Interreg - IPA CBC
Greece - Republic of North Macedonia
TRAP

DELIVERABLE 3.1.2 Development of Regional Emission Inventory of Regional Unit of Florina, Greece

TRAP

Transboundary Air Pollution Health Index Development and Implementation

July 2020

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Acknowledgments

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1. INTRODUCTION

1.1 Project Overview

Information on real time air pollution levels is now more necessary than ever before. At present, air pollution is one of the most significant factors posing threat to the health of individuals worldwide. It is associated with a range of diseases, symptoms and conditions that impair health and quality of human life. According to the WHO, outdoor air pollution was responsible for the deaths of some 3.7 million people under the age 60 around the world in 2012, representing 6.7% of the global disease burden while outdoor air pollution combined are among the largest risks to health worldwide. Apart from habitants, air quality impacts natural environment and biodiversity. The main sources of air pollution at both countries are mainly caused by industrial activities, transportation and heating.

Air Pollution has been recognized as of the most pressing problems in both Greece and the Republic of North Macedonia, following the economic and social development of the two countries the sources of air pollution are mainly industrial activities, transport and central heating. The major challenges of transport in urban areas are the rising number of vehicles, their increased average age and traffic congestion. Air quality problems from industrial sources mainly concern areas with thermo-electrical power stations and industrial units located close to residential areas. Air quality is strongly influenced by pollutants trapped due to thermal inversions caused by from land local breezes and thermal internal boundary layers.

Identification of the emission sources and development of regional and TRAP developed on the necessity for developing ICT applications in environmental protection, monitoring and management of the eligible areas. Environmental initiatives is a privileged field for developing cooperation in the cross-border area contributing significantly to economic and social development of the population and public health, therefore, the opportunity for mutual cooperation and understanding between public authorities, scientific institutions and residents of the area. The major challenge is the development of an integrated approach including air quality monitoring with providing health indicator for vulnerable groups of the population.

TRAP project addresses a series of issues, such as:

- CB emission for vulnerable groups of the population

- Assessment of each emission source
- Development of air quality plans
- Monitoring data, validation and analysis
- Basic demographic, health and public health profile
- Air quality and Health Indicators
- Joint CB comparative analysis
- Capacity Building at user level (Health and authority stakeholders)
- Air quality and health sensitization campaigns
- Protection of human health
- Citizen involvement
- Implementation of air quality directives

Partners aim to improve management and protection of areas in both countries by establishing air quality monitoring networks. The measurements of all station in areas involved in this project will create a system that will display real-time measurements through the internet. Moreover, epidemiological indicators and indicators of air quality, based on the effects of air pollution on human health, will be calculated and displayed on the web. The best way for someone to use an Air Pollution Health Indicator (APHI) is to regularly check the current index value, to pay attention to personal symptoms and self –calibrate to personal symptoms and self-calibrate to the report current APHI value. Therefore, the strategic objective of TRAP project is the creation of an ICT application integrating Air Quality Monitoring with Air Pollution Health Indicator) (APHI) in CB area.

The specific sub-objectives of the project are to:

- Develop and evaluate emission inventories at partner areas
- Assess the health risk related to air quality measurements
- Create integrated ICT tool including air quality information correlated to possible health impacts and providing emergency mechanism to policy makers and vulnerable groups
- Evaluate the CB conditions regarding air quality and transported pollution in CB areas
- Engage relevant stakeholders to inform them on the created tool operation and indexes
- Disseminate and communicate the project results to key stakeholders as well as to the general public and vulnerable groups

TRAP project results will positively affect and contribute to the programmes' result indicator for ecosystems with improved protection status for the eligible areas of Florina, Bitola and Gevgelija where the monitoring stations will be placed. The innovative character of TRAP is served by its approach that favours the interaction and exchange of ideas as well as the knowledge diffusion and integration among the targeted stakeholders. Many of the project activities will be jointly implemented creating unified framework for problem resolutions and providing added value to the CB area as a total. The expected results are focused on the development of an ICT tool for better air quality monitoring in CB area integrated with Air pollution Health Indicator.

1.2 Purpose of this deliverable

Emissions and releases to the environment are the starting point of every environmental pollution problem. Information on emissions therefore is an absolute requirement in understanding environmental problems and in monitoring progress towards solving these. Emission inventories provide this type of information.

Emission inventories are developed for a variety of purposes[1]:

- **Policy use**: by policy makers to
  - track progress towards emission reduction targets
  - develop strategies and policies or
- **Scientific use**: Inventories of natural and anthropogenic emissions are used by scientists as inputs to air quality models

Two more or less independent types of emission reporting schemes have been developed:

- Annual reporting of national total emissions of greenhouse gases and air pollutants in response to obligations under international conventions and protocols; this type of emissions reporting aims at monitoring the progress towards agreed national emission reduction targets;
- Regular emission reporting by individual industrial facilities in response to legal obligations; this type of emission reporting is developed to support public participation in decision-making.

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[1] https://en.wikipedia.org/wiki/Emission_inventory

Governments[2] use emission inventories to help determine significant sources of air pollutants and to target regulatory actions. Emissions inventories are an essential input to mathematical models that estimate air quality. The effect on air quality of potential regulatory actions can be predicted by applying estimated emissions reductions to emissions inventory data in air quality models.

Emission trends over time can be established with periodic updates of the emissions inventory. Inventories also can be used to raise public awareness regarding sources of pollution.

An emissions inventory includes estimates of the emissions from various pollution sources in a geographical area. It should include all pollutants associated with the air quality problems in the area. For example, an emissions inventory to support the management of ground-level ozone should include sources of nitrogen oxides (NOx) and of volatile organic compounds (VOC).

1.3 Emissions and emissions inventories[3]

Substances emitted into the atmosphere by human and natural activities are the cause of many current and potential environmental problems, including :

- acidification
- air quality degradation
- global warming/climate change
- damage and soiling of buildings and other structures
- stratospheric ozone depletion
- human and ecosystem exposure to hazardous substances.

It is necessary to have quantitative information on these emissions and their sources in order to help:

- inform the policy makers and the public
- define environmental priorities and identify the activities and actors responsible for the problems

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[2] *https://www.epa.gov/air-quality-management-process/managing-air-quality-emissions-inventories*

[3] *https://www.eea.europa.eu/publications/EMEPCORINAIR/page005.html*

- set explicit objectives and constraints
- assess the potential environmental impacts and implications of different strategies and plans
- evaluate the environmental costs and benefits of different policies
- monitor the state of the environment to check that targets are being achieved
- monitor policy action to ensure that it is having the desired effects
- ensure that those responsible for implementing the policies are complying with their obligations.

There are many types of sources of atmospheric emissions and many examples (often millions) of each type, for example :

- power plants
- refineries
- incinerators
- factories
- domestic households
- cars and other vehicles
- animals and humans
- fossil fuel extraction and production sites
- offices and public buildings
- trees and other vegetation
- distribution pipelines
- fertilised land
- land with biological decay.

It is not possible to measure emissions from all of the individual examples of these sources or, in the short term, from all the different source types. In practice, atmospheric emissions are estimated on the basis of measurements made at selected or representative samples of the (main) sources and source types.

The basic model for an emission estimate is the product of (at least) two variables, for example:

- an activity statistic and a typical average emission factor for the activity, or

- an emission measurement over a period of time and the number of such periods emissions occurred in the required estimation period.

For example, to estimate annual emissions of sulphur dioxide in grams per year from an oil-fired power plant you might use, either:

- annual fuel consumption (in tonnes fuel/year) and an emission factor (in grams SO_2 emitted/tonne fuel consumed), or
- measured SO_2 emissions (in grams per hour) and number of operating hours per year.

In practice, the calculations tend to more complicated but the principles remain the same. Emission estimates are collected together into inventories or databases which usually also contain supporting data on, for example: the locations of the sources of emissions; emission measurements where available; emission factors; capacity, production or activity rates in the various source sectors; operating conditions; methods of measurement or estimation, etc. Emission inventories may contain data on three types of source, namely point, area and line. However, in some inventories all of the data may be on area basis - region, country, sub-region etc.

Point sources - emission estimates are provided on an individual plant or emission outlet (usually large) usually in conjunction with data on location, capacity or throughput, operating conditions etc. The tendency is for more sources to be provided as point sources as legislative requirements extend to more source types and pollutants as well as more openness provides more such relevant data.

Area sources - smaller or more diffuse sources of pollution are provided on am area basis either for administrative areas, such as counties, regions etc, or for regular grids (for example the EMEP 50x50 km grid).

Line sources - in some inventories, vehicle emissions from road transport, railways, inland navigation, shipping or aviation etc are provided for sections along the line of the road, railway-track, sea-lane etc.

1.4 Methodology

The technical guidance to prepare the atmospheric emission inventory for the Regional Unit of Florina comes from the joint EMEP/EEA air pollutant emission inventory guidebook 2019. The Guidebook is published by the EEA with the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) Task Force on Emission Inventories and Projections responsible for the technical content of the chapters. The only exception was in the case of methane calculation coming from lignite mines, where the methodology used was the “2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines”. The methodology followed for each source category in given in Table 1.

The corresponding chapters of the Guidebook followed for the calculation of each emission source is given in the table below. Tier 1 approach was used for all source types based on the available data for the Regional Unit of Florina. The decision tree for each source category is presented in all chapters.

Table 1 Methodology used for each source type

EMISSION SOURCES			**Relative chapter of the joint EMEP/EEA air pollutant emission inventory guidebook 2019[4]**
INDUSTRY	Quarrying	Emissions from Quartz extraction	2.A.5.a Quarrying and mining of minerals other than coal
		Emissions from Inert materials extraction (sand, gravel etc for concrete preparation)	2.A.5.a Quarrying and mining of minerals other than coal

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[4] The only exception is for methane calculation from lignite mines, where the methodology used was the “2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines”

	Lime production	Process Emissions	2.A.2 Lime production
	Pulp and paper production		2.H.1 Pulp and paper industry
	Food and beverages	Process emissions	2.H.2 Food and beverages industry
ENERGY PRODUCTION	Lignite mines	NMVOCs and PM	1.B.1.a Fugitive emissions from solid fuels: coal mining and handling
		Methane CH_4	***Chapter 4: Fugitive Emissions of the "2006 IPCC Guidelines for National Greenhouse Gas Inventories"***
	Lignite-fired plants		1.A.1.a Public electricity and heat production
TRANSPORTATION	Emissions PCs		1.A.3.b.i-iv Road transport
	Emissions from LCVs		1.A.3.b.i-iv Road transport
	Emissions from HDV		1.A.3.b.i-iv Road transport
	Emissions from L-category vehicles		1.A.3.b.i-iv Road transport
RESIDENTIAL BUILDING HEATING	Emission from biomass (firewood, pellet)		1.A.4 Small combustion
	Emission from lignite (mainly used in village houses)		1.A.4 Small combustion
AGRICULTURE	NH3 and NO from crop production and agricultural soils		3.D Crop production and agricultural soils
	NMVOCs and PMs from crop		3.D Crop production and agricultural soils

	production and agricultural soils		
LIVESTOCK			3.B Manure management

2. MAIN CHARACTERISTICS OF THE TARGET AREA

2.1 Background information for the Regional Unit of Florina

The Region of Western Macedonia (see Map 1) covers a total surface of 9,451 km^2, 7.2% of country's total. The Region of Western Macedonia is situated in the northern part of Greece and borders with Albania and North Macedonia. The lake of Big Prespa is the meeting point of three countries, the tri-national and it is the only Greek Region without a maritime coastline. Western Macedonia is divided into the regional units of **Grevena, Kastoria, Kozani** and **Florina.**

Map 1 Region of Western Macedonia and Regional Unit of Florina

Florina was created as a prefecture in 1915. As a part of the 2011 Kallikratis government reform, the regional unit Florina was created out of the former prefecture Florina. The prefecture had the same territory as the present regional unit. At the same time, the municipalities were reorganised. Florina's Regional Unit borders with North Macedonia, Albania and within Greece with Pella, Kastoria and Kozani (see Map 2). The Regional Unit of Florina has a population of 51,414 (National Statistical Authority, 2011) and covers an area of

1,924 km^2 (https://florina.pdm.gov.gr). Around 74% of the Unit's area is covered by mountainous or semi mountainous areas whereas only 26% consists of lowland areas.

