demand in each end-use activity is based on the determination and correlation of the parameters influencing the amount of energy needed and its time and spatial variation. These parameters have to depict the social, economic, technological and geographical factors and refer to (a) a clear description of the consumers' behaviour, (b) the determination of the number and characteristics of the consuming units and (c) the identification of the general conditions under which consumers behave. The parameters used are presented in **Table 3.1**.

Table 3.1 List of parameters determining energy demand

Demand sector	Consumers' behaviour	Number of consuming units	General conditions
Residential	1. Comfort standards (temperature of space and water) 2. Operation hours of appliances	3. Population 4. Households 5. Number and type of buildings 6. Appliance stock	7. Technical characteristics of appliances 9. Heating degree-days 10. Overall heat-transfer coefficient per building type
Primary	1. Operation hours of machinery	2. Area and type of cultivation 3. Area and type of greenhouses 4. Machinery stock including fishing boats	5. Climatic conditions 6. Technical characteristics of machinery
Tertiary	1. Comfort standards (temperature of space and water) 2. Operation hours of appliances	3. Number of offices, commercial stores, schools and hotel / hospitals beds 4. Appliance stock	5. Technical characteristics of appliances 6. Heating degree-days 7. Overall heat-transfer coefficient per building type
Road transportation	1. Mileage per vehicle category (operation hours for port machinery)	2. Number of vehicles	3. Technical characteristics per vehicle category and technology
Industry	1. Base year data		

The procedures followed for the estimation of the energy demand in the end-use activities defined in Figure 3.1, can be classified into the following basic categories:

- **Space heating method**. This method is used for estimating the energy demand for space heating in the residential sector and in hotels. It is a simplified model of the thermal heat balance of a building. Heat losses are estimated by a set of equations that represent heat loss through the ceiling, walls, glass and air infiltration. Values for the thermal conductivity used are drawn from the Greek Insulation Code. A similar method is used for the estimation of space heating demand in greenhouses.

- **Appliance / Equipment method**. This method is used for estimating the energy demand in air-conditioning and electric appliances in the residential sector as well as in road transportation and fishing. The keys parameters for the implementation of this method are the number of the appliances / equipment per activity and the characteristics of the appliance / equipment stock (technical characteristics and usage).

- **End-use floor-space method**. This method is used for estimating energy demand in all activities of the tertiary sector (with the exception of water heating in hotels). It is similar to the appliance method, except that each end-use activity is defined on the basis of the respective building surface area. Moreover, the method used for the estimation of energy demand in agriculture is based on the same principle since cultivation areas are used instead of building area in combination with machinery standards.

- **Water heating method**. This method is used for the estimation of energy demand for water heating in the residential sector and in hotels. Energy demand is correlated with the population data, water consumption per capita and comfort standards (temperature of hot water).
- **Base year actual data**. Base year actual energy data are mainly used in industry and in some sub-sectors or buildings within the tertiary sector. In the case of the tertiary sector (mainly public buildings) data were provided by the building operators and/or local agencies of energy (electricity, natural gas) suppliers (e.g. the hospital in the city of Volos, electricity consumption in schools, public lighting, etc.). In the case of industry different sources have been used including verified reports within the framework of the EU-ETS and the Industrial Activity Report submitted by industrial units to the Ministry for Development.

3.2 Results

The year 2007 was selected as the base year for the formulation of the energy balance of the greater Volos area. The data required for the formulation of the energy balance are those presented in Paragraph 3.1.

Local energy and energy-related information provided by the Municipality of Volos include:

- Total natural gas consumption as well as natural gas consumption in the two industrial areas operating within the boundaries of the greater Volos area.
- Electricity and fuels consumption in schools and major buildings operated by the Municipality of Volos.
- Electricity consumption for public lighting.
- The composition, characteristics and fuel consumption of the vehicles fleet operated by the municipality of Volos.
- Number, characteristics and transportation work covered by urban busses.
- Electricity and fuel consumption of major public buildings (e.g. hospital, university)
- Electricity consumption in the municipal enterprise for water supply and wastewater treatment.

Additional information includes:

- Patterns of energy consumption in households are drawn from a national survey carried out in 2004/5 by National Statistical Service of Greece.
- Unit energy consumption in tertiary sector is drawn from relevant reports (e.g. NOA 2003) and refereed papers for energy consumption in Greek buildings in international journals (e.g. Georgopoulou 2006; Gaglia et al. 2007).
- Efficiency per vehicle category is drawn from the TREMOVE model runs[3] (Transport & Mobility Leuven 2007), the 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines on national GHG inventories (IPCC 1997), while EMEP/CORINAIR Emissions

[3] Latest runs available at (http://www.tremove.org/documentation/index.htm - last accessed at 31.03.2009) refer to February 2009

Inventory Guidebook (EEA 2007) provides information regarding the efficiency of fishing boats and other machinery.

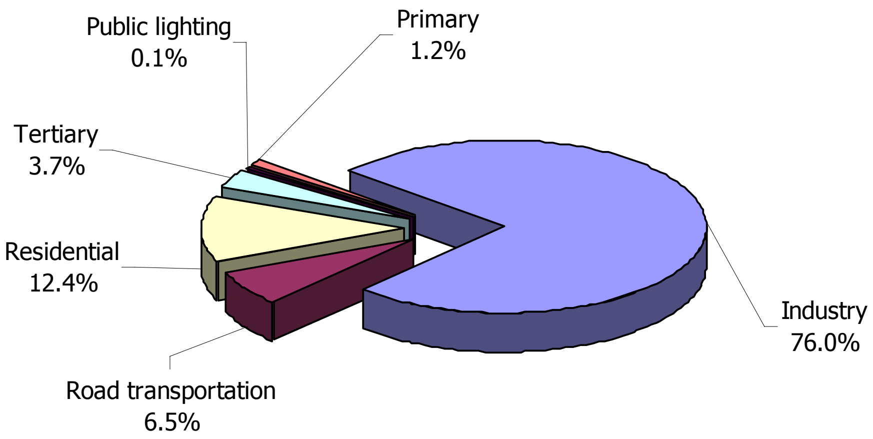
The detailed energy balance for the greater Volos area is presented in **Table 3.2**, while **Figure 3.2** presents the distribution of final consumption per fuel and sector. The comparison of the results obtained and the available data at the level of prefecture indicate that:

- Electricity consumption in the residential, tertiary and industrial sector represents 63%, 40% and 51% respectively of total (per sector) electricity consumption at Magnesia Prefecture.
- Heavy fuel oil consumption accounts for 80% of total fuel oil consumption in the prefecture.
- Diesel oil consumption (excluding road transportation) in the greater Volos area accounts for 41% of total diesel oil consumption at Magnesia Prefecture. On the contrary, the ratio of gasoline and transport diesel consumption in the greater Volos area to the total consumption in the Prefecture is low (27% and 22% respectively) as only mileage within the boundaries of the greater Volos area is considered.

The main findings of the analysis can be summarized as follows:

- Total final consumption is estimated at about 521 ktoe, 73.7% of which concerns major industrial activities (i.e installations participating in the EU-ETS). The residential sector accounts for 12.4% of total final consumption, while road transportation (as defined in the context of the present analysis) and tertiary sector account for 6.5% and 3.7% respectively. Public lighting and primary sector account for 1.3% of total final consumption, while the rest 2.3% concerns energy consumption in rest industry including the municipal enterprise for water supply and wastewater treatment. This distribution of final energy consumption per sector is in line with the socio-economic profile of the greater Volos area, presented in the previous chapter.
- The consumption of solid fuels (and petroleum coke) represents 55% of final consumption. This amount of consumption refers exclusively to the industrial sector and more specifically to cement and lime production installations.
- A significant penetration is estimated for natural gas, the consumption of which accounts for 9% of total final consumption. Industry is the major natural gas consumer (about 26 ktoe) while the residential sector with a total consumption of 17 ktoe (mainly space heating) is the second largest consumer of natural gas. As a result of natural gas penetration the LPG consumption is limited.
- The use of RES in final consumption (biomass and solar) accounts for 2% of final consumption. About 85% of RES consumption concerns biomass consumption for space heating.

A. Energy consumption per sector



B. Energy consumption per fuel

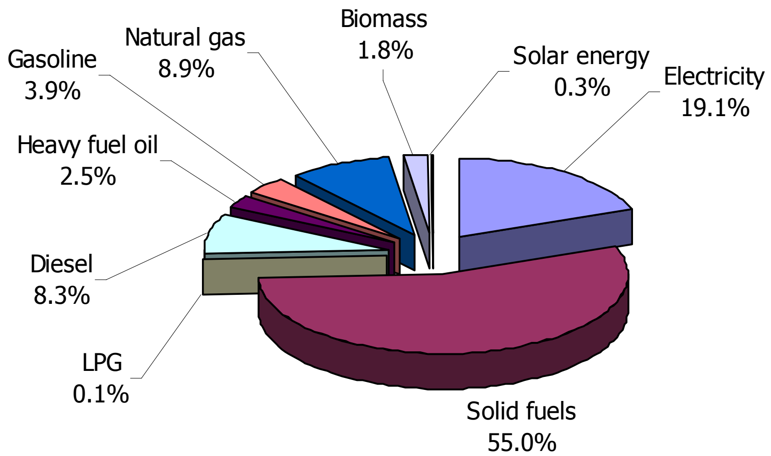


Figure 3.2 Energy consumption in the greater Volos area for 2007 (a) per sector and (b) per fuel

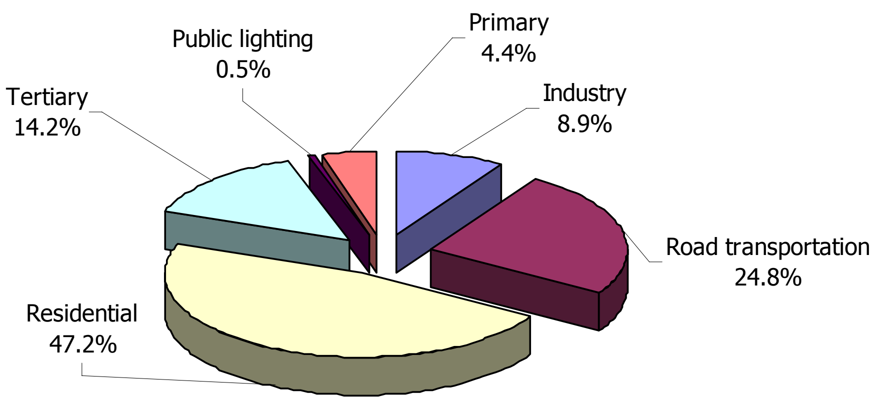
Table 3.2 Energy balance for the greater Volos area in 2007 (in toe)