Map 2 Western Macedonia Region[5]

2.2 Land use

A total of 534 km^2 are cultivated areas and fallow lands meaning a 27.26% of the total percentage. Moreover, 700 km^2 are pasture areas with 79.85% being public and 20.15% private. Additionally, 6.06% of the unit's area is covered with waters, 25.88% are forestlands and 2.08% is built settlements. The productive character of the area is still determined by the energy industry; however, the virgin and still underexplored landscapes provide a fruitful ground for tourism to develop. The Region is the house of 6 NATURA protected lakes and mountains as well as significant wildlife.

2.3 Financial characteristics

As aforementioned, the population of Florina's Unit is 54,571 whereas 50.9% are male and 49.1% female. Out of the total population 18,880 are financially active, whereas approximately 88% are employed and 12% unemployed. Out of the unemployed percentage

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[5] *Source: https://www.pdm.gov.gr/periferia/chorika-oria/geografiki-armodiotita*

of the population of Florina, more than half of them (52,12%) belong to the 18-28 age group. Finally, out of the total financially active population, 41% are self-employed, 39% full time employees and 20% part-time employees. Moreover, 33.25% are employed under agriculture, fishery, stock raising, etc, whereas the majority of those (77%) are self-employed. Additionally, trade, repairs, hotels and restaurants are 10.38% of the total percentage, whereas construction is 7.35%, manufacturing services 6.25% and transportation, storage and telecommunications 4.06%. Finally, energy and water services are 2.54% and quarries and mines 1.40% and financial organisation 0.88%.

2.4 Sectors of economy

The regional unit has mainly agricultural and stock raising activities through small family businesses as well as logging which is of low productivity and does not contribute to the formation of a satisfactory agricultural income. Florina is the most agricultural unit of the region of Western Macedonia while main agricultural activities at 50% of overall activities are livestock food. Moreover, cultivation of grain is significant for the area as well as beans cultivation mostly in the Prespes area which is a protected designation of origin product as well as viticulture in Amyntaio producing exquisite products. Other cultivation activities stand in sugar beets, potatoes and tree crops as well. The larger area of Prespes houses mild fishing activities as well. In the livestock sector, the study area includes almost all agricultural livestock. Sheep, goats and dairy cows predominate. Regarding the secondary sector, energy productions is the dominant activity with multiple energy stations operating the wider area. Finally, tertiary sector covers the most financial activities of the unit mainly due to the urban areas of Florina and Amyntaio showcasing development of trade, health, education, sports, tourism and cultural activities. The city of Florina remains the major business hub in the Regional Unit and the wider area.

2.5 Transportation connections

Map 3 illustrates the major road connections in Northern Greece (Csil, 2012).

Map 3 Road Infrastructure of Northern Greece[6]

More specifically for the greater area of Florina, the Egnatia motorway which is a high-speed four-lane motorway with a length of 670 km and a width of 24.5 m is the most crucial motorway since it improves accessibility to and from the area to the rest of North Greece. From its starting point at Igoumenitsa (Epirus Region), the Egnatia motorway runs through five Greek regions: East Macedonia & Thrace, Central Macedonia, West Macedonia, Epirus and Thessaly. The Egnatia motorway is connected to the rest of Greece via the PATHE motorway and the Western axis of the Ionian motorway. Moreover, the main roads of Florina regional unit are Greek National Road 2 (Albania - Krystallopigi - Florina) and Greek National Road 3 (North Macedonia - Niki - Florina - Amyntaio). The main railway axis (see Map 4) in the area is the Thessaloniki–Bitola railway which runs through the regional unit, as of 2014 used by passenger trains between Florina and Thessaloniki. Finally, no available airport is located in the area and thus no air transportation is available at this time nor foreseen for the future.

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[6] *Source: https://ec.europa.eu/regional_policy/sources/docgener/evaluation/pdf/projects/egnatia_motorway.pdf*

Map 4 Railway axis Source: Trail Organisation of Greece

2.6 Climate

The climate of the Regional Unit of Florina is affected by the geographical position and altitude of the area, combined with the large mountains and the presence of lakes in Prespes and in Amyntaio. The climate is purely continental, with cold winters, snow and rainfall and an average annual temperature of 12,1° C. We have to note that there is a perceptible difference between the three uplands of Amyntaio, Florina and Prespes.

Throughout the year, in Florina, there are 116.3 rainfall days, and 645.7mm of precipitation is accumulated. In August rain falls for 5.8 days and accumulates 31mm of precipitation. The month with the most rainfall is December when the rain falls for 12.9 days and typically aggregates up to 86.2mm of precipitation (see Figure 1 and 2).

Not only is precipitation plentiful but it is also reliable and frequent. Fog is common in autumn and winter, but thunderstorms are infrequent. Strong gales with high winds may be encountered in winter.

Figure 1 Rainfall mean by month[7]

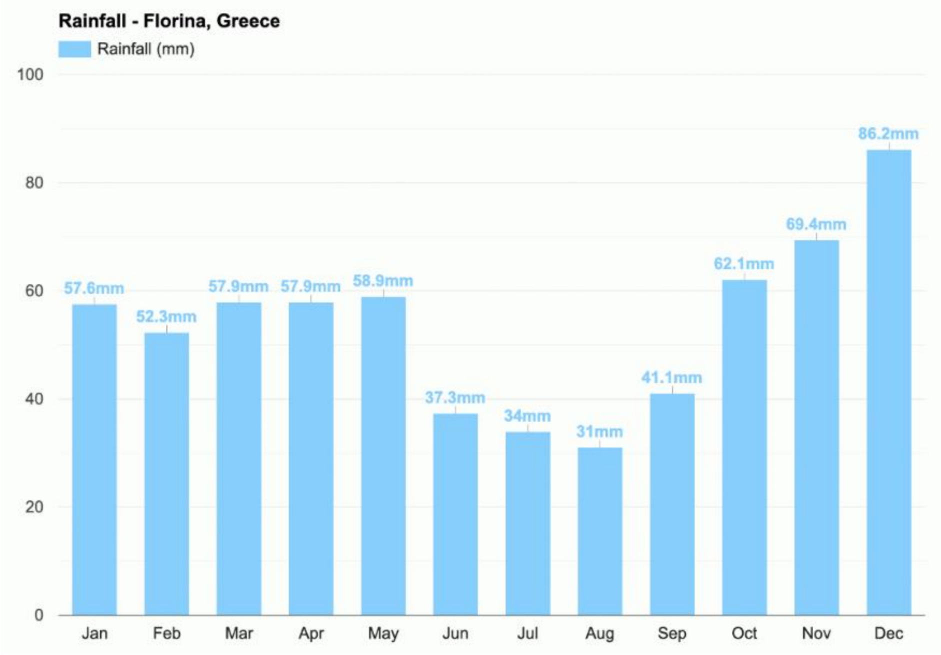
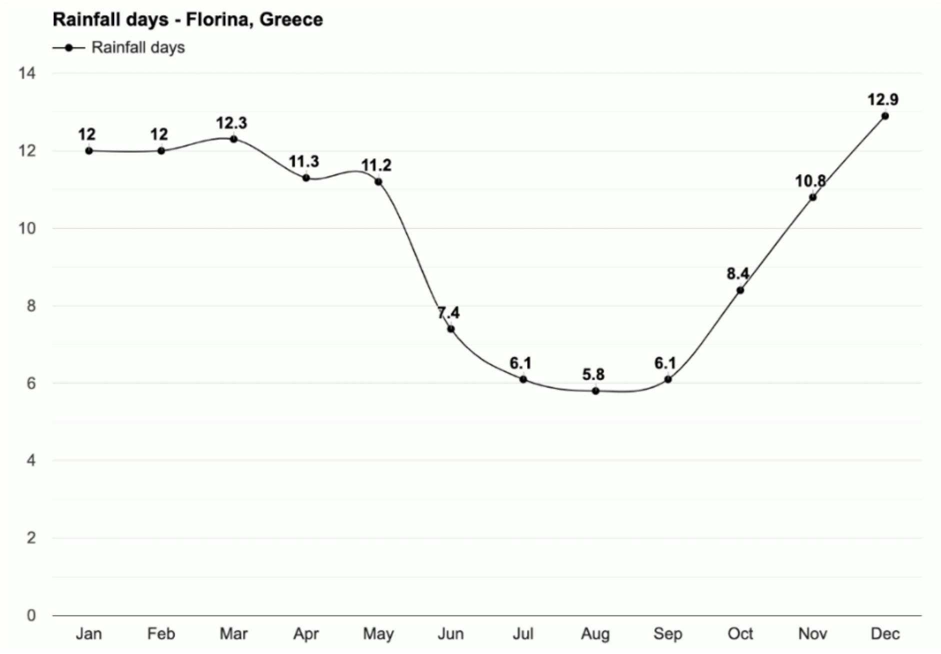


Figure 2 Rainy days[8]



Months with snowfall in Florina are January through May and October through December. Throughout the year, there are 27.2 snowfall days in Florina. January is the month with the most snowfall days with approximate 7.5 days of snowfall (see Figure 3).