	Electricity	Solid fuels	LPG	Diesel	Heavy fuel oil	Gasoline	Natural gas	Biomass	Solar energy	Total
Final Consumption	99616	286514	450	42997	13281	20494	46556	9519	1626	521053
Industry	71009	286514	21	52	12542	0	26059			396197
EU-ETS installations	66762	286514			9483		21225			383984
Water - Wastewater	1075									1075
Rest industry	3172		21	52	3059		4833			11137
Road transportation	89			13374		20494				33956
A. Per vehicle										
Passenger cars				2126		18169				20295
Light duty				5640		17				5658
Heavy duty				4160						4160
Busses				977						977
Motorcycles						2307				2307
Port machinery	89			471						560
B. Per use										
Passengers				8729		20454				29183
Local authorities				200		40				240
Goods transportation				3974						3974
Port of Volos	89			471						560
Residential sector	16764		356	19079			17386	9519	1626	64729
Space heating	1093			18694			16981	9459		46226
Water heating	4207			386			267		1626	6486

	Electricity	Solid fuels	LPG	Diesel	Heavy fuel oil	Gasoline	Natural gas	Biomass	Solar energy	Total
Cooking	2546		356				138	60		3100
Lighting	1458									1458
Air-conditioning	2107									2107
Electric appliances	5353									5353
Tertiary sector	10201		74	6082			3111			19468
A. Per use										
Space heating	428			5222			2834			8484
Water heating				861			215			1075
Cooking			74				63			136
Lighting	2394									2394
Air-conditioning	3168									3168
Electric appliances	4211									4211
B. Per sector										
Offices	1901			1141			608			3650
Trade	5392			3052			1356			9800
Hotels	232		74	297			326			928
Hospitals	1993			1503			196			3691
Schools	684			90			626			1400
Public lighting	683									683
Primary sector	870			4411	739					6019
Fishing				555						555
Greenhouses	12			2217	739					2968
Agricultural machinery	858			1639						2496

It is evident from both Figure 3.2 and Table 3.2 that energy consumption in the greater Volos area is dominated by the energy consumption of industrial installations participating in the EU-ETS. It should be mentioned that the share of industrial energy consumption to total final energy consumption at national level is 21% for 2007. A totally different allocation of energy consumption per sector and fuel (**Figure 3.3**) is obtained by excluding energy consumption of EU-ETS installations from the analysis. Such an allocation with the residential sector being the major energy consumer, followed by road transportation and a more balanced contribution of the various energy forms to total energy consumption is more representative for an urban area such as the greater Volos area. In this case (i.e. excluding energy consumption of industrial installations participating in the EU-ETS) the energy consumption associated with activities controlled by municipal authorities in the greater Volos area accounts for 3% of total final consumption (2.7 ktoe approximately).

A. Energy consumption per sector



B. Energy consumption per fuel

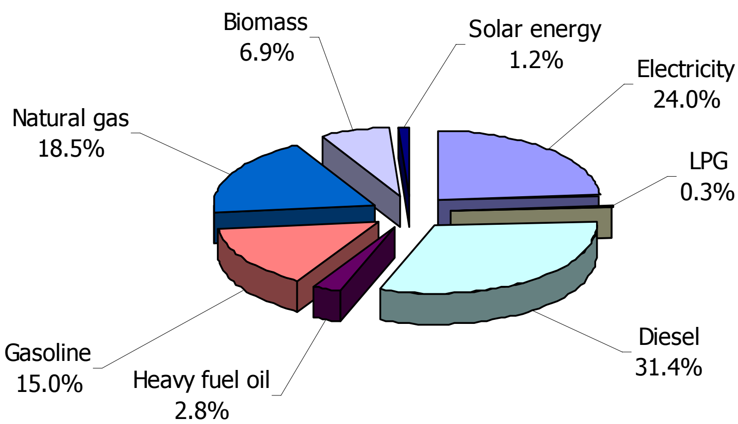


Figure 3.3 Energy consumption in the greater Volos area for 2007 excluding large industrial installations (a) per sector and (b) per fuel

4 Emissions inventory for the greater Volos area

4.1 General overview

Annual inventories of greenhouse and other gases emissions form an essential element of the environmental policy-making process at any administrative level. They can be used to derive information on emissions trends, with reference to a pre-selected base year, and can assist in monitoring the progress of existing abatement measures for the reduction of greenhouse gases emissions.

Emission inventories represent a core element of international agreements (e.g. United Nations Framework Convention on Climate Change, Kyoto Protocol, Convention on Long Range Transboundary Air Pollution, etc.) as well as environmental legislation of the European Union (e.g. Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, Emissions Trading Directive, etc.). Significant guidance has been developed in the context of these international environmental agreements so as to facilitate reporting and provide necessary assistance for the estimation of the emissions controlled.

This guidance provides the basis for the compilation of the emissions inventory for the greater Volos area taking into consideration local circumstances. In this context the boundaries set for the analysis include, to the extent possible, the stationary and mobile emission sources operating in the administrative area of the Municipality of Volos, as well as in neighbouring municipalities that form the greater Volos area:

- Energy use, including electricity consumption, in the residential and commercial sector, municipal infrastructures and buildings, rest tertiary sector activities, transport, agriculture and industry. Mobile combustion includes urban passenger transportation of local population, the activity of the vehicle fleet of the municipal authorities, inshore fishing by vessels of 19 hp or less, agricultural machinery and the machinery of the port of Volos.
- Industrial processes, including the use of F-gases especially for refrigeration and air-conditioning.
- Solvents
- Agriculture
- Waste management (both solid waste and wastewater treatment).

Specific attention was paid in order to quantify all emission sources on which municipal authorities have direct control. Emissions estimates from the above-mentioned sectors refer to all greenhouse gases (CO_2, CH_4, N_2O, F-gases), as well as basic air pollutants (PM10, NOx, SO_2, NMVOC). Emissions estimates include also the indirect emissions attributed to electricity consumption. The reporting year for the emissions inventory is 2007.

Calculation of greenhouse gases (GHG) emissions is mainly based on IPCC guidelines, while the EMEP/CORINAIR methodology (EEA 2007) is mainly used for the estimation of non-GHG emissions. Additionally, the indirect emission factors for electricity consumption derive from the latest national GHG emissions inventory (MINENV 2009). More specifically, the development of the emissions inventory for the greater Volos area is based on the:

- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (henceforth 1996 IPCC Guidelines, IPCC 1997).
- Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (henceforth IPCC Good Practice Guidance, IPCC 2000).
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories (henceforth 2006 IPCC Guidelines, IPCC 2006).
- Joint EMEP/CORINAIR Atmospheric emission inventory guidebook (henceforth CORINAIR, EEA 2007)

In all resources different methodologies are described for the same source category with increasing data requirements and accuracy. Data availability represents the main parameter determining the selection of calculation methodologies from the above-mentioned methodological resources i.e. the calculation methodology selected was the one that best fitted to the available data.

The aggregation of GHG emissions to a single unit (i.e. t CO_2 eq) relies upon the application of the Global Warming Potential (GWP) index. This index is defined as the cumulative radiative forcing between the present and some chosen time-horizon caused by a unit mass of gas emitted now, expressed relative to that for some reference gas. The values for GWP for selected greenhouse gases are given in **Table 4.1**.

Table 4.1 Global Warming Potential (in t of CO_2 eq) for selected gases for the 100-year horizon

Gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Hydrofluorocarbons (HFC)	
HFC-23	11700
HFC-125	2800
HFC-134a	1300
Perfluorocarbons (PFC)	
CF_4	6500
C_2F_6	9200
Sulphur hexafluoride (SF_6)	23900

The calculation methodologies selected as well as emissions estimates per sector and source category are described in the following paragraphs (4.2 – 4.5). **Table 4.2** provides an overview of GHG and other gases emissions per sector.

- Total GHG emissions at the greater Volos area for 2007 are estimated at 4569.49 kt, representing 3.5% of total GHG emissions at national level (excluding Land Use, Land Use Change and Forestry, LULUCF).
- Stationary combustion is the major source of CO_2, N_2O, GHG and other gases emissions, followed by Industrial processes in the case of CO_2 and PM10 emissions. Methane emissions from Waste account for about 90% of total methane emissions in the greater Volos area, while the contribution of Agriculture to total CH_4 and N_2O emissions is estimated at 8% and 18% respectively.
- Emissions estimates are clearly dominated (in the cases of GHG and PM10 emissions) by industrial installations participating in the EU-ETS as indicated by the high share of industrial processes (cement, lime and steel production) to total GHG emissions (about 40% compared to 7% at national level).
- Indirect emissions associated with electricity consumption in all sectors represent a significant part of total emissions as they account for 22% of total GHG emissions, 28% of total NOx emissions, 84% of total SO_2 emissions, 8% of total NMVOC emissions and 34% of total PM10 emissions.
- If both indirect emissions from electricity consumption and emissions from installations participating in the EU-ETS are excluded from totals, then GHG emissions are estimated at 394.50 kt (about 12 times lower compared with the total figure presented in Table 4.2a). In this case, the contribution of the various sectors to total GHG emissions (**Figure 4.1**) is totally different compared to the one presented in Table 4.2a.

  Stationary combustion is still the major contributor to total GHG emissions but its share is reduced to 40%. The share of emissions from mobile combustion increased to 28% of total emissions, while the Waste sector accounts for 25% of the total. On the contrary, the contribution of industrial processes and solvents use is minor (about 0.4% of total emissions) as in this case only GHG emissions from Solvents use and F-gases emissions are considered.

Table 4.2a GHG emissions per sector in the greater Volos area for 2007

	CO_2 (t)	CH_4 (t)	N_2O (t)	F-gases (t CO_2 eq)	GHG (t CO_2 eq)
Stationary combustion	2401174.63	41.31	186.38	-	2459819.26
Of which, EU-ETS installations	*1916387.08*	*22.18*	*179.53*	-	*1972505.79*
Mobile combustion	117455.41	55.05	11.66	-	122227.38
Industrial processes	1863806.62	4.50	-	414.28	1864315.41
Of which, EU-ETS installations	*1863806.62*	*4.50*	-	*0.00*	*1863901.12*
Solvents	1338.28	-	-	-	1338.28
Agriculture	-	411.23	46.14	-	22940.51
Waste	-	4502.38	13.87	-	98851.08
Total	4382179.79	5014.44	258.04	414.28	4567891.04
Total excluding EU-ETS installations	603581.24	4987.78	78.54	414.28	733084.99

Table 4.2b Other gases emissions per sector in the greater Volos area for 2007

	NOx (t)	SO2 (t)	NMVOC (t)	PM10 (t)
Stationary combustion	8203.95	8183.24	522.81	858.73
Of which, EU-ETS installations	*7126.44*	*5754.76*	*96.50*	*388.01*
Mobile combustion	1081.76	76.34	344.96	43.22
Industrial processes	90.00	58.50	40.50	799.32
Of which, EU-ETS installations	*90.00*	*58.50*	*40.50*	*799.32*
Solvents	-		429.39	-
Agriculture	1.05	-	-	-
Waste	-	-	-	-
Total	9376.77	8318.09	1337.66	1702.78
Total excluding EU-ETS installations	2164.49	2515.75	1200.84	516.35

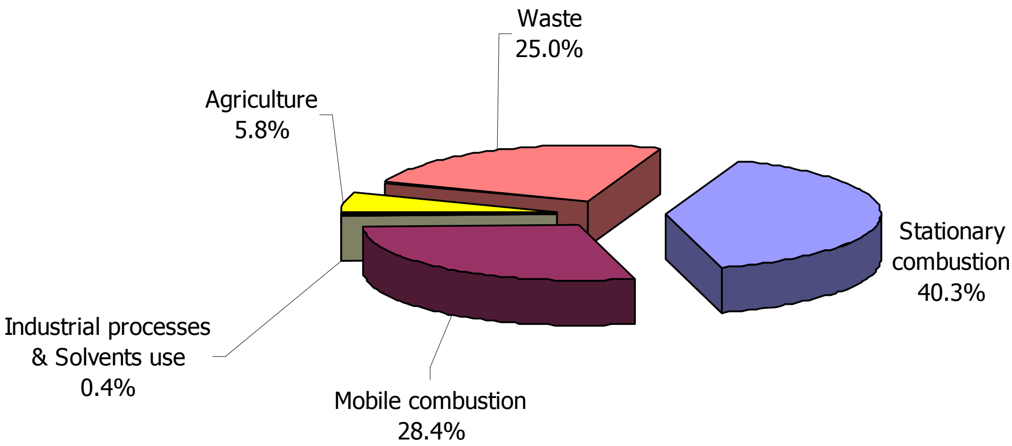


Figure 4.1 Total GHG emissions in the greater Volos area for 2007 excluding indirect emissions and emissions from EU-ETS installations

4.2 Energy sector

This paragraph includes information on GHG and other gases emissions from *Energy* and a description of the methodologies applied per source for the calculation of emissions.

The following source categories are included in *Energy*:

- Stationary combustion. This source category includes emissions from the combustion of fuels in buildings (residential and tertiary sectors), industrial units and greenhouses. Emissions from the biogas electricity generation unit (from the wastewater treatment plant) are also included.
- Mobile combustion includes urban passenger transportation of local population, the activity of the vehicle fleet of the municipal authorities, inshore fishing by vessels of 19 hp or less, agricultural machinery and the machinery of the port of Volos[4].

Table 4.3 and **Table 4.4** provide an overview of the emissions per source category (with and without electricity respectively) considered in *Energy*, while emissions per fuel are presented in **Table 4.5**. It should be mentioned that following IPCC Guidelines, CO_2 emissions from biomass consumption are estimated but not included in total figures.

➯ GHG emissions from the Energy sector in the greater Volos area are estimated at 2.58 Mt CO_2 eq including electricity and at 1.56 Mt CO_2 eq excluding electricity. Total GHG emissions including electricity account for 2.4% of total GHG emissions from fuel combustion activities

[4] Following IPCC guidelines, emissions from agricultural machinery and the machinery operated at the port of Volos should be included in stationary combustion. However, it was considered more appropriate to create a set of activities with similar estimation methods.

at national level for 2007. Indirect GHG emissions from electricity use account for about 2% of GHG emissions from electricity generation at national level for 2007.

- The emissions of other gases (including electricity) in the greater Volos area amount to:
  - 9.29 kt for NOx emissions (2.5% of NOx emissions from fuel combustion activities at national level)
  - 8.27 kt for SO_2 emissions (1.5% of SO_2 emissions from fuel combustion activities at national level)
  - 0.87 kt for NMVOC emissions (0.8% of NMVOC emissions from fuel combustion activities at national level) and
  - 0.9 kt for PM10 emissions
- The significance of industry in the "local" economic activities in the greater Volos area is also depicted in the GHG and other gases emissions calculated for the area. Emissions from industrial activities account for 79% of total GHG emissions, 78% of total NOx emissions, 74% of SO_2 emissions, 13% of NMVOC emissions and 46% of PM10 emissions. It should be mentioned that PM10 emissions from cement and lime production are reported under Industrial Processes (see Paragraph 4.3) and as a result the contribution of industry to total PM10 emissions appears to be less than expected.

  Solid fuels consumption for cement and lime production represent a major source of direct GHG, NOx and SO_2 emissions, with a contribution of about 80% of total excluding indirect emissions.
- Road transportation is the second more significant (following industry) source of NOx emissions and a major source of NMVOC emissions even in the case that industry is included in the estimated totals. In addition it is the most significant direct source of N_2O emissions (excluding industry) as a result of the increased number of catalytic passenger cars.
- Residential sector represents the most significant source (excluding industry) of direct and indirect GHG, SO_2, NMVOC and PM10 emissions in the greater Volos area.
- The considerable penetration of natural gas in the local energy system (excluding industry) is also depicted in its contribution to total GHG emissions (see Table 4.5), which is similar to the one of heating diesel.

Table 4.3 GHG and other gases emissions from the Energy sector in the greater Volos area (including electricity)

	CO_2 (t)	CH_4 (kg)	N_2O (kg)	GHG (t)	NOx (kg)	SO_2 (kg)	NMVOC (kg)	PM10 (kg)
Primary sector	24981.82	625.00	2975.11	25917.23	112512.60	91376.69	18288.31	12262.41
Inshore fishing	1722.66	99.75	698.25	1941.21	28728.00	54.06	7620.90	4428.90
Greenhouses	9394.76	109.88	75.56	9420.49	12695.56	24790.55	1869.82	440.96
Agricultural machinery	13864.40	415.37	2201.30	14555.53	71089.05	66532.07	8797.59	7392.56
Residential sector	272607.84	16079.73	4639.16	274383.65	601149.32	1265812.75	402118.44	377125.47
Road transportation	101868.35	54530.59	8765.00	105730.64	981946.52	9755.77	328542.26	32908.49
Urban passenger	86432.39	52069.19	7588.60	89878.31	798286.01	2783.19	316029.71	23373.89
Municipal vehicles	735.83	169.52	32.80	749.56	8298.97	23.23	1497.81	352.43
Port of Volos	2371.03	102.05	641.10	2571.91	28353.90	6562.40	2445.69	2501.43
Goods transportation	12329.10	2189.82	502.50	12530.86	147007.64	386.94	8569.05	6680.73
Tertiary sector	130819.12	1671.43	1349.84	131272.67	307358.23	739259.84	15804.01	60055.01
Offices	24430.84	312.29	252.78	24515.76	57366.95	137792.25	2943.57	11191.83
Trade	67860.40	864.98	698.51	68095.10	160864.08	390097.00	8187.36	31720.29
Hotels	4253.25	56.31	44.31	4268.17	8515.62	17423.08	541.50	1387.38
Hospitals	25523.12	317.84	251.61	25607.79	60120.65	145611.23	3222.77	11769.04
Schools	8751.51	120.01	102.63	8785.84	20490.93	48336.28	908.81	3986.47
Public lighting	6998.09	91.11	74.87	7023.22	18268.06	47940.07	773.29	3972.42
Industry	1981354.82	23335.40	180235.89	2037717.99	7267210.93	6116369.05	102358.11	417905.52
EU-ETS installations	1916387.08	22181.41	179525.51	1972505.79	7126443.10	5754763.88	96495.24	388011.49
Water & Wastewater	11010.54	143.35	117.79	11050.07	28742.30	75427.17	1216.67	6250.06
Rest industry	53957.20	1010.65	592.59	54162.12	112025.53	286178.00	4646.20	23643.98
Biogas unit		23.93	2.39	1.24	1435.59	0.00	59.82	136.38
TOTAL	2518630.04	93842.06	198042.26	2582046.64	9289881.25	8270514.17	867944.24	904365.71

Table 4.4 GHG and other gases emissions from the Energy sector in the greater Volos area (excluding electricity)

	CO_2 (t)	CH_4 (kg)	N_2O (kg)	GHG (t)	NOx (kg)	SO_2 (kg)	NMVOC (kg)	PM10 (kg)
Primary sector	16078.60	509.08	2879.87	16982.05	89271.34	30385.66	17304.51	7208.57
Inshore fishing	1722.66	99.75	698.25	1941.21	28728.00	54.06	7620.90	4428.90
Greenhouses	9271.96	108.28	74.25	9297.25	12374.98	23949.28	1856.25	371.25
Agricultural machinery	5083.99	301.05	2107.37	5743.59	48168.36	6382.31	7827.36	2408.42
Residential sector	100971.54	13845.15	2802.94	102131.20	153104.14	90027.20	383152.63	279697.37
Road transportation	100957.22	54518.73	8755.25	104816.24	979568.06	3514.09	328441.58	32391.29
Urban passenger	86432.39	52069.19	7588.60	89878.31	798286.01	2783.19	316029.71	23373.89
Municipal vehicles	735.83	169.52	32.80	749.56	8298.97	23.23	1497.81	352.43
Port of Volos	1459.89	90.19	631.35	1657.50	25975.44	320.72	2345.01	1984.24
Goods transportation	12329.10	2189.82	502.50	12530.86	147007.64	386.94	8569.05	6680.73
Tertiary sector	26372.83	311.61	232.45	26451.43	34708.11	23755.94	4262.69	766.83
Offices	4966.95	58.88	44.55	4982.00	6557.78	4455.93	792.81	143.29
Trade	12655.02	146.24	107.91	12691.54	16754.09	11915.42	2087.16	383.36
Hotels	1879.81	25.41	18.91	1886.21	2319.93	1163.99	279.24	40.12
Hospitals	5122.52	52.24	33.36	5133.96	6866.22	5857.93	968.50	188.79
Schools	1748.52	28.83	27.71	1757.72	2210.09	362.67	134.98	11.27
Public lighting	Not applicable							
Industry	1254320.72	13869.96	172457.86	1308073.93	5369336.60	1135859.62	22020.83	5209.87
EU-ETS installations	1232838.37	13282.11	172212.70	1286503.23	5342084.49	1072148.81	20963.10	0.00
Water & wastewater	Not applicable[5]							
Rest industry	21482.36	587.85	245.16	21570.70	27252.12	63710.80	1057.73	5209.87
Biogas unit		23.93	2.39	1.24	1435.59	0.00	59.82	136.38
TOTAL	1498700.91	83078.46	187130.76	1558456.09	6627423.86	1283542.50	755242.05	325410.31