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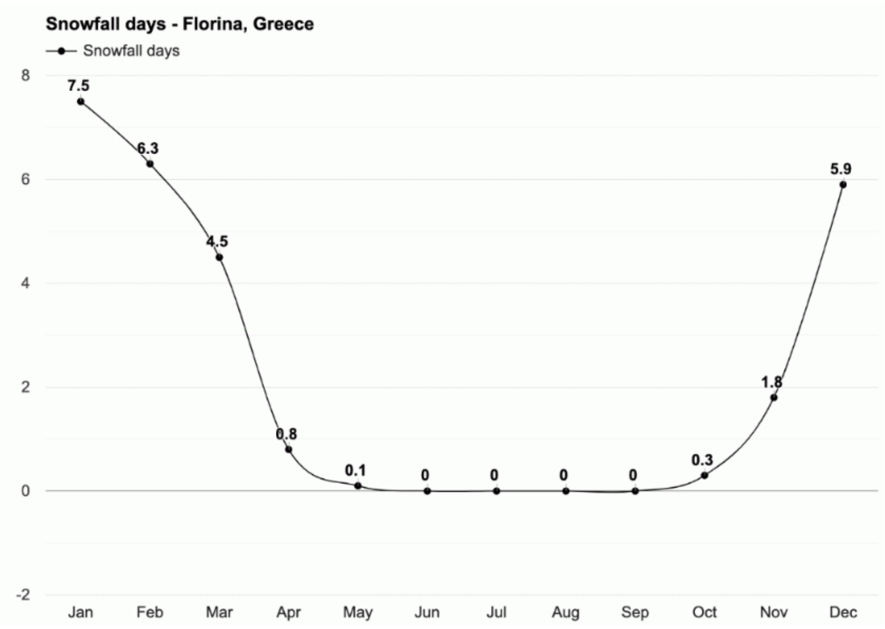
[7] *Source: https://www.weatherbase.com/weather/weather-summary.php3?s=592007&cityname=Florina,+Greece*

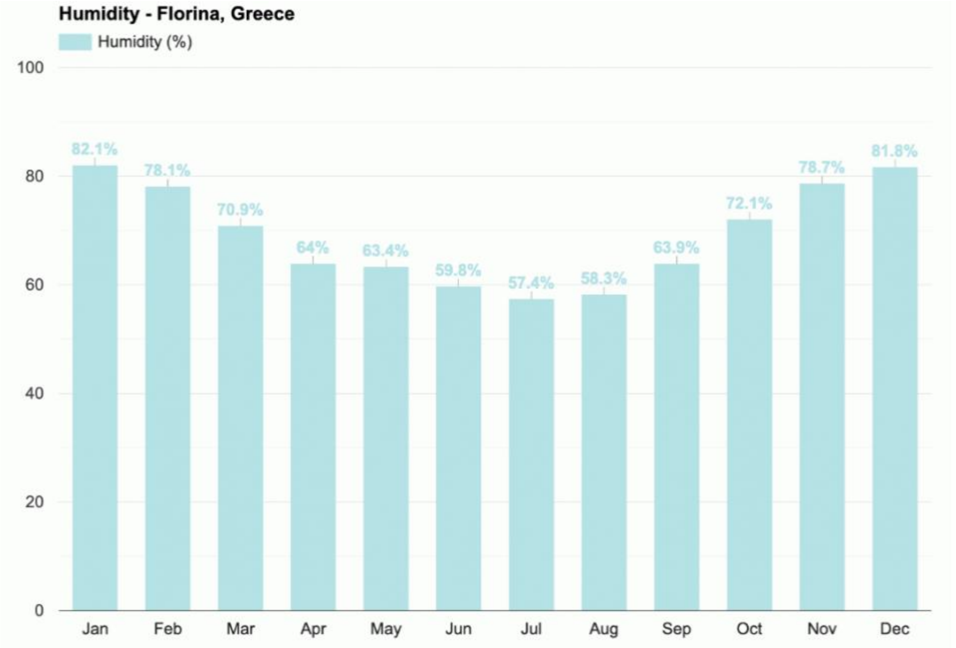
[8] *Source: https://www.weatherbase.com/weather/weather-summary.php3?s=592007&cityname=Florina,+Greece*

Figure 3 Snowfall days[9]



The months with higher monthly mean humidity in Florina are November to February ranging from 78% to 82% humidity while during summer months and more specifically June, July and August humidity falls down to 57% to 59% (see Figure 4).

Figure 4 Monthly Mean Humidity[10]



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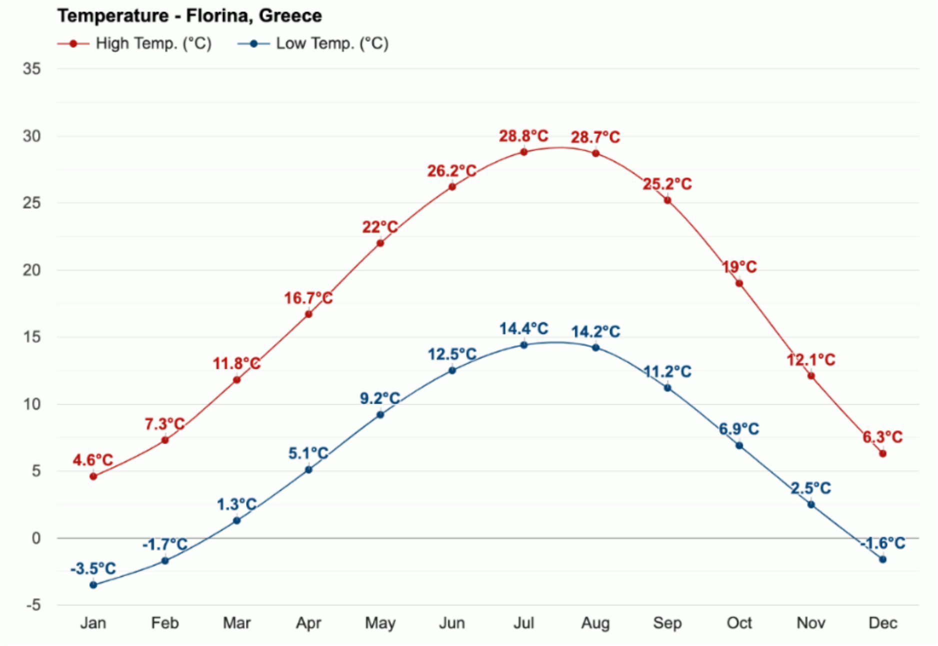
[9] *Source:* https://www.weatherbase.com/weather/weather-summary.php3?s=592007&cityname=Florina,+Greece

[10] *Source:* https://www.weatherbase.com/weather/weather-summary.php3?s=592007&cityname=Florina,+Greece

The coldest month is January, with an average high-temperature of 4.6°C and an average low-temperature of -3.5°C. July is the warmest month in Florina, with an average high-temperature of 28.8°C and an average low-temperature of 14.4°C (see Figure 5).

Figure 5 Average temperature per month[11]



2.7 Air pollution in the area

The Regional Unit of Florina is located in the Region of Western Macedonia that is the main production center of electrical power of the whole country. Consequently, numerous lignite mines as well as several power plants using lignite fuel lie within the Regional Unit or in the adjacent units.

Additionally, in near distance, a few kilometres away from the borders, there is a power plant and two lignite mines of North Macedonia. In a study from AUTH, Repatsis ''Body pollution in Florina's region'' through the analysis of data derived from the PPC S.A. (Public Power Corporation S.A. / largest national & private-owned power generator in Greece) between the years 2009-2013 they found that each year the area was largely exceeding the allowed PM_{10} emissions of an average around 35% more than the EU standard. Following table 2 presents detailed data for the analysed timespan.

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[11] *Source:* https://www.weatherbase.com/weather/weather-summary.php3?s=592007&cityname=Florina,+Greece

Table 2 Number of days exceeding PM_{10} limit[12]

Year	Number of days exceeding PM10 limit	Days with data	Percentage
2009	123	262	46.9
2010	237	365	64.9
2011	116	355	32.7
2012	96	366	26.2
2013	114	365	31.2

According to the EU regulation the allowed number of days exceeding PM_{10} limits are 35 per year. In Florina’s case the unit has exceeded permissible limits consistently. In conclusion, there is a considerable particle pollution problem as there are often high concentrations observed. According to Repatsis et. Al, 2015, quite high concentrations were observed during the winter period when temperatures are low. The most likely cause is due to emissions of building’s heating, which is achieved with oil boilers, wood chip boilers, wood stoves and fireplaces that have resulted in the creation of many sources of suspended particles in the city.

However, the overall plan of PPC S.A. and of the Greek government is to complete the process of closing all lignite mining within the next years (see section 4.1 “Public Power Corporation” activity in the area). According to KEPE and Waqi, existing conditions are considered good in terms of pollutants’ concentration. Map 5 and Map 6 show existing air pollution conditions in the wider area surrounding Florina’s regional unit.

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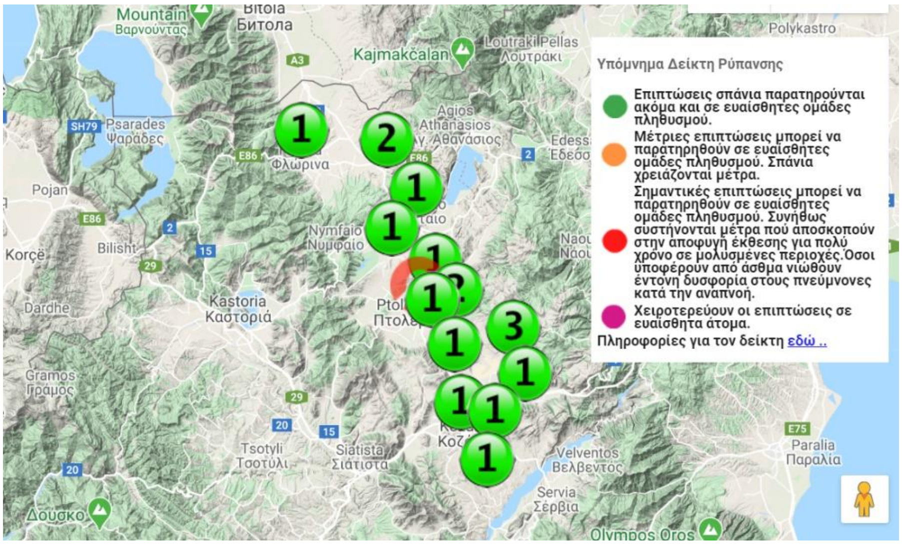
[12] *Source: Repatsis, 2015*

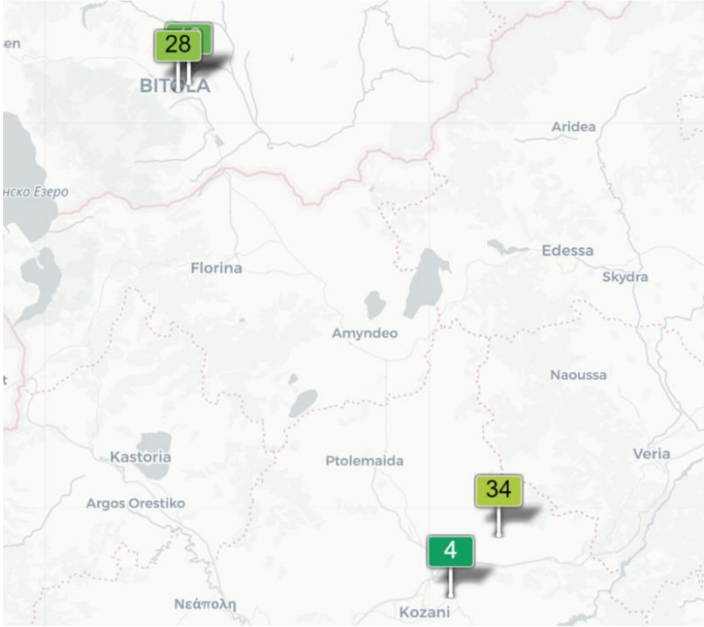
Map 5 Air pollution conditions through Western Macedonia[13]


Υπόμνημα Δείκτη Ρύπανσης

- 🟢 Επιπτώσεις σπάνια παρατηρούνται ακόμα και σε ευαίσθητες ομάδες πληθυσμού.
- 🟠 Μέτριες επιπτώσεις μπορεί να παρατηρηθούν σε ευαίσθητες ομάδες πληθυσμού. Σπάνια χρειάζονται μέτρα.
- 🔴 Σημαντικές επιπτώσεις μπορεί να παρατηρηθούν σε ευαίσθητες ομάδες πληθυσμού. Συνήθως συστήνονται μέτρα πού αποσκοπούν στην αποφυγή έκθεσης για πολύ χρόνο σε μολυσμένες περιοχές.Όσοι υποφέρουν από άσθμα νιώθουν έντονη δυσφορία στους πνεύμονες κατά την αναπνοή.
- 🟣 Χειροτερεύουν οι επιπτώσεις σε ευαίσθητα άτομα.

Πληροφορίες για τον δείκτη εδώ ..

Map 6 Air pollution condition in North Macedonia and Western Macedonia[14]



Finally, main emissions of NO_x are emitted by energy production, carbon and lignite, as well as different transportation modes. In Map 7 it is obvious that the maximum values of NO_x

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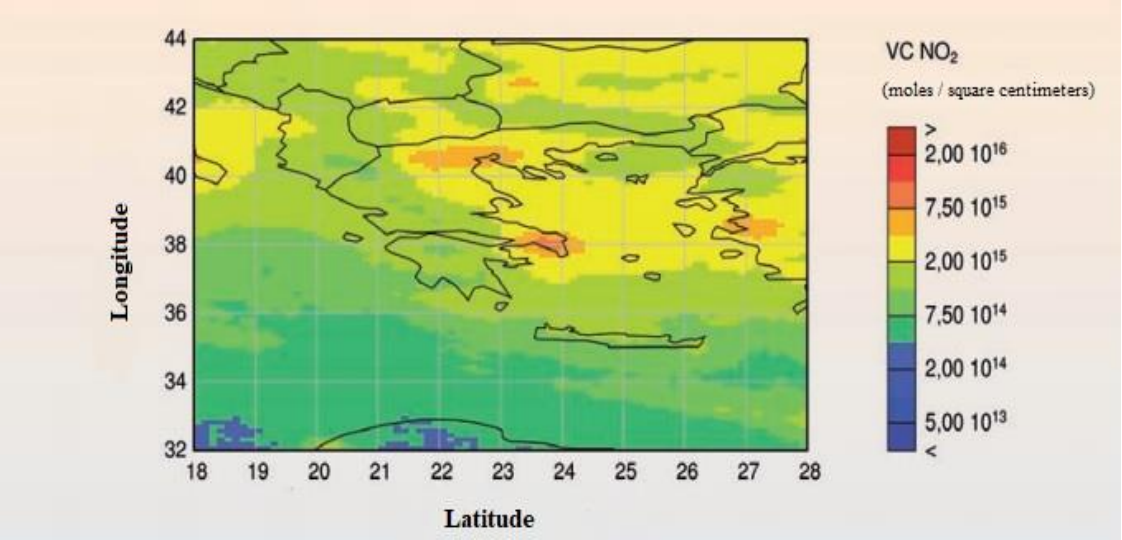
[13] *Source: http://www.kepekozani.gr/*

[14] *Source: http://www.waqi.info/#/c/40.722/21.469/9.2z*

concentration in Greece are in the area of Athens and in Central Makedonia (Thessaloniki / Ptolemaida).

Map 7 Emissions of NO_2[15]



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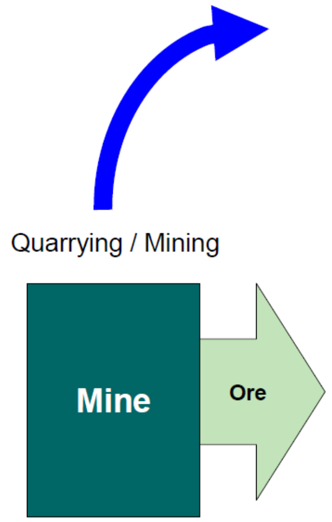
[15] *Source: Bank of Greece, 2011*

3. EMISSIONS FROM INDUSTRY

3.1 Quarrying

Emissions from non-coal quarrying and mining includes mainly dust and particulate matter. Depending on national circumstances, emissions from quarrying can be significant and contribute sizable amounts to the national total of TSP, PM_{10} and $PM_{2.5}$. Emissions of other pollutants are considered insignificant; however, this judgement could change in light of e.g. ore mining in some countries where heavy metals might be emitted. A simple process scheme is given in Figure 6.

Figure 6 A simple process scheme for source category 2.A.5.a Quarrying and mining of minerals other than coal



The Tier 1 approach for quarrying and mining of minerals other than coal uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant}$$

Where:

$E_{pollutant}$ = the emission of the specified pollutant

$AR_{production}$ = the activity rate for the quarrying/mining

$EF_{pollutant}$ = the emission factor for this pollutant

The Tier 1 emission factors assume worst-case, old technology and little to no abatement implementation in the country and integrate all sub-processes (see Table 3).

Table 3 Tier 1 emission factors for source category 2.A.5.a Quarrying and mining of minerals other than coal

Pollutant	Emission factor (g/Mg mineral)
TSP	102
PM_{10}	50
$PM_{2.5}$	5.0

As described in detail in Deliverable 3.3.1, there are two industries in the Regional Unit of Florina that exploit mines for inert materials such as sand, gravel, crashed rocks (to be used for the preparation of concrete) and one that extracts quartz (mineral ore). The total annual production is given in Table 4.

Table 4 Calculation of Activity Rate for the quartz & «sand, gravel, crashed rocks» quarries in the Regional Unit of Florina

Industry	Annual production of material (in tonnes)
METE A.E	63,000 tonnes of quartz in 2019
ERGON ATTEBE	163,572 tonnes of inert material (sand, gravel, crashed rocks) in 2019
Latomeia Ag. Panteleimona	35,000 tonnes of inert material (sand, gravel, crashed rocks) in 2019 (20 days of activity in the whole year)
Total annual production from quarrying and mining of minerals other than coal & lime in the Regional unit of Florina	261,572 tonnes (activity rate)

The final emissions are given in Table 5 below.

Table 5 Calculation of emissions for each pollutant by the quartz & «sand, gravel, crashed rocks» quarries in the Regional Unit of Florina.

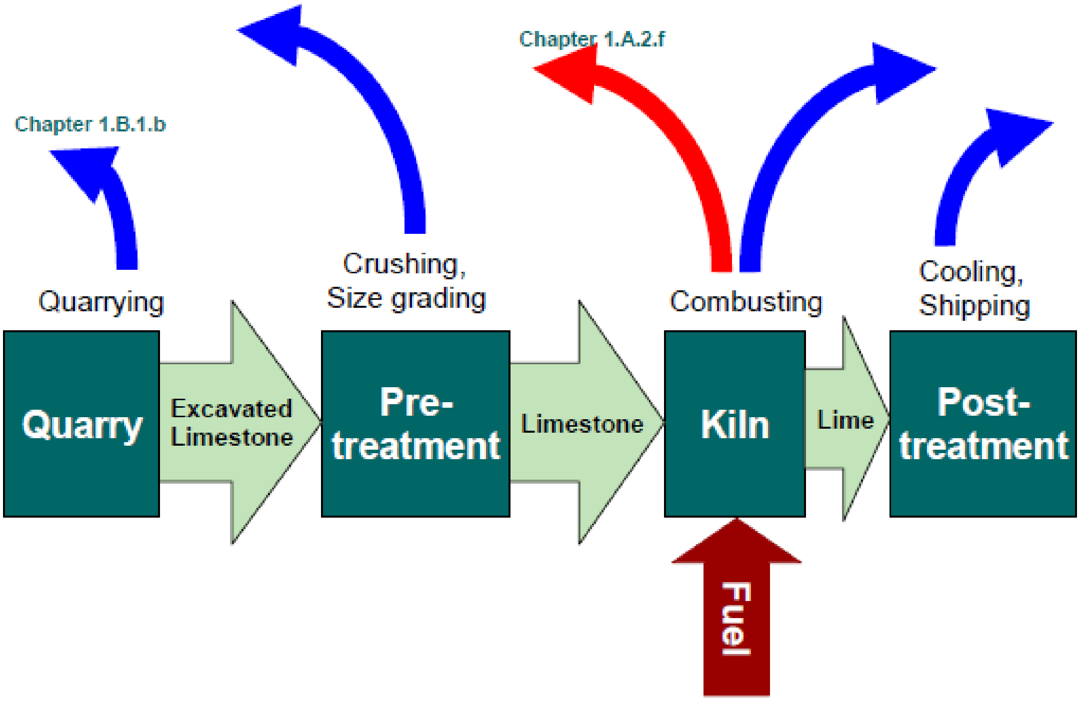
pollutant	Emission factor (g/Mg mineral)	Activity Rate (tonnes)	$E_{pollutant}$ (tonnes)
TSP	102	261,572	26.68
PM_{10}	50		13.08
$PM_{2.5}$	5.0		1.31

3.2 Lime production

Lime (CaO) is the high-temperature product of the calcination of limestone. The production occurs in vertical and rotary kilns fired by coal, oil or natural gas. Calcium limestone contains 97–98 % calcium carbonate on a dry basis. The rest includes magnesium carbonate, aluminium oxide, iron oxide and silica. However, some limestone contains as much as 35–45 % magnesium carbonate and is classified as dolomite. Atmospheric emissions in the lime manufacturing industry include particulate emissions from the mining, handling, crushing, screening and calcining of the limestone and emissions of air pollutants generated during fuel combustion in kilns. These emissions are not very significant on a global or even regional scale. However, lime works can be an important emission source of air pollutants on a local scale.

Two major types of processes can be considered within the lime work operations: quarrying, crushing, and size grading of minerals; and combustion of fuels in lime kilns. A schematic overview of the different processes occurring during the production of lime is shown in Figure 7.

Figure 7 Process scheme for source category 2.A.2 Lime production[16]



Lime causes emissions on all stages of production, i.e

1. Emissions from quarries (dust and particulate matter)
2. Process emissions (TSP, PM10, PM2.5)
3. Fuel-based combustion emissions (NOx, SOx, NMVOC, CO)

There are no lime quarries in the Regional Unit of Florina. There is only one lime production plant (Thessaliki Asvestopoiia S.A) in Amyntaio Florina. The company is in a transition period, i.e changing of ownership and name, and thus, it was not possible at this time to acquire data on “fuel used in the industrial combustion (TJ)” or “annual consumption of fuel (J)” in order to calculate emission pollutants using Tier 1 or Tier 2 respectively (following the methodology 1.A.2 Manufacturing industries and construction (combustion) /1.A.2.f — Non-metallic minerals). Thus, below we calculate only process emissions and not fuel-based combustion emissions from that plant.