Table 4.5 GHG and other gases emissions per fuel from the Energy sector

	CO_2 (t)	CH_4 (kg)	N_2O (kg)	GHG (t)	NOx (kg)	SO_2 (kg)	NMVOC (kg)	PM10 (kg)
Heating diesel	93369.23	1880.48	4074.69	94671.87	209558.52	113592.85	35126.43	12525.56
Electricity	1019929.12	13278.72	10911.50	1023590.54	2662457.40	6986971.67	112702.19	578955.40
Solid fuels	1152250.56	11996.36	167949.07	1204566.69	5206421.04	1019690.76	17994.54	0.00
Natural gas	109355.15	1949.29	1949.29	110000.36	136282.38	974.64	4819.76	4.20
Heavy fuel oil	43040.04	824.62	3431.92	44121.25	89356.63	130737.28	2295.64	5216.18
LPG	1188.62	18.75	5.29	1190.65	1085.08	9.42	190.36	8.98
Gasoline	59464.62	48200.66	7047.05	62661.42	657555.56	1936.96	300119.38	1998.12
Transport diesel	40032.70	6227.88	1076.85	40497.31	296037.06	1256.40	25977.20	28408.93
Biomass		11956.51	1594.20	745.29	29691.99	15344.18	368658.94	277111.96
Biogas		23.93	2.39	1.24	1435.59	0.00	59.82	136.38
TOTAL	2518630.04	93842.06	198042.26	2582046.64	9289881.25	8270514.17	867944.24	904365.71

[5] Energy consumption of the installations operated by Municipal Enterprise for Water Supply & Effluent Treatment and Discharge (DEYAMV) refers exclusively to electricity consumption

4.2.1 Calculation of CO_2 and SO_2 emissions

The calculation of CO_2 and SO_2 emissions is based on fuel consumption per source and the fuel characteristics (carbon and sulphur content, net calorific value, etc.). Since fuel characteristics do not differentiate among the different technologies, the same methods are applied for stationary and mobile sources.

More specifically, the following equations are applied:

$$E_{CO_2} = \sum_f FC_f \cdot EF_{CO2,f} \cdot 0.04187$$

$$E_{SO_2} = \begin{cases} \sum_f \frac{FC_f \cdot SC_f \cdot 2}{NCV_f} \cdot 41870 \\ \sum_f FC_f \cdot EF_{SO2,f} \cdot 0.04187, \text{cement - lime production, natural gas, LPG and electricity} \end{cases}$$

where, E_{CO2} is CO_2 emissions (in t), E_{SO2} is SO_2 emissions (in kg), f is an index referring to the fuel consumed, FC_f is the consumption of fuel-f (in toe), $EF_{CO2,f}$ is CO_2 emission factor of fuel-f (in t/TJ), SC_f is the sulphur content of fuel-f (% w/w), NCV_f is the net calorific value of fuel-f (in MJ/kg) and $EF_{SO2,f}$ is SO_2 emission factor of fuel-f (in kg/TJ).

The energy balance formulated for the greater Volos area (presented in Chapter 3) provides all necessary fuel and electricity consumption data for the calculation of emissions. **Table 4.6** provides an overview of the values used for the parameters appeared in the above equations. The references used and the assumptions made for selecting the appropriate values are summarised below:

- The emission factors used for electricity consumption are estimated according to CO_2 and SO_2 emissions estimates presented in the latest national GHG emissions inventory (2009 submission covering the period 1990 – 2007) and the final electricity consumption (including energy sector consumption) as reported in the national energy balance for 2007 (62209 GWh[6]).
- The CO_2 emission factors for all fuels (except electricity) are those provided by the 2006 IPCC Guidelines (Table 1.4, IPCC 2007). The emission factors used, assume an oxidation factor of 1 and the carbon content presented in Table 1.3 of the 2006 IPCC Guidelines.
- The sulphur content of heating & transport diesel, heavy fuel oil and gasoline derives from national legislation regarding the quality of fuels available in the Greek market. For the rest of the fuels as well as for the fuels consumed in cement and lime production, values proposed by CORINAIR are applied. These emission factors include also process related emissions.

[6] Available online at the web-site of the Ministry for Development: http://www.ypan.gr/docs/(040209)energy%20balance%20%202007%20%20final.xls

- The Net Calorific Value (NCV) of all fuels (except natural gas) is provided by the 2006 IPCC Guidelines (Table 1.2, IPCC 2007). The NCV of natural gas (an average country specific value) is equal to 10.035 kWh/Nm^3.

Table 4.6 Basic fuel characteristics and CO_2 – SO_2 emission factors

Fuel	NCV (MJ/kg)	Sulphur content	SO2 emission factor (kg/TJ)	CO2 emission factor (t/TJ)
Heating diesel	43.0	0.2%		74.1
Transport diesel	43.0	50 ppm		74.1
Gasoline	44.3	50 ppm		69.3
Heavy fuel oil	40.4	1%	131.0[7]	77.4
Solid fuels	29.2[8]		85.0[9]	96.1
LPG	47.3		0.5	63.1
Natural gas	36.1 MJ/Nm^3		0.5	56.1
Electricity			1675.2	244.5
Biomass	15.6	0.03%[10]		112.0
Biogas (sludge)	50.4		0.0	

4.2.2 Stationary sources

For the estimation of CH_4, N_2O emissions as well as of the other gases emissions from stationary combustion the disaggregation of energy consumption into different activities / technologies is required. The detailed energy balance formulated for the greater Volos area (presented in Chapter 3) provides all necessary activity data for the estimation of emissions according to the following equation:

$$E_g = \sum_{f,t} FC_{f,t} \cdot EF_{g,f,t} \cdot 0.04187$$

where, *g* is an index referring to a gas (CH_4, N_2O, NOx, NMVOC and PM10), E_g is emissions of gas-g (in kg), *f* is an index referring to the fuel consumed, *t* is an index referring to an activity / technology, $FC_{f,t}$ is the consumption of fuel-f in activity-t (in toe) and $EF_{g,f,t}$ is the emission factor for gas-g in activity-t using fuel-f (in kg/TJ).

Since the emission factors applied are both technology and fuel specific, some additional (to the ones already presented in Paragraph 4.2.1) assumptions need to be made for the selection of the appropriate emission factors (**Table 4.7**).

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[7] Applicable only for cement – lime production
[8] Average value for steam coal and petroleum coke
[9] Applicable only for cement – lime production
[10] CORINAIR (EEA 2007)

Table 4.7 Technology and fuel specific emission factors applied for stationary combustion (in kg/TJ)

	CH4	N2O	NOx	NMVOC	PM10
Greenhouses					
Natural gas	1.0	1.0	70.0	3.0	0.0
Diesel	0.7	0.6	100.0	15.0	3.0
Heavy fuel oil	1.4	0.6	100.0	15.0	3.0
Residential sector					
Diesel in boilers	0.7	0.6	100.0	15.0	3.0
Diesel in other equipment	3.0	0.6	68.0	15.5	3.7
Natural gas	1.0	1.0	70.0	3.0	0.0
LPG	1.0	0.1	57.0	10.5	0.5
Tertiary sector					
Natural gas	1.0	1.0	70.0	3.0	0.0
Diesel	0.7	0.4	100.0	15.0	3.0
LPG	1.0	0.1	57.0	10.5	0.5
Industry					
Cement - Lime production					
Solid fuels	1.0	14.0	434.0	1.5	I.E.
Heavy fuel oil	1.0	8.5	185.0	3.0	I.E.
Rest industry					
Heavy fuel oil	3.0	0.3	100.0	5.0	40.0
Diesel	0.2	0.4	100.0	5.0	40.0
LPG	0.9	4.0	70.0	2.0	0.0
Natural gas	1.0	1.0	70.0	2.0	0.0
Electricity	3.2	2.6	638.3	27.0	138.8
Biomass	30.0	4.0	74.5	925.0	695.3
Biogas	1.0	0.1	60.0	2.5	5.7

- The emission factors used for electricity consumption are estimated according to CH_4, N_2O, NOx and NMVOC emissions estimates presented in the latest national GHG emissions inventory (2009 submission covering the period 1990 – 2007) and the final electricity consumption (including energy sector consumption) as reported in the national energy balance for 2007.

  The annual national GHG and other gases emissions inventory do not contain estimates of PM10 emissions. In order to apply a procedure similar to the one described above for the estimation of an average PM10 emission factor, PM10 emissions from electricity generation need to be estimated. To this end, energy consumption per fuel for electricity generation is multiplied by the following emission factors, provided by CORINAIR:

  - Solid fuels: 80 kg/TJ
  - Gaseous fuels: 0.1 kg/TJ
  - Diesel: 5 kg/TJ
  - Heavy fuel oil: 50 kg/TJ

- The CH_4 and N_2O emission factors applied derive from the following categories presented in the 2006 IPCC Guidelines:
    - Natural gas boilers in buildings and industrial units (natural gas combustion).
    - Commercial/institutional diesel oil boilers (diesel oil combustion in buildings of the tertiary sector).
    - Industrial boilers (fuels consumption in rest industry).
    - Diesel oil boilers in the residential sector (only for CH_4). The Tier 1 emission factor is applied for N_2O.
    - Tier 1 emission factors are used for non-boiler energy uses in the residential sector.
    - The emission factors used for greenhouses are those selected for the residential sector.
    - Biomass consumption in residential sector (Tier 1 emission factors).
- Emission factors for the estimation of other gases emissions derive from CORINAIR under the following assumptions:
    - The capacity of boilers in the residential sector ranges from 50 kW to 1 MW.
    - The capacity of boilers in the tertiary sector as well as in rest industry is less than 50 MW.
    - Tier 1 emission factors are used for non-boiler energy uses in buildings (e.g. stoves) as well as for biomass and LPG consumption in the residential sector.

4.2.3 Mobile combustion

Mobile combustion includes urban passenger transport, the activity of the municipal vehicle fleet, agricultural and port machinery and inshore fishing.