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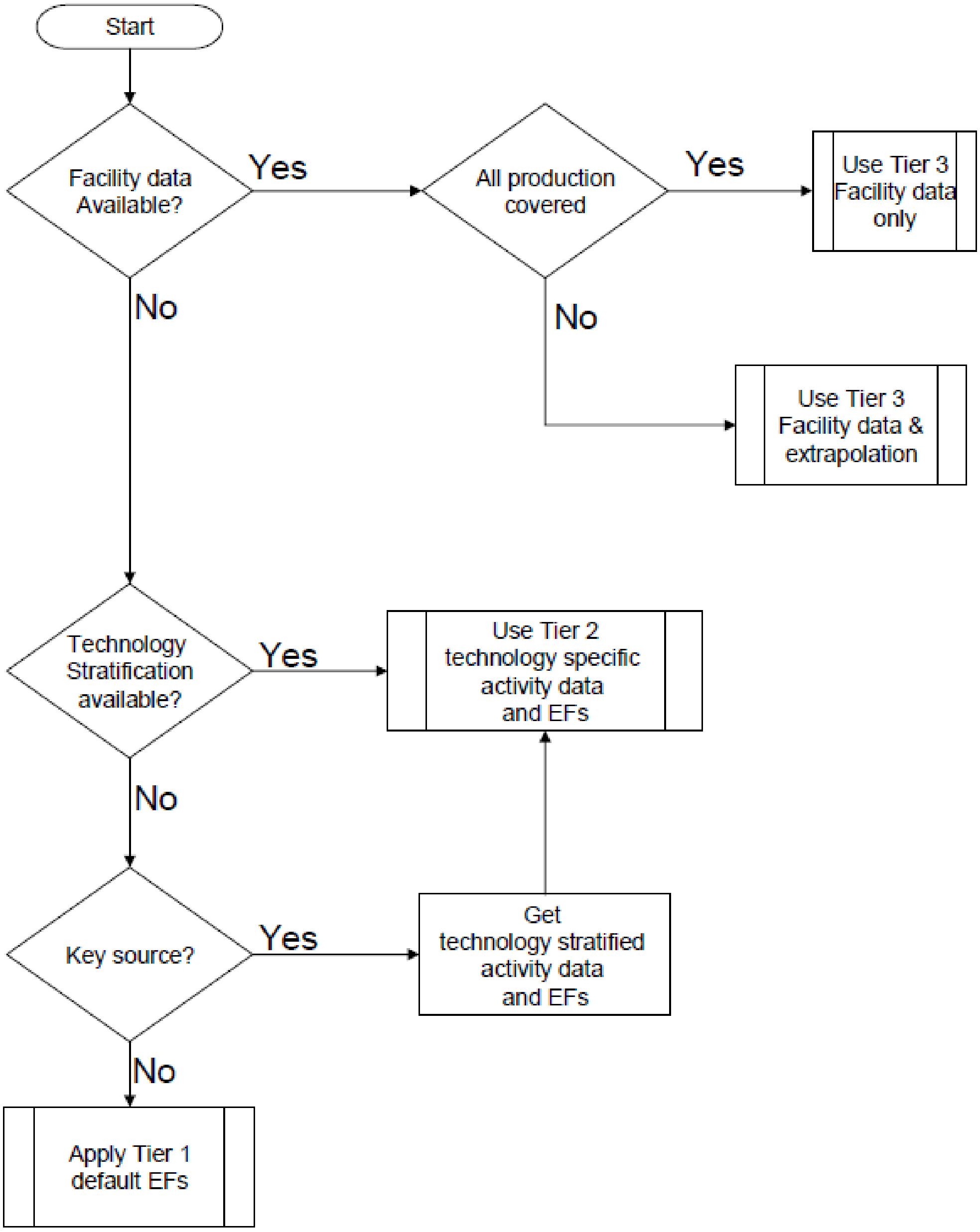
[16] *Source: EMEP/EEA emission inventory 2009*

Process Emissions

Pollutants released are sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOC and methane (CH_4)), carbon monoxide (CO), carbon dioxide (CO_2), nitrous oxide (N_2O) and particulate matter. According to CORINAIR90 the main relevant pollutants are SO_2, NO_x, CO and CO_2 (Bouscaren, 1992).

Figure 8 Decision tree for source category 2.A.2 Lime production[17]



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[17] *Source: EMEP/EEA emission inventory 2009*

The Tier 1 approach (selected using decision tree-Figure 8) for process emissions from lime uses the general equation:

$$E_{pollutant} = AR_{production} \text{ x } EF_{pollutant}$$

Where:

$E_{pollutant}$ = the emission of the specified pollutant

$AR_{production}$ = the activity rate for the lime production

$EF_{pollutant}$ = the emission factor for this pollutant

Emission factors (Table 6) are provided for particulate fractions only. This does not imply that there are no process emissions for other pollutants but since it is very difficult to separate process and combustion emissions and we expect the majority of emissions for other pollutants (NO_x, SO_x, NMVOC, CO, cadmium (Cd), mercury (Hg) and lead (Pb)) to be due to the combustion of fuels (see next section). Emissions of other heavy metals are assumed to be negligible.

Table 6 Tier 1 Emission factors for source category 2A.2 Lime production

Pollutant	**Emission factor (g/Mg lime produced)**
TSP	9000
PM_{10}	3500
$PM_{2.5}$	700

As described also in Deliverable 3.3.1, the mean total annual lime production from the single lime plant active in the Regional unit of Florina is approximately 30,000 tonnes (activity rate). The total emissions are given in Table 7.

Table 7 Calculation of emissions for each pollutant by the lime industry in the Regional Unit of Florina

pollutant	**Emission factor (g/Mg lime produced)**	**Activity Rate (tonnes)**	**$E_{pollutant}$ (tonnes)**
TSP	9,000	30,000	270
PM_{10}	3,500		105
$PM_{2.5}$	700		21

3.3 Pulp and paper production

Pulp and paper production consist of three major processing steps: pulping, bleaching and paper production. The type of pulping and the amount of bleaching used depends on the nature of the feedstock and the desired qualities of the end product. Emissions from paper and pulp production include non-methane volatile organic compounds (NMVOC), sulphur oxides (SO_x), particulates, nitrogen oxides (NO_x) and carbon monoxide (CO). Except of process emissions, emissions from combustion in boilers/furnaces also exist. However, in the case of Florina, the latter is not calculated since the area maintains only one paper industry and the pollution can be considered negligible. See process scheme in Figure 9 below.

Figure 9 Process scheme for source category 2.H.1 Pulp and paper industry

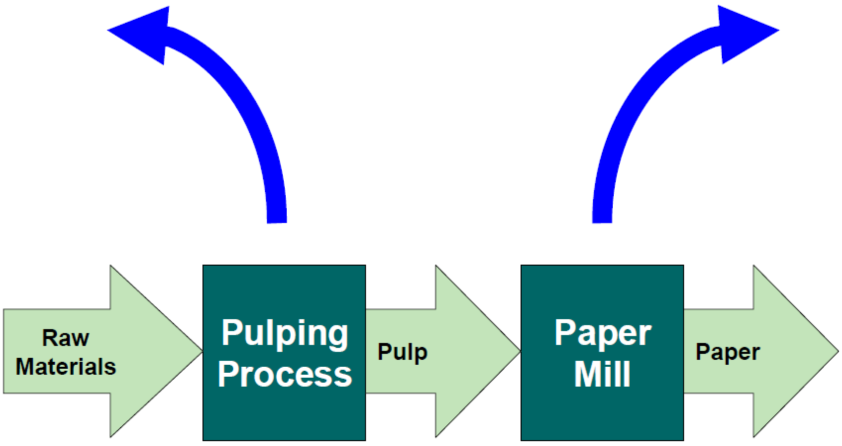
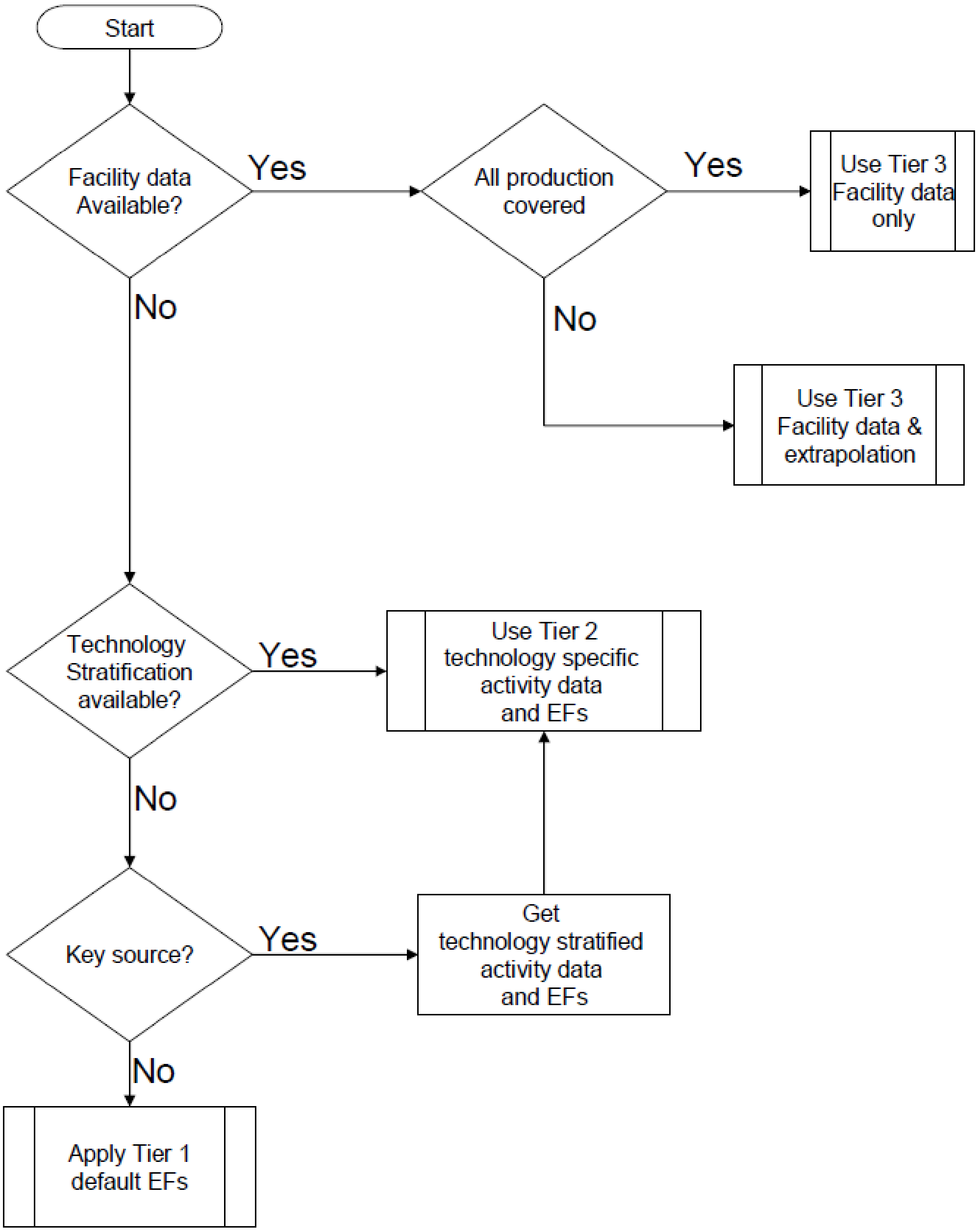


Figure 10 Decision tree for source category 2.H.1 Pulp and Paper



The Tier 1 approach (selected using decision tree-Figure 10) for process emissions from pulp and paper uses the general equation:

$$E_{pollutant}=AR_{production} \times EF_{pollutant}$$

The production of paper in the Tottis Pack industry (see deliverable 3.1.1.) was 17,250 tonnes in 2019. The process emissions are calculated in Table 8.

Table 8 Calculation of process emissions from pulp and paper in the Regional Unit of Florina

Pollutant	Default emission factor for Tier 1 source category 2.H.1 (kg/Mg air dried pulp)	$E_{pollutant}$ (kg)	$E_{pollutant}$ (tonnes)
NOx	1	17,250	17.25
CO	5.5	94,875	94.88
NMVOCs	2	34,500	34.5
SO_2	2	34,500	34.5
TSP	1	17,250	17.25
PM_{10}	0.8	13,800	13.8
$PM_{2.5}$	0.6	10,350	10.35

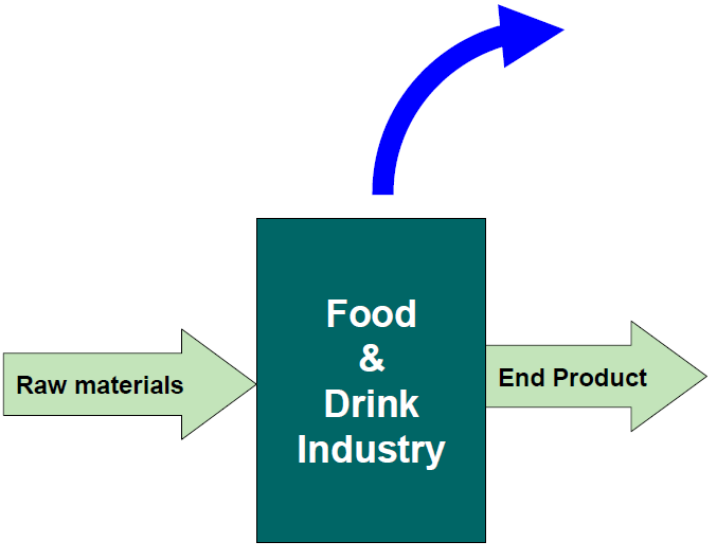
3.4 Food and beverages production

Food manufacturing (see process scheme Figure 11) may involve the heating of fats and oils and foodstuffs containing them, the baking of cereals, flour and beans, fermentation in the making of bread, the cooking of vegetables and meats, and the drying of residues. These processes may occur in sources varying in size from domestic households to manufacturing plants.

When making any alcoholic beverage, sugar is converted into ethanol by yeast. This is fermentation. The sugar comes from fruit, cereals or other vegetables. These materials may need to be processes before fermentation. For example, in the manufacture of beer, cereals are allowed to germinate, then roasted and boiled before fermentation. To make spirits, the fermented liquid is then distilled. Alcoholic beverages, particularly spirits and wine, may be stored for a number of years before consumption.

For the scope of this inventory, only the process emissions have been taken into account in this source category. Emissions originating from combustion activities within the food and beverages industry are very difficult to gather and since «food and beverages» is not a key category for the Regional Unit of Florina, those emissions will not be included.

Figure 11 Process scheme for source category 2.H.2 Food and beverages industry



Emissions from ***Food manufacturing*** occur primarily from the following sources:

- the cooking of meat fish and poultry, releasing mainly fats and oils and their degradation products;
- the processing of sugar beet and cane and the subsequent refining of sugar;
- the processing of fats and oils to produce margarine and solid cooking fat;
- the baking of bread, cakes biscuits and breakfast cereals;
- the processing of meat and vegetable by-products to produce animal feeds;
- the roasting of coffee beans.

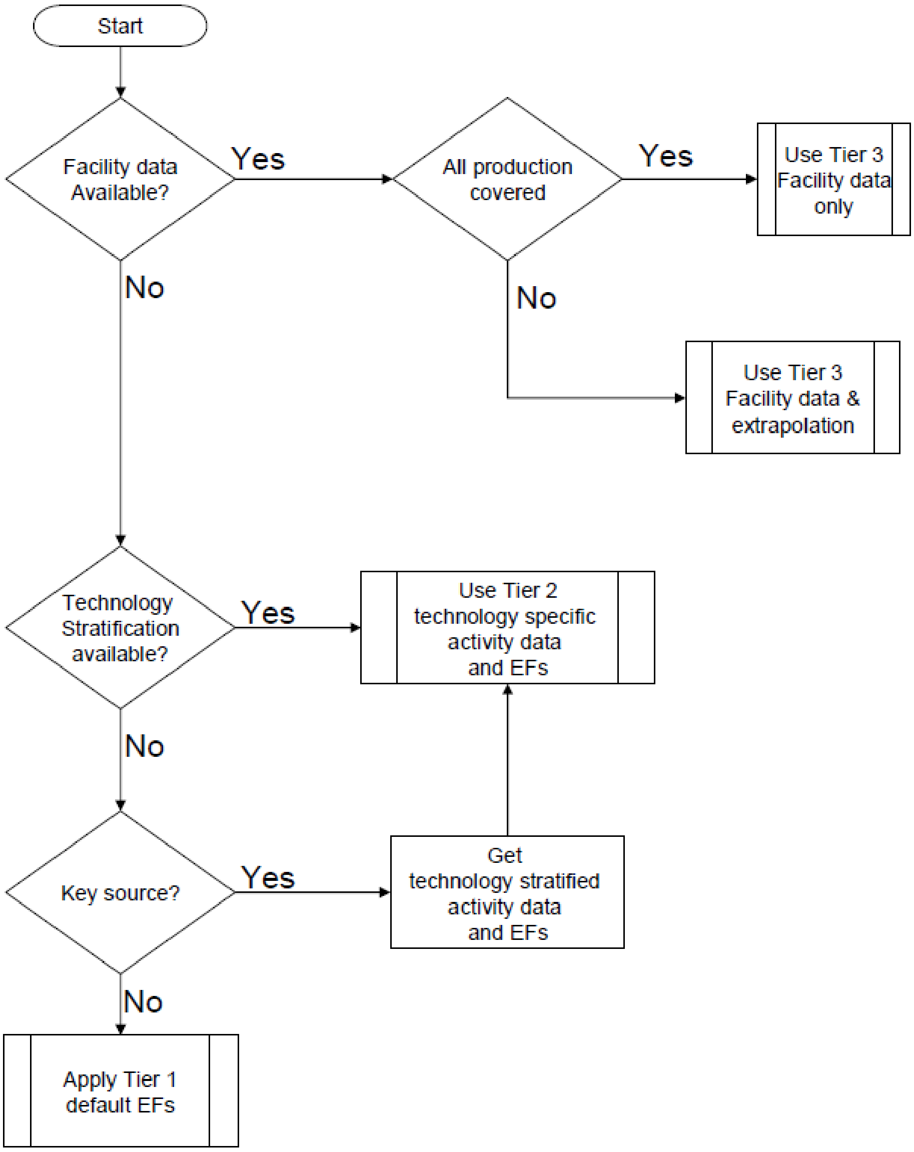
Where cooking or putrefaction is not involved, such as the production of fresh and frozen foods, emissions are considered negligible. Emissions from the pasteurisation of milk and the production of cheeses are also considered negligible.

Emissions from drink manufacturing may occur during any of the four stages which may be needed in the production of an alcoholic beverage.

- During preparation of the feedstock, the most important emissions appear to occur during the roasting of cereals and the drying of solid residues.
- During fermentation, alcohol and other NMVOCs are carried out with the carbon dioxide as it escapes to atmosphere. In some cases, the carbon dioxide may be recovered, reducing the emission of NMVOC as a result.

- During the distillation of fermentation products emissions are to be expected, but very little data is available. Losses occur as a result of poor maintenance and the use of old plant.
- During maturation NMVOCs evaporate from the stored beverage. The mass of emission will be proportional to the length of the maturation period.

Figure 12 Decision tree for source category 2.H.2 Food and beverages industry



The Tier 1 approach (selected using decision tree-Figure 12) for process emissions from the food and beverages industry uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant}$$

The emission factors integrate all sub-processes within the industry from the feed of raw material to the final shipment of the products off site.

The Emission Factor of NMVOCs is 2 kg/Mg product produced.

For use in Tier 1, the total mass of the products of the following industries have been added together:

- TOTTIS FOODS AE (http://www.tottis-bingo.gr/factories.htm): chips, extruded snacks, chocolates, croissant , waffles, pastries etc. (5500-6000 tonnes per year)
- PAMI ABEE (http://www.pami.gr/): dry nuts, spreads with nuts, wafers, confectionery raw materials (1500 tonnes 2019)

Thus, $AR_{production}$=7500 tonnes

The total emissions are given in Table 9.

Table 9 Calculation of process emissions from food & beverages in the Regional Unit of Florina

Pollutant	**Default emission factor for Tier 1 source category 2.H.2 Food and beverages industry (kg/Mg product produced)**	**$E_{pollutant}$ (kg)**	**$E_{pollutant}$ (tonnes)**
NMVOCs	2	15,000	15

4. EMISSIONS FROM ENERGY PRODUCTION

4.1 «Public Power Corporation» activity in the area

Historical review

Few years ago, Greece was ranked second in the production of lignite within the European Union, third in Europe overall, and fourth worldwide, following Germany, the United States, and Russia[18]. During the post World War II period and particularly after the oil crisis of 1973, the Greek energy policy was based on the lignite mining from the region of Western Macedonia and its lignite-fired power generation plants.

PPC S.A., is the leading power generation and supply company in Greece engaged in the generation, distribution and sale of electricity to consumers. PPC lignite mines provided lignite for power generation. PPC is the only company in Greece that owns lignite-fired plants for energy production. The 34 major thermal and hydroelectric power plants and the 3 aeolic parks of the interconnected power grid of the mainland, as well as the 61 autonomous power plants located on Crete, Rhodes and other Greek islands (39thermal, 2 hydroelectric, 15 aeolic and 5 photovoltaic parks) formed PPC's industrial colossus and constituted the energy basis of all financial activities of the country. Its total installed capacity in Greece in 2008 was 12.2 GW, with thermal and hydroelectric power plants as well as Renewable Energy Sources (RES) installations both on the mainland and the islands[19].

As it can be seen in the Map 8 below, the Region of Western Macedonia was the major contributor in lignite extraction and utilization and thus in electricity production. More than one-eighth of the region’s surface was used for the lignite mining.