Emissions from agricultural / port machinery and inshore fishing (CO_2 and SO_2 are not included) are estimated according to the following equation:

$$E = \left(N \cdot P \cdot H \cdot eff \right) \cdot EF$$

where, *E* is emissions, *N* is the number of machinery/vessels, *H* is the operating hours on an annual basis, *eff* is the energy efficiency of the machinery/vessel category and *EF* is the emission factor. The product in parenthesis in the above equation represents the relevant energy consumption per machinery/vessel category.

It should be mentioned that the total number of machinery/vessels is not disaggregated to different technology types as there is not sufficient background information and the expected contribution to total emissions is low.

Table 4.8 provides an overview of the emission factors applied (derived from CORINAIR). Agricultural machinery refers to tractors that comply with Stage I requirements. The latter is not appeared in the following table as the emission factors applied has already been presented in Paragraph 4.2.2. In all other cases the uncontrolled emission factors were selected.

Table 4.8 Emission factors used (in kg/TJ) for the estimation of emissions from agricultural / port machinery and inshore fishing

	CH4	N2O	NOx	NMVOC	PM10
Agricultural machinery	4,4	30,7	702,1	114.1	35.1
Inshore fishing	4,3	30,0	1235,7	327.8	190.5
Port of Volos	4,6	32,0	1318,4	119.0	100.7

A similar equation to the one presented above is applied for the estimation of emissions from road transportation. In this case and especially for urban passenger transportation with private passenger cars different technologies are considered.

$$E = (N \cdot M \cdot eff) \cdot EF$$

where, *E* is emissions, *N* is the number of vehicles, *M* is the annual mileage, *eff* is the energy efficiency of the vehicle category and *EF* is the emission factor. The product in parenthesis in the above equation represents the relevant energy consumption per vehicle technology.

As already discussed in Chapter 3, efficiency per vehicle category is drawn from the TREMOVE model runs and the 1996 IPCC Guidelines. For consistency reasons, the emission factors (**Table 4.9**) applied, are also drawn from these references respectively.

Table 4.9 Emission factors used (in kg/TJ) for the estimation of emissions from road transportation

	CH_4	N_2O	NOx	NMVOC	PM10
Gasoline passenger cars					
Pre EURO	59.2	5.5	2098.7	510.1	0.9
EURO I - III	36.0	11.1	215.0	148.3	0.8
EURO IV	36.7	2.5	22.4	22.9	0.4
Diesel passenger cars	1.6	2.1	211.9	20.8	18.4
Busses (Diesel – EURO I)	17.3	3.0	748.1	49.2	33.0
Motorcycles					
Up to EURO II	154.8	1.6	134.6	996.3	14.4
EURO III	68.8	1.7	111.7	473.3	4.3
Light duty vehicles					
Diesel (up to EURO II)	13.2	1.0	390.4	55.5	78.1
Gasoline					
Pre EURO	15.1	1.9	735.8	515.3	0.6
EURO I	5.5	10.2	110.8	90.7	0.5
Heavy duty vehicles					
Municipal fleet	9.9	3.5	948.6	56.9	39.5
Other	13.2	3.0	883.5	51.5	40.2

4.3 Industrial processes and Solvents use

This paragraph includes information on GHG and other gases emissions from *Industrial Processes and Solvents* and a description of the methodologies applied per source for the calculation of emissions.

The following source categories are included *Industrial Processes*:

- Mineral products
- Metal production
- Consumption of halocarbons and SF_6

while the sector Solvents include (in the context of the present analysis) the following source categories:

- Paint application
- Dry Cleaning
- Other, including use of other products as well as uses of solvents not listed above.

Table 4.10 provides an overview of the emissions per source category considered in the sectors *Industrial Processes and Solvents*. It should be mentioned that due to the limited data availability regarding industrial production at regional / local level (as well as confidentiality issues) the analysis concerns only the installations that participate in the EU-ETS.

Table 4.10 Overview of emissions (in t for all gases except F-gases that t CO_2 eq are used) from Industrial Processes and Solvents

Source category	CO_2	CH_4	F-gases	GHG	NOx	SO_2	NMVOC	PM10
Mineral products	1823341.29	-	-	1823341.29	-	-	-	792.12
Metal production	40465.33	4.50	-	40559.83	90.00	58.50	40.50	7.20
Consumption of halocarbons and SF_6	-		414.28	414.28	-			
Solvents	1338.28	-	-	1338.28	-	-	429.39	-
TOTAL (t)	1865144.90	4.50	414.28	1865653.69	90.00	58.50	469.89	799.32

4.3.1 Mineral products

4.3.1.1 Cement production

Emissions of CO_2 occur during the production of clinker, which is an intermediate product in the cement manufacturing process. CO_2 emissions are attributed to the calcination of limestone (mainly CaCO3), to produce lime (CaO) and carbon dioxide as a by-product.

Cement production in the greater Volos area refers to one unit. Calculation of CO_2 emissions from cement production is based on clinker production (Tier 2 methodology) according to the following equation (IPCC 2000):

$$E = (0.785 \cdot CaO + 1.092 \cdot MgO) \cdot P_{CL} \cdot CKD$$

where, *E* is carbon dioxide emissions, *CaO* is the CaO content (weight fraction) in clinker, *MgO* is the MgO content (weight fraction) in clinker, P_{CL} is the total clinker production and *CKD* is a correction factor used to account for the CO_2 contained in the non-recycled calcined cement kiln dust.

- Clinker production is estimated on the basis of the verified CO_2 emissions reported by the installation in the framework of the EU-ETS.
- According to the latest national GHG emissions inventory, the average (of all cement production units in Greece) CaO and MgO content in clinker is 64.47% and 3.26% respectively. Additionally, the CKD parameter is equal to 1.

CO_2 emissions from cement production are estimated at 1733.40 kt (**Table 4.11**).

PM10 emissions are estimated on the basis of clinker production and an emission factor relevant for modern facilities proposed by CORINAIR, assuming a clinker content of cement of 75% (180 g/t cement).

Table 4.11 Emission factors and emissions from cement production

Gas	Emission factors	Reference	Emissions (t)
CO_2	0.5417 t / t	MINENV 2009, average value for Greek installations	1733403.84
PM10	240 gr / t	CORINAIR, EEA 2007	768.00

4.3.1.2 Lime production

Lime production leads to carbon dioxide emissions because of the calcination of limestone ($CaCO_3$) or dolomite ($CaCO_3.MgCO_3$) to produce lime or dolomitic lime. The emissions estimated from lime production concern two installations that participate in the EU-ETS.

The calculation of carbon dioxide emissions from lime production is based on the lime production (high-calcium lime and hydrated lime), according to the following equation (IPCC 2000):

$$E = 0.785 \cdot p_{CaO} \cdot PROD \cdot (1 - x \cdot y)$$

where, *E* is carbon dioxide emissions, p_{CaO} is the content of lime in the final product, *PROD* is the total production of high-calcium lime and hydrated lime, *x* is the proportion of hydrated lime in total production and *y* the water content in hydrated lime.

- It is assumed that all production in the greater Volos area refers exclusively to high-calcium lime. As a result the parameters *x* and *y* in the above equation are set to zero. According to the IPCC Good Practice Guidance the default values for these parameters are 10% and 28% respectively.
- The lime content in the final product (p_{CaO}) is considered to be 95%, as suggested by the IPCC Good Practice Guidance (IPCC 2000).
- Lime production is estimated on the basis of the verified CO_2 emissions reported by the installations in the framework of the EU-ETS

CO_2 emissions from lime production are estimated at 89.94 kt (**Table 4.12**).

PM10 emissions are estimated on the basis of lime production and the default emission factor proposed by CORINAIR (0.2 kg/t lime).

Table 4.12 Emission factors and emissions from lime production

Gas	Emission factors	Reference	Emissions (t)
CO_2	0.74575t / t	IPCC 2006	89937.45
PM10	0.2 kg / t	CORINAIR, EEA 2007	24.12

4.3.2 Metal production

In the case of the greater Volos area, this source category concerns steel production. There is one steel production unit in the area the production process of which is based on the use of electric arc furnace (EAF). It should be mentioned that steel production in Greece is exclusively based on the use of EAF.

The main source of CO_2 emissions from EAF is the consumption of electrodes within the furnace. Additional reducing agents (e.g. coal, coke, etc.) may be used resulting to additional CO_2 emissions.

Emissions from steel production are calculated by using production data and appropriate emission factors (**Table 4.13**). Steel production is estimated on the basis of the verified CO_2 emissions reported by the installation in the framework of the EU-ETS.

Table 4.13 Emission factors and emissions from steel production

Gas	Emission factors	Reference	Emissions (t)
CO_2	89.9 kg / t	MINENV 2009, average value for Greek installations	40465,33
CH_4	10 gr / t	IPCC 2006	4,50
NOx	200 gr / t	CORINAIR, EEA 2007	90,00
SO_2	59 gr / t	CORINAIR, EEA 2007	58,50
NMVOC	41 gr / t	CORINAIR, EEA 2007	40,50
PM10	16 gr / t	CORINAIR, EEA 2007	7,20

4.3.3 Consumption of halocarbons and SF_6

Emissions of F-gases are generated during the manufacturing, operation/maintenance and final disposal of the following materials/equipment:

- Refrigerating and air conditioning equipment
- Foam blowing
- Fire extinguishers
- Aerosols / metered dose inhalers
- Solvents
- Semiconductor manufacture
- Electrical equipment

Assembly emissions are associated with product manufacturing, even if the products are eventually exported. **Operation emissions** include annual leakage from equipment stock in use (regardless of where they were manufactured) as well as servicing emissions and **disposal emissions** include the amount of refrigerant released from scrapped systems, regardless of where they were manufactured.

Emissions estimates presented in the present inventory concern residential refrigeration and air condition as well as mobile air conditioning (passenger cars). In addition, only the operation / maintenance phase is considered.

The following equation is applied for the estimation of emissions:

$$EM = \sum_i Neq_i \cdot IC_i \cdot x_i$$

where, *EM* is F-gases emissions, *i* is an index referring to equipment category, *Neq* is the equipment stock per category, IC_i is the initial charge per equipment category, x_i is the leakage rate during operation.

According to the National Association of Refrigerating and Cooling Technicians the use of F-gases started in 1993 as regards refrigeration equipment, in 2000 as regards stationary air-conditioning and in 1995 for mobile air-conditioning. Taking into consideration this information as well as the equipment stock estimated in the context of formulating the local energy balance (see Chapter 3), the passenger cars' distribution per legislation class and the lifetime of the equipment (15 year for split units and refrigerators and 12 years for mobile air conditioning, IPCC 2000) it is assumed that

- 50% of the split units installed in the residential sector (23228 units)
- 50% of the air conditioning systems in passenger cars (20653 cars)
- 100% of the residential refrigerators (46455 units)

use F-gases as refrigerants.