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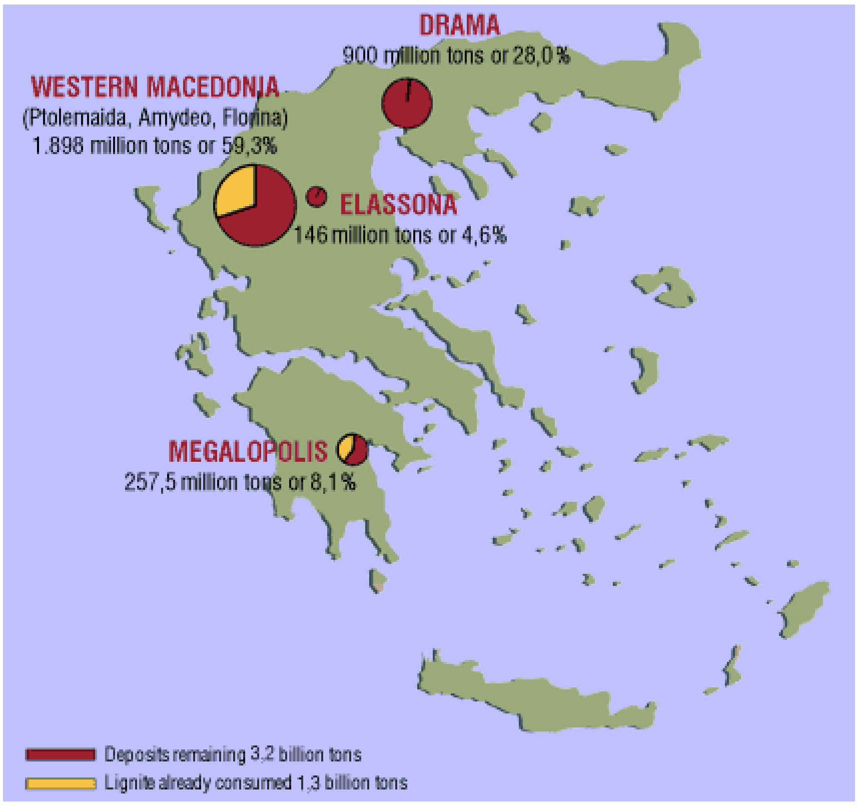
[18] Konstantinos Kavouridis, ‘‘Lignite Industry in Greece within a Worldwide Context: Mining, Energy Supply and Environment,’’ Energy Policy, April 2008, pp. 1257–272.

[19] www.dei.gr

Map 8 Lignite extractions in Greece



Western Macedonia consists of four Regional Units: Kozani, Florina, Kastoria, and Grevena. The first two Regional Units is where the lignite was found. The lignite deposit of the Florina area, compared with the rest of Greek reserves, contains the largest calorific value, ranging from between 1,927 to 2,257 kcal/gr[20].

Table 10 below shows the diachronic contribution of Western Macedonia' Regional Units to the Gross Regional Sectoral output of the energy and non-energy minerals mining sector and the energy production sector.

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[20] Public Power Corporation S.A., Deposits and Quality/Statistical Data, also available at www.dei.gr. Lignite is a coal in which the fossilization of organic material has advanced beyond peat but not to the extent of sub-bituminous coal. It contains about 30 percent to 40 percent water; its heat value is around 13,900 to 19,290 kilojoules per kilogram (6,000 to 8,300 British thermal units per pound).

Table 10 Diachronic contribution of Western Macedonia' Regional Units to the Gross Regional Sectoral output of the energy and non-energy minerals mining sector and the energy production sector, 1995-2003 (in percent)[21]

Regional Unit	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Energy and Non-Energy Minerals Mining Sector									
Kozani	93.35	93.34	86.34	86.91	77.42	73.66	75.92	74.71	74.43
Florina	5.60	5.60	13.17	12.65	21.97	25.14	22.93	23.26	24.41
Grevena	0.92	0.93	0.06	0.05	0.04	0.04	0.03	0.01	0.01
Kastoria	0.13	0.13	0.43	0.39	0.57	1.17	1.10	1.14	1.14
Energy Production Sector (i.e. the lignite-fired power generation)									
Kozani	97.49	97.39	96.42	96.27	96.31	96.07	95.89	95.81	95.72
Florina	1.23	1.28	1.75	1.97	1.93	2.16	2.23	2.23	2.24
Grevena	0.57	0.59	0.84	0.80	0.81	0.84	0.91	0.96	1.03
Kastoria	0.71	0.73	0.98	0.96	0.96	0.94	0.98	1.00	1.01

Although these economic activities created employment in the region, at the same time they have caused some of the most significant problems for Western Macedonia, mainly environmental impacts, health issues for the inhabitants, and the costs to the quality of the living standards.

For reference, Table 11 presents the lignite-fired power stations of the Regional Unit of Florina in the years 2002 and 2004, including generation and emissions.

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[21] Fotios Chatzitheodoridis, Argyrios D. Kolokontes, and Lavrentios Vasiliadis, "lignite mining and lignite-fired power generation in Western Macedonia of Greece: economy and environment", The Journal of Energy and Development, Vol. 33, No. 2, 2010 International Research Center for Energy and Economic Development (ICEED)

Table 11: Lignite-fired power generation plants of Regional Unit of Florina: power capacity (in megawatts — MW) and emissions (in thousand tons), 2002 and 2004[22]

Lignite-Fired Station/Emissions	Power (MW)	2002	2004
Amyntaio	600		
CO		3.3 (M[23])	5.1 (M)
CO_2		5,480 (C)	4,670 C)
NO_X		6.0 (M)	7.5 (M)
SO_X		24.2 (M)	35.8 (M)
Melitis	330		
CO		n.a.	n.a.
CO_2		n.a.	2,630 (C)
NO_X		n.a.	2.0 (M)
SO_X		n.a.	3.0 (M)

Current situation

The overall plan of PPC S.A. and of the Greek government is to complete the process of closing all lignite mining within the next years and move to the transition to the post-lignite era until 2023, a quite challenging task. Out of the 14 lignite plants PPC has today in total, the state-run utility will likely hang onto the plant at Agios Dimitrios and a new unit at Ptolemaida, which is under construction, both located in the Regional Unit of Kozani.

The closing of most minings in the Regional Unit of Florina has been already completed. The following lignite mines of PPC S.A. are currently found within the boundaries of the Regional Unit of Florina:

1. Location: Kleidi (closed)

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[22] Sources: European Environment Agency (EEA), The European Pollution Emission Register (Copenhagen, Denmark: EEA, 2007), also available at www.eper.sec.eu.int, and Public Power Corporation S.A. (PPC), First Public Report for the P.P.C.'s S.A. Activities (Athens: PPC, 2007), also available at www.dei.gr.

[23] M, C, E, and N.A. state either the size that has been measured, calculated, estimated, or not available, respectively. As indicated by Fotios Chatzitheodoridis, Argyrios D. Kolokontes, and Lavrentios Vasiliadis, "lignite mining and lignite-fired power generation in Western Macedonia of Greece: economy and environment", The Journal of Energy and Development, Vol. 33, No. 2, 2010 International Research Center for Energy and Economic Development (ICEED)

The operation of Kleidi lignite mine started in 2004 and was temporarily suspended in 2008. It was permanently ceased in 2012, after a short period of operation in 2011, due to lack of sufficient storage space for the excavated materials. The depth of the lignite mine, during its operation period, reached about 80 meters. Its maximum annual production was 470,000 tonnes (2008).

2. Location: Amyntaio (will be closed in June 2020)

The operation of the Amyntaio lignite mine began in 1989. The mining operations of the lignite mine will be completed within the current month. The depth of the lignite mine is about 150 meters. Its maximum annual production amounted to 8.2 million tonnes (2003), while the production last year (2019) was 1.72 million tonnes.

3. Location: Lakkia (a small amount to extract and then will be closed)

The operation of the Lakkias lignite mine started in 2014. It has been discovered that the mine maintains about 500,000 tonnes. This amount is estimated to be mined within the next two years. The depth of the lignite mine is about 50 meters. Its maximum annual production amounted to 1.28 million tonnes (2018).

In addition, research and exploitation rights have been granted to PPC SA for the following lignite mines within the Regional Unit of Florina but excavation is not active:

4. Location: Lofos - Melitis (no excavation)
5. Location: Vevi (no excavation)

There is one more lignite mine where the production is made by private entities:

6. Achlada

It will remain in operation until around 2024. The production of lignite in 2019 was approximate 1 million tonnes.

The current Power Plants in the Regional Unit of Florina shown in Table 12.

Table 12 Power Plants located in the Regional Unit of Florina

POWER STATION	INSTALLED CAPACITY (MW)
AMYNTAIOY (2 units)	2x300 = 600
MELITIS-ACHLADAS (1 unit)	1x330 = 330
TOTAL	**930**

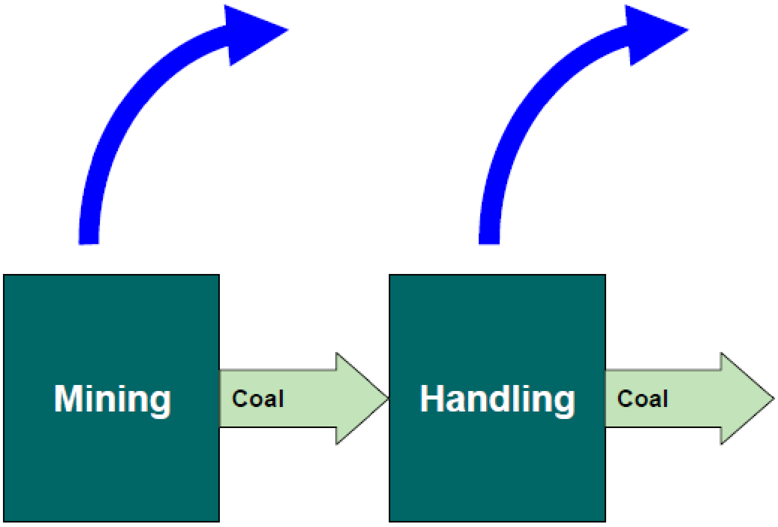
4.2 Lignite mines

The extraction and treatment of coal (see process scheme Figure 13) result mainly in emissions of methane. However, also non-methane volatile organic compounds (NMVOC), particulate matter and CO_2 are emitted. Emissions of the methane are estimated using the methodology provided by the “2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines”, while NMVOC and particulate matter (TSP, PM_{10} and $PM_{2.5}$) using the “EMEP/EEA air pollutant emission inventory guidebook 2019”.

NMVOCs and particulate matter (TSP, PM10 and PM2.5)

Coalfields contain a proportion of highly volatile material which is released during the working, extraction and storage of coal. The volatile material is known as firedamp, made up primarily of methane, although other compounds are also present in minor amounts. The release of firedamp often results in an emission to air as it not always economical to contain the gas for flaring or use as a fuel.

Figure 13 Process scheme for source category 1.B.1.a Coal mining and handling



Releases of particulate matter occur during mining activities, including drilling, and during storage and handling, including loading, wind erosion, equipment traffic, load out and any drop related operations.

In the Regional Unit of Florina there are only open cast mines. In addition, it is important to note that coal varies considerably from one field to another, depending on its age and geological location. The proportion of firedamp associated with the different types of mining and the different types of coal have shown considerable variation. Attempts to model the relationship between the proportion of firedamp and factors such as depth of coal seam, nature of coal and local geology have shown some correlations although the associated uncertainty is very large.

Once coal is extracted it may be stored, transported internally or exported, or a combination of all three. Associated gaseous emissions continue to occur and it is thought that these will be related to the coal type, the size of the coal pieces, and the mechanical disturbance during handling, etc.

Methane is contained in the coal extracted to the surface and released during the extraction processes. Emission related to these processes is called emission from extraction processes. This emission constitutes the second methane emission source in coal mining (the first is in underground mines).

Some methane is also contained in the bedrock extracted to the surface with coal and gets released during bedrock disposal. This is the third source of methane emission. The fourth source is the demethaning systems. The methane collected by these systems is not totally utilised or combusted in flames and some or all of the volume is emitted as ‘whistler’ to the atmosphere.