The values of the basic parameters used for the estimation of emissions (MINENV 2009), as well as the type of refrigerant used in each category are presented in **Table 4.14**.

Table 4.14 Basic assumptions for the calculation of HFC emissions and HFC emissions (in t CO_2 eq) per equipment category

	Initial charge (kg)	Leakage rate (%)	Refrigerant used	Emissions (t F-gases)
Refrigeration	0.18	0.02	HFC-134a	2.17
Air-conditioning (split-units)	2.00	0.33	R-410A (50% HFC-32 & 50% HFC-125)	264.45
Mobile air-conditioning	1.00	0.55	HFC-134a	147.67

4.3.4 Solvents

Most solvents are part of a final product, e.g. paint, and will sooner or later evaporate to the atmosphere. This evaporation of solvent and other products containing volatile organic compounds represents a major source of NMVOC emissions that, once released into the atmosphere, will react with reactive molecules (mainly HO-radicals) or high energetic light to finally form CO_2. This sector also includes evaporative emissions of greenhouse gases arising from other types of product use (e.g. N_2O emissions from medical use).

Emissions estimates presented in the present inventory concern the following activities (defined according to CORINAIR):

- Paint application - Domestic use
- Dry cleaning
- Domestic solvents use (except for paint application)

Table 4.15 presents the emission factors used (NMVOC and CO_2) per category and the emissions calculated. Carbon dioxide emissions are calculated from NMVOC emissions, assuming that the carbon content of NMVOC is 85%.

Table 4.15 Emission factors and emissions from solvents use

Gas	Emission factors (kg/capita)		Emissions (t)	
	NMVOC	CO_2	NMVOC	CO_2
Paint application – Domestic use	0.50	1.56	64.18	200.04
Dry cleaning	0.25	0.78	32.09	100.02
Domestic solvents use	2.60	8.09	333.12	1038.22

4.4 Agriculture

This paragraph includes information on GHG and other gases emissions from *Agriculture* and a description of the methodologies applied per source for the calculation of emissions. The following source categories are included in *Agriculture*:

- Enteric fermentation
- Manure management
- Agricultural soils
- Field burning of agricultural residues

The calculation of emissions from Agriculture is based on the methodologies and emission factors suggested by the IPCC Guidelines and the IPCC Good Practice Guidance.

Animal population, agricultural production and cultivated areas are estimated on the basis of information provided by the National Statistical Service of Greece (NSSG) at regional level and municipal level (only for 2000/2001). Data on the amount of synthetic fertilizers applied to soils derive from the correspondent national figures that are disaggregated according to the cultivated areas available.

Table 4.16 provides an overview of the emissions per source category considered in the sector *Agriculture*.

Table 4.16 Overview of emissions from Agriculture

Source category	CH4	N2O	GHG	NOx
Enteric fermentation (t)	289.90		6087.97	
Manure management (t)	119.87	4.08	3782.14	
Field burning of crop residues (t)	1.46	0.03	39.62	1.05
Animal production (t)		14.59	4521.84	
Direct emissions from Agricultural soils				
Synthetic N fertilisers (t)		6.72	2082.54	
Animal manure used as fertiliser (t)		4.42	1371.74	
Crop residues remaining in soils (t)		0.25	79.01	
Indirect emissions from Agricultural soils				
Atmospheric deposition (t)		2.91	901.36	
Leaching and run-off (t)		13.14	4074.29	
Disposal of human sewage N (t)	*Reported under the sector Waste*			
TOTAL (t)	411.23	46.14	22940.51	1.05

4.4.1 Enteric fermentation

Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The amount of methane that is released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of methane with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). The ruminant gut structure fosters extensive enteric fermentation of their diet.

Methane emissions from enteric fermentation are estimated according to the Tier 1 IPCC methodology (IPCC 2006). The application of this methodology requires livestock population data and emission factors per livestock category. The following equation is applied:

$$EM = \sum_i N_i \cdot EF_i \cdot 10^{-6}$$

where, *EM* is methane emissions (in t), *i* refers to livestock category, N_i is the population per livestock category and EF_i is the emission factor (in gr per head) per livestock category.

Population data were obtained from the NSSG and the emission factors used (with the exception of cattles) are those suggested by 2006 IPCC Guidelines (IPCC 2006) for *Developed Countries*. The emission factor for cattle is related to milk productivity. Following UN Food and Agriculture Organization (FAO) data milk productivity in Greece increased from 2500 kg per head in 1990 to 3650 kg per head in 2007, i.e. moving from an Eastern Europe average (2550 kg per head) to a western Europe average (6000 kg per head). As a result the emission factor used (**Table 4.17**) is an interpolation of the emission factors for Western and Eastern Europe.

Methane emissions are estimated at 289.90 t in 2007.

Table 4.17 Methane emissions (in t) from enteric fermentation in the greater Volos area

Livestock categories	Number of animals (number of heads)	CH_4 emission factor (gr per head)	Emissions (t CH_4)
Dairy cow	1426	95362	135.99
Other cattle	434	57682	25.03
Sheep	8798	55000	70.38
Swine	10951	8000	16.43
Horses	36	1500	0.65
Goats	8285	18000	41.43
Total			289.90

4.4.2 Manure management

Manure management is responsible for methane and nitrous oxide emissions. Methane is produced during the anaerobic decomposition of manure, while nitrous oxide is produced during the storage and treatment of manure before its use as fertilizer.

Methane emissions from manure management were estimated according to the IPCC Tier 1 methodology (IPCC 2006). In accordance with the latest national GHG emissions inventory (MINENV 2009) the methane emission factors used are those of Eastern Europe for dairy cow, other cattle and swine (temperate climate with an average temperature of 17°C) and those of developed countries for the rest of the livestock categories. **Table 4.18** provides an overview of the emission factors used and the methane emissions estimated per livestock category.

Methane emissions are estimated at 119.9 t in 2007.

Table 4.18 Methane emissions (in t) from manure management in the greater Volos area

Livestock categories	Number of animals (number of heads)	CH_4 emission factor (gr per head)	Emissions (t CH_4)
Dairy cow	1426	22000	31.37
Other cattle	434	11000	4.77
Sheep	8798	280	2.46
Swine	10951	7000	76.66
Horses	36	2340	0.08
Poultry	24434	117[11]	2.86
Goats	8285	200	1.66
Total			119.87

[11] 1996 IPCC Guidelines (IPCC 1997)

In order to calculate N_2O emissions from manure management, the default IPCC methodology was used, according to the following equation.

$$E = \left[\sum_S \left(\sum_T \left(N_T \cdot Nex_T \cdot MS_{(T,S)} \right) \right) \cdot EF_S \right] \cdot \frac{44}{28} \cdot 10^{-3}$$

where E is N_2O emissions (in t), T is the livestock category index, S is the manure management system index, $N_{(T)}$ is the livestock population, $Nex_{(T)}$ the annual average nitrogen excretion per livestock category (in kg N per head), $MS_{(T,S)}$ the fraction of total annual excretion for livestock category T that is managed in system S, $EF_{(S)}$ is the N_2O emission factor for system S (in kg N per kg of N excreted).

Values for nitrogen excretion ($Nex_{(T)}$) and N_2O emission factor per management system (**Table 4.19**) are those suggested by the IPCC Guidelines. Especially for N excretion, the values referring to Mediterranean countries were chosen (IPCC 1997). The shares of manure management systems per livestock category are those reported in the latest national GHG emissions inventory (MINENV 2009). Total N_2O emissions from manure management systems are estimated at 4.08 t.

Table 4.19 Nitrogen excretion and manure management systems per livestock category – N_2O emission factors per manure management system

Livestock categories	Manure management systems					Nitrogen excretion (kg N per head)
	Liquid system	Daily spread	Solid storage and dry lot	Pasture range and paddock	Other systems	
Dairy cow		2%	90%	8%		70.0
Other cattle		3%	62%	33%	2%	50.0
Sheep				100%		12.0
Swine	90%		10%			16.0
Horses				100%		40.0
Poultry				72%	28%	0.6
Goats				100%		40.0
Emission factor (kg N / kg Nex)	0.001	0.000	0.020	0.020	0.005	

4.4.3 Field burning of agricultural residues

The generation of crop residues is a result of the farming practices used. Disposal practices for residues include ploughing them back into the ground, composting, landfilling and burning them on-site. Burning of agricultural residues is responsible for emissions of CH_4, N_2O, CO and NOx.

For the estimation of emissions from field burning of agricultural residues, the default methodology suggested in IPCC Guidelines has been applied. In order to calculate the biomass that is burned, the default factors proposed by IPCC (IPCC 2000, IPCC 1997) related to the residues to crop product ratio, the dry matter fraction and the oxidation factor, as well as to the fraction of residues burned were used (**Table 4.20**). The emission factors used are the default ones suggested by IPCC Guidelines (IPCC 1997). The following equations are applied:

$$C = \sum_i PR_i \cdot RCR_i \cdot DM_i \cdot FB_i \cdot OX \cdot CC_i$$

$$E_{CH4} = C \cdot EF_{CH4} \cdot 16/12$$

$$E_{N2O} = C \cdot NCR_i \cdot EF_{N2O} \cdot 44/28$$

$$E_{NOx} = C \cdot NCR_i \cdot EF_{NOx} \cdot 46/14$$

where, *C* is total carbon release (in t), *i* is the crop category index, PR_i is agricultural production (in t), RCR_i is the residue to crop ratio, DM_i is the dry matter of the residue (in t / t), FB_i is the fraction of the residue actually burnt on-site, *OX* is the oxidation factor, CC_i is the carbon content of the dry matter, NCR_i is the nitrogen to carbon ratio and *EF* is the emission ratios for CH_4, N_2O and NOx.

Table 4.20 Agricultural production (in t) from enteric fermentation in the greater Volos area

Crop categories	Production (t)	Residue to crop ratio	Dry matter fraction	Fraction burnt	Oxidation factor	Carbon content	Nitrogen to carbon
Wheat	1708	1.3	0.85	10%	0.9	0.4853	0.012
Barley	168	1.2	0.85			0.4657	0.015
Potato	77	0.4	0.30			0.4226	0.015

The emission ratios used in the calculations are 0.005 for CH_4, 0.007 for N_2O and 0.121 for NOx, while total emissions are estimated at 1.46 t, 0.03 t and 1.05 t respectively.

4.4.4 Agricultural soils

N_2O is produced naturally in soils through the microbial processes of nitrification and denitrification. Agricultural activities add nitrogen to soils, increasing the amount of N_2O released in the atmosphere. Anthropogenic N_2O emissions from agriculture are produced either directly from nitrogen inputs to soils or indirectly, after the removal of nitrogen from soils. The N_2O emissions sources examined are the following:

- Pasture, range and paddock (animal production)
- Direct N_2O emissions
- Indirect N_2O emissions

4.4.4.1 Animal production

The estimation of N_2O emissions from pasture, range and paddock is based on the methodology used for the calculation of N_2O from manure management, using the default factors suggested by IPCC Guidelines (see Paragraph 4.4.2 – Table 4.19). Nitrogen input from pasture, range and paddock and N_2O emissions for 2007 are estimated at 9.28 t and 14.59 t respectively.

4.4.4.2 Direct N_2O emissions for agricultural soils

Direct N2O emissions from agricultural soils derive from:

- The use of synthetic fertilizers
- Animal manure used as fertilizers
- The cultivation of N-fixing crops (not applicable for the greater Volos area)
- Crop residues that remain in soils
- Organic soils cultivation (not applicable for the greater Volos area)

For the estimation of N_2O emissions from **the use of synthetic fertilizers**, Tier 1a methodology suggested by the IPCC Good Practice Guidance (IPCC 2000) was applied.

$$EM = N_{FERT} \cdot (1 - FRAC_{GASF}) \cdot EF \cdot {}^{44}\!/_{28}$$

where, *EM* is N_2O emissions (in t), N_{FERT} is the fertiliser consumption (in t of nitrogen), $FRAC_{GASF}$ is the conversion factor used to account for the part of the nitrogen contained in the fertiliser that is volatised in ammonia and nitrogen oxides (in kg NH_3-N + NOx-N / kg of synthetic fertiliser N applied) and *EF* is the emission factor (in kg N in the form of N_2O / kg N to soil).

The consumption of synthetic fertilizers consumed (in terms of nitrogen contained) in the greater Volos area is estimated at 380 t N. As a part of the nitrogen contained in the fertilizer is volatised in ammonia and nitrogen oxides, the relevant conversion factor suggested by IPCC (0.1 kg NH3-N + NOx-N / kg of synthetic fertiliser N applied) was used (IPCC 1997). The emission factor applied is 0.0125 kg N in the form of N_2O / kg N to soil (IPCC 1997). This emission actor is also applied to the other sources of direct N2O emissions from soils. **N_2O emissions are estimated at 6.72 t**.

The basic methodology was also applied for the estimation of N_2O emissions from **the use of animal manure as a fertilizing agent**.

$$EM = \sum_{T} (N_T \cdot Nex_T) \cdot (1 - FRAC_{GASM}) \cdot [1 - (FRAC_{FUEL-AM} + FRAC_{PRP})] \cdot EF \cdot {}^{44}\!/_{28}$$

where *EM* is N_2O emissions (in t), *T* is the livestock category index, $N_{(T)}$ is the livestock population, $Nex_{(T)}$ the annual average nitrogen excretion per livestock category (in kg N per head), $FRAC_{GASM}$ is the conversion factor used to account for the part of the nitrogen contained in animal manure that is volatised in ammonia and nitrogen oxides (in kg NH_3-N + NOx-N / kg of animal manure N applied), $FRAC_{FUEL-AM}$ is the conversion factor used to account for the part of the manure used as fuel (in kg N/kg N totally excreted), $FRAC_{PRP}$ is the conversion factor used to account for the part of the manure deposited onto soils by grazing livestock (in kg N/kg N totally excreted) and *EF* is the emission factor (in kg N in the form of N_2O / kg N to soil).

Specifically, the total nitrogen excretion from animals is calculated as in the case of manure management (see Table 4.16), and then corrected to account for the fraction that volatises in ammonia and nitrous oxides (0.2 kg NH3-N + NOx-N / kg of N excreted) and the fraction that is deposited in soils through pasture, range and paddock (see Table 4.X2). The fraction used as fuel is equal to zero. **N_2O emissions are estimated at 4.42 t**.

The calculation of N_2O emissions from **crop residues that remain in soils** is based on the application of the following equation (Tier 1b methodology according to IPCC Good Practice Guidance, IPCC 2000):

$$EM = \left[\sum_i \left(PR_i \cdot RCR_i \cdot DM_i \cdot NCR_i \right) \cdot \left(1 - FB_i \right) \right] \cdot EF \cdot 44/28$$

where, *EM* is N_2O emissions (in t), *i* is the crop category index, PR_i is agricultural production (in t), RCR_i is the residue to crop ratio, DM_i is the dry matter of the residue (in t / t), FB_i is the fraction of the residue actually burnt on-site, NCR_i is the nitrogen to carbon ratio and *EF* is the emission factor (in kg N in the form of N_2O / kg N to soil).

All parameters appeared in the above equation have been presented in Table 4.X (see Paragraph 4.4.3). It should be mentioned, that in accordance with the national GHG emissions inventory (MINENV 2009) other uses of crop residues (fuel, fodder and construction) are not considered. **N_2O emissions are estimated at 0.25 t**.

4.4.4.3 Indirect N2O emissions from agricultural soils

Indirect N2O emissions from agricultural soils derive from:

- Volatilisation of nitrogen included in synthetic fertilizers and animal manure (used as fertilizers) as NOx and NH_3, followed by atmospheric deposition as NOx, HNO_3 and NH_4 on soils and surface waters and subsequent N_2O formation.
- Leaching and runoff of nitrogen contained in applied fertilizers (synthetic and animal manure).
- Disposal of human sewage N

For the first two sources of indirect N_2O emissions, the Tier 1a methodology suggested by IPCC Good Practice Guidance has been applied. The activity data on the amount of nitrogen from synthetic fertilizers and animal manure are those used for the calculation of direct emissions. The emission factors used are the default ones suggested by IPCC (IPCC 1997). The emission factor for atmospheric deposition reflects the fraction of nitrogen that volatiles as ammonia and nitrous oxides, while for leaching and runoff it reflects the fraction of nitrogen that leaks from synthetic fertilizers and animal manure.

N2O emissions from human consumption of food and their subsequent treatment through wastewater handling systems are estimated by the following equation:

$$EM = Pop \cdot PR \cdot FRAC_{NPR} \cdot EF \cdot 10^{-3} \cdot 44/28$$

where, *EM* is N_2O emissions (in t), *Pop* is population, *PR* is the annual protein consumption (in kg per capita), $FRAC_{NPR}$ is the nitrogen content of protein and *EF* is the emission factor (in kg N in the form of N_2O / kg N in sewage).

The population of the greater Volos area is 129206 (including overnight staying of tourists). The annual protein is 42.71 kg per capita (as provided by FAO), while for the N content of protein the default value suggest by IPCC is applied (16%, IPCC 1997).

Table 4.21 provides an overview of the emission factors used and the indirect N_2O emissions calculated per source.

Table 4.21 Emission factors and indirect N2O emissions management in the greater Volos area

Source	N2O emission factor	Emissions (t)
Atmospheric deposition	0.01 kg N2O-N/kg NH3-N and NOX–N emitted	2.91
Leaching and run-off	0.025 kg N2O-N/kg N leaching/runoff	13.14
Disposal of human sewage	0.01 kg N2O-N/kg sewage-N produced	12.64
Total		28.69

4.5 Waste

This paragraph includes information on GHG and other gases emissions from the sector *Waste* and a description of the methodologies applied per source for the calculation of emissions. According to the IPCC Guidelines, the following source categories are included in the sector *Waste*:

- Solid waste disposal on land
- Wastewater handling

The calculation of emissions from the sector *Waste* is based on the methodologies and emission factors suggested by the IPCC Guidelines and the IPCC Good Practice Guidance.

Table 4.22 provides an overview of the emissions per source category considered in the sector *Waste*.

Table 4.22 Overview of emissions (in t) from the sector Waste

Source category	CH4	N2O	GHG
Solid waste disposal on land	4486.19		94209.89
Domestic wastewater treatment			
Treatment facilities	16.19	13.87	4641.19
Energy utilisation of biogas produced	Reported under the sector Energy		
TOTAL	4502.38	13.87	98851.08

4.5.1 Solid waste disposal on land

In the greater Volos area a solid waste disposal facility is in operation since 1982. For the period up to 1998 it was actually an uncontrolled dumpsite and since then it is referred as a legal landfill site. The facility covers an area of 24.7 Ha and receives solid waste from 21 municipalities of the Magnesia Prefecture. According to information provided by the local authority responsible for solid waste management (see also **Table 4.23** for the quantities disposed in 2007 and 2008), the facility has:

- received 826784 t of solid waste for the period 1982 – 1998 (dump site) and 1011800 t of solid waste for the period 1999 – 2008 (landfill).
- a remaining capacity of 1.1 Mt of solid waste

Table 4.23 Solid waste disposal on land (in t) for 2007 and 2008

	2007	2008
Domestic	89808.00	97323.00
Industrial		
Steel production	5814.45	7584.33
Other (similar to domestic)	7902.55	8637.67
Sludge from wastewater treatment plant	7044.00	7681.00

Solid waste disposal on land is responsible for methane emissions. Methane is emitted during the anaerobic decomposition of organic waste disposed of in various solid waste disposal sites (SWDS). The main characteristic of this process is that organic waste decomposes at a diminishing rate over time and takes many years to decompose completely. Moreover, other factors such as the type of waste disposed, the characteristics of the disposal sites and the climate conditions, affect the decomposition rate.

The estimation of methane emissions from solid waste disposal on land is based on the application of the First Order Decay (FOD) method that is described by the following set of equations (IPCC 2000):

CH_4 generated at year t: $P_t = \sum_{x=x_0}^{t} \left(A \cdot k \cdot MSW_T(x) \cdot MSW_F(x) \cdot Lo(x) \right) \cdot e^{-k \cdot (t-x)}$

CH_4 emissions at year t: $E_t = (P_t - R_t) \cdot (1 - OX)$

$$Lo(x) = MCF \cdot DOC \cdot DOC_F \cdot F \cdot 16/12$$

where, P_t is methane generation in the year t, E_t is methane emissions in the year t, A is the normalization factor which corrects the summation, k is the methane generation rate constant, MSW_T is the total municipal solid waste (MSW) generated, MSW_F is the fraction of MSW disposed at solid waste disposal sites, Lo(x) is the methane generation potential, R is the recovered CH_4, OX is the oxidation factor, MCF is the methane correction factor, DOC is the degradable organic carbon, DOC_F is the fraction DOC dissimilated and F the fraction by volume of CH_4 in landfill gas.

The application of the FOD method requires historical data of several decades related to the waste generated, their composition over the years, the waste management practices applied and the specific conditions at the sites (e.g. organic matter, humidity, temperature). Therefore, the application of the FOD method was based on assumptions and estimations of certain parameters that could not be calculated analytically.

- The starting year for the application of the FOD method is 1982.
- The product $MSW_T(x)*MSW_F(x)$ represents the amount of solid waste disposed in a site. The estimation of MSW disposed since 1982 is based on the information from the local authority responsible for solid waste management in the greater Volos area;

- Composition of generated / landfilled MSW. Data on the composition of municipal solid waste generated at any spatial level are not systematically available, as a comprehensive analysis covering a complete time period has not been accomplished. However, measurements in some regions have been carried out. **Table 4.24** presents two sets of MSW composition data, one referring at national level for 1997 (MINENV 1998) and one referring to Magnesia Prefecture (presented in the site of the Hellenic Solid Waste Management Association[12]). Since the two data sets are similar, calculations are based to the data referring to Magnesia Prefecture. Additionally, according to the Hellenic Solid Waste Management Association the realisation of recycling programmes in the Prefecture produced minor results. Therefore, it is assumed that the composition of the disposed MSW is similar to the composition of the generated MSW.

Table 4.24 Composition of generated municipal solid waste

MSW category	National Level	Magnesia Prefecture
Putrescibles[13]	47.0%	47.0%
Paper	20.0%	25.0%
Plastics	8.5%	10.0%
Metals	4.5%	3.7%
Glass	4.5%	3.5%
Rest	15.5%	10.8%

- The methane generation rate constant *k* is related to the time taken for the degradable organic carbon in waste to decay to half its initial mass: $k = \ln2 / t_{1/2}$, where $t_{1/2}$ is the time taken for the DOC in waste to decay to half its initial mass ("half life") of waste during degradation process.

  The estimation of *k* is determined by the conditions in the disposal sites (e.g. moisture content, temperature, soil type) and by the composition of waste disposed. Considering that climate in Greece is dry temperate (the ratio of mean annual precipitation to potential evaportranspiration (MAP/PET) is around 0.5), "half life" was estimated at 17 years for paper and 12 years for food waste.

- Methane Correction Factor (*MCF*) is equal to 1 for managed disposal sites (since 1999) and 0.6 for unmanaged disposal sites (1989 – 1998).

- Degradable organic carbon (*DOC*) is 0.4 for paper (default value), 0.15 for food waste (default value) and 0.4 for sewage sludge.

- The fraction of DOC dissimilated (DOC_F) is 0.77 (default value) for solid waste and 0.4 for sewage sludge.

[12] http://volos.eedsa.gr

[13] This category also includes textiles, wood, garden waste, etc.

- The fraction of methane in landfill gas (*F*) is 50% (default value) for solid waste and 60% for sewage sludge.
- The oxidation factor (*OX*) is set to 0 (default value).
- Biogas recovery (for CHP generation) accounts for 3% of the total biogas generated (about 404.000 m^3). The emissions of the cogeneration unit are reported under the sector *Energy*.

Total methane emissions from solid waste disposal on land for 2007 are estimated at 4486.19 t.

4.5.2 Wastewater treatment

A centralized wastewater treatment facility is in operation since 1987 in the greater Volos area. All infrastructure works within the facility has been concluded since 1998. Presently, the facility can serve the needs of 135000 people and can receive up to 32000 m^3 of wastewater (both domestic and pre-treated industrial wastewater). The efficiency of the treatment is more than 90% (97.7% for 2008). **Table 4.25** provides an overview of organic material received by the treatment facility in 2008 (on a monthly basis) as well as the BOD in the input and output stream of the facility.

The sludge generated by the wastewater treatment facility is further treated in anaerobic digesters. Biogas production is estimated at 2400 m^3 per day. The biogas produced is recovered and is fed in a cogeneration unit of an installed capacity of 353 kW (2 gas turbines). Electricity generation is estimated at 1400 MWh.

Table 4.25 Key data of the wastewater treatment in the greater Volos area

Month	Organic load (m^3)	BOD input (mg/lt)	BOD output (mg/lt)
January	793160	603	9
February	750500	432	10
March	819350	364	10
April	847000	381	8
May	843150	487	11
June	786700	301	8
July	782850	372	10
August	754600	304	7
September	803260	279	7
October	878960	342	8
November	778400	424	8
December	868850	317	8

Wastewater as well as its sludge components can produce CH_4 if it degrades anaerobically. The extent of CH_4 production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system. With increases in temperature, the rate of CH_4 production increases.

The calculation of methane emissions from the wastewater treatment facility is based on the application of the following equation (IPCC 2000):

$$EM = \left(\sum_i B_0 \cdot f_i \cdot MCF_i \right) \cdot (TOW - S) - MR$$

where, *EM* is methane emissions from wastewater treatment (in kg), *i* is an index referring to the different wastewater treatment types, *TOW* is total organics in wastewater (in kg BOD), B_0 is the methane generation potential (in kg CH_4 / kg BOD), f_i is the share of wastewater per treatment type, MCF_i is the methane correction factor per treatment type, S is the organic component removed as sludge (in kg BOD) and MR_i is methane recovery (in kg).

Total organics in wastewater are provided by the Municipal Enterprise for Water Supply & Effluent Treatment and Discharge in the greater Volos Area (see Table 4.22). It is assumed that there is no sludge removal to the solid waste disposal site. Two treatment types are considered in the calculations, an anaerobic one applicable to the sludge treatment (21% of total BOD) with a MCF of 0.8 (IPCC 2006) and an aerobic one for the rest of the wastewater with a MCF equal to 0 (IPCC 2006). The methane generation potential (B_0) is 0.6 kg CH_4 / kg BOD (developed countries, IPCC 2006).

Methane recovery is equal to the methane consumed (as sludge biogas) in the cogeneration unit. The operation of the unit (for the production of 1400 MWh) requires the consumption of about 800000 m^3 biogas with a methane content of 60% (MINENV 2009). Therefore methane consumption (i.e. methane recovery) is estimated at 333 t (assuming a density of 0.7 kg/m^3).

Total methane emissions from wastewater treatment are estimated at 16.19 t.

The estimation of emissions from the operation of the cogeneration unit is presented in **Table 4.26**. It should be mentioned that CO_2 emissions are not estimated as they are of biogenic origin. Emission factors derive from IPCC (Tier 1 methodology for Stationary Combustion, IPCC 2000) for the GHG and from CORINAIR for the rest of the gases considered. The estimated emissions are reported under the sector *Energy*.

Table 4.26 Estimation of emissions (in kg) from biogas consumption in the cogeneration unit

	CH_4	N_2O	NOx	SO_2	NMVOC	PM10
Emission factor (kg/TJ)	1.0	0.1	60.0	0.0	2.5	5.7
Emissions (kg)	16.80	1.68	1008.0	0.0	42.0	95.76

5 Remarks

Climate change is already happening and represents one of the greatest environmental, social and economic threats facing the planet. Combating climate change requires the active participation of governments, enterprises, citizens. The discussion on what needs to be done with respect to climate change mitigation after 2012 and by what actions and means ambitious GHG emissions reduction targets can be achieved is underway. In this context, the role of local authorities that in many cases remain passive, waiting to see first what will be the new national reduction targets is twofold.

- Decisions affecting future GHG emissions are taken at present establishing local infrastructures with a long lifetime, which will not be altered soon once created.
- Appropriate policies decided at central level require in most cases the participation of local communities for an efficient implementation (e.g. energy conservation in buildings) or at least their consensus (e.g. exploitation of wind energy at a large scale).

At the same time, local authorities are faced with a lack of systematic approaches, methodologies and tools which can assist them in investigating, assessing and realizing their local potential with respect to GHG emissions reductions. Although some tools may exist at national level, these require several adjustments so that they can be used at local scale. Annual inventories of greenhouse and other gases emissions form an essential element of the environmental policy-making process at any administrative level. They can be used to derive information on emissions trends, with reference to a pre-selected base year, and can assist in monitoring the progress of existing abatement measures for the reduction of greenhouse gases emissions.

Action 1 of the CLIM-LOCAL2020 project (entitled *Calculation of present local GHG emissions*) aims at the calculation of present GHG emissions generated from stationary and mobile emission sources operating in the administrative area of the Municipality of Volos, as well as from neighbouring areas that form part of the greater Volos area. The outcome of Action 1 (together wit the results of Action 2) will provide the basis for the identification of possible policies and measures to be defined at local level as well as the quantification of their expected effect.

The main results of Action 1 can be summarized to the following.

- Total GHG emissions at the greater Volos area for 2007 are estimated at 4567.89 kt, representing 3.5% of total GHG emissions at national level (excluding Land Use, Land Use Change and Forestry, LULUCF).
- Emissions estimates are dominated (in the cases of GHG and PM10 emissions) by industrial installations participating in the EU-ETS as they account of 84% of total GHG emissions in the greater Volos area.
- Indirect emissions associated with electricity consumption in all sectors represent a significant part of total emissions as they account for 22% of total GHG emissions, 28% of total NOx emissions, 84% of total SO_2 emissions, 8% of total NMVOC emissions and 34% of total PM10 emissions.

- If both indirect emissions from electricity consumption and emissions from installations participating in the EU-ETS are excluded from totals, then GHG emissions are estimated at 395.5 kt CO_2 eq.

The emissions inventory compiled provides a first hint of the priorities for the policies and measures to be defined at local level.

- GHG emissions of EU-ETS installations though dominating local emissions cannot be considered for the formulation of local policies and measures as they are regulated by the emissions trading directive.
- Local authorities do not have the means to significantly affect the electricity generation mix. However, electricity conservation would result in GHG and other gases emissions reductions and could have a positive economic effect for the consumers.
- Local authorities are responsible for the operation of installations, buildings, etc. that account for about 25% of total GHG emissions, excluding indirect emissions from electricity consumption as well as emissions from EU-ETS units. Policies and measures to be developed should deal with this part of emissions.
- The residential sector together with urban transportation of local population account for 50% of total GHG emissions, excluding indirect emissions from electricity consumption as well as emissions from EU-ETS units. It is clear that a local action plan for climate change mitigation should, at least, address this part of emissions by means of awareness campaigns and the provision of information to the population regarding potential mitigation measures. In addition, transportation-related interventions implemented by local authorities need to consider climate change as a design parameter.

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