In open-cast coal extraction, there are two main sources of ventilation emission:

- emission from the extracted coal;
- emission from the deposits coating the working.

The primary emission of firedamp is believed to occur during the extraction of deep mine coal. Open cast mining, since it involves the extraction of coal seams close to the surface and the handling and storage of coal, are not considered to be as important.

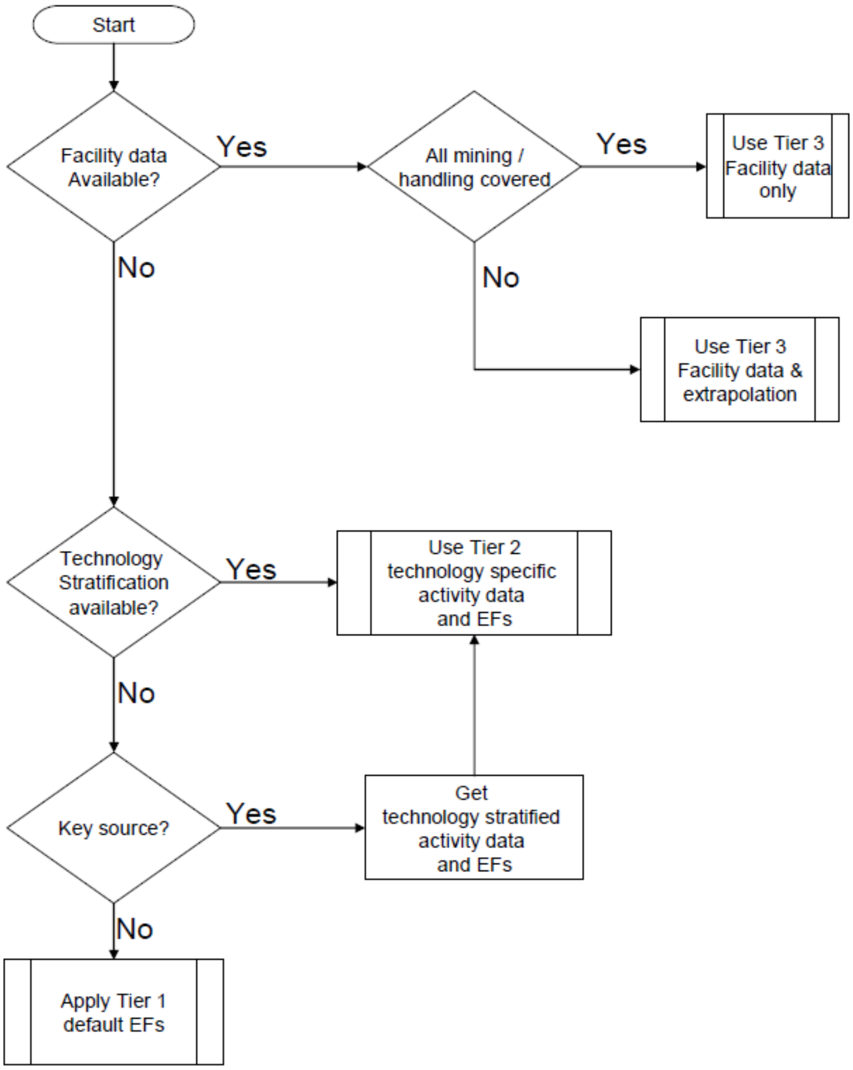
In many cases, firedamp is actively removed from the coalfield by various methods, normally described collectively as methane drainage. This is primarily for reasons of safety.

Data from Russia (Tsibulski, 1995) indicates that the balance of methane emissions from coal seams and enclosing rocks is distributed as follows:

- 60% emitted to atmosphere from mines together with ventilation air
- 12 % captured in mines and if not utilised then also emitted;
- 15 % emitted to atmosphere from coal extracted to the surface;
- 13 % remains in the seam and surrounding rock.

Firedamp may be removed before the mining of a coal seam (pre-drainage) or as a consequence of mining (post-drainage). The latter approach is likely to be the most common.

Figure 14 Decision tree for source category 1.B.1.a Coal mining and handling the ("EMEP/EEA air pollutant emission inventory guidebook 2019")



The Tier 1 approach (selected using decision tree-Figure 14) for coal mining and handling uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant}$$

where:

$E_{pollutant}$ = the emission of the specified pollutant,
$AR_{production}$ = the activity rate for the coal mine production,
$EF_{pollutant}$ = the emission factor for this pollutant.

The Tier 1 emission factors (Table 13) assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes within the coal mining and handling process.

Table 13 Tier 1 emission factors for source category 1.B.1.a Coal mining and handling

Pollutant	Emission Factor (kg/Mg coal)
NMVOCs	0.8
TSP	0.089
PM_{10}	0.042
$PM_{2.5}$	0.005

For the purpose of this deliverable we will calculate the pollutants released from the lignite mines last year (2019), eventhough we are in a transition period, i.e. more than 10million tonnes was the annual production few years ago, while the extraction will permanently cease after 2024 (i.e. zero emissions). The total extraction is given in Table 13.

Table 13 Activity Rate for the lignite mine production in the Regional Unit of Florina

Lignite mine	Amount of extracted coal (tonnes per year)	For the year
Amyntaio (PPC S.A. owned)	1,720,000	2019
Achlada (other private ownership)	1,000,000 (estimated figure)	2019
TOTAL	**2,720,000 tonnes per year**	

The total emissions are given in Table 14.

Table 14 Emission of pollutants (other than methane) from the lignite mine production in the Regional Unit of Florina

Pollutant	**$AR_{production}$**	**Emission Factor (kg/Mg coal)**	**$E_{pollutant}$ (kg)**	**$E_{pollutant}$ (tonnes)**
NMVOCs	2,750,000 tonnes	0.8	2,200,000	2200
TSP		0.089	244,750	244.75
PM_{10}		0.042	115,500	115.5
$PM_{2.5}$		0.005	13,750	13.75

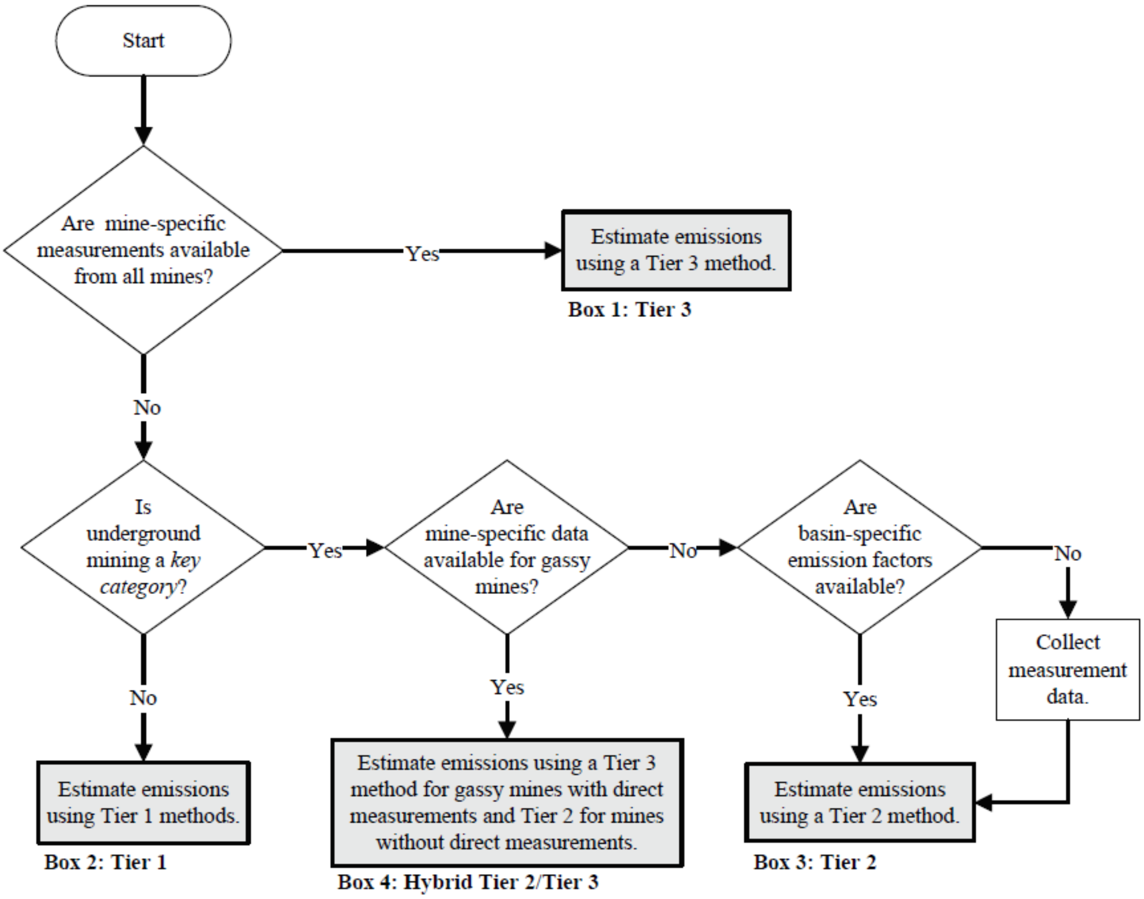
Methane CH4

The following *potential* source categories for fugitive emissions for active underground coal mines are considered:

Seam gas emissions vented to the atmosphere from coal mine *ventilation air* and *degasification systems*

- Post-mining emissions
- Low temperature oxidation
- Uncontrolled combustion

Figure 15 Decision tree for underground coal mines ("2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines")



Tier 1 methodology (selected using decision tree-Figure 15) to estimate methane emissions from surface coal mines (see section 4.1.4.2 in the "2006 IPCC Guidelines") is given by the equation:

CH_4 emissions = CH_4 Emission Factor x Surface Coal Production x Conversion Factor

Where units are:

Methane Emissions (Gg year^{-1})

CH_4 Emission Factor (m^3 tonne^{-1})

Surface Coal Production (tonne year^{-1})

Emission Factor:

Low CH_4 Emission Factor = 0.3 m^3 tonne^{-1}

Average CH_4 Emission Factor =1.2 m^3 tonne^{-1}

High CH_4 Emission Factor = 2.0 m^3 tonne^{-1}

For the Tier 1 approach, it is good practice to use the low end of the specific emission range for those mines with average overburden depths of less than 25 meters and the high end for overburden depths over 50 meters. For intermediate depths, average values for the emission factors may be used. The maximum depth for the lignite mines in the Regional Unit of Florina is 50-150m, so the High Emission Factor will be used.

Conversion Factor:

This is the density of CH_4 and converts volume of CH_4 to mass of CH_4. The density is taken at 20°C and 1 atmosphere pressure and has a value of 0.67×10^{-6} Gg m^{-3}.

The total emissions are calculated in Table 15.

Table 15 Emission of methane from the lignite mine production in the Regional Unit of Florina

***CH_4* Emission Factor** (in m^3 $tonne^{-1}$)	***Surface Coal Production*** (in tonnes per year)	***Conversion Factor*** (in Gg m^{-3})	***CH_4* emissions** (in Gg per year)	***CH_4* emissions** (in tonnes per year)
2	2,720,000	0.67×10^{-6}	3.64	3,644.80

4.3 Lignite-fired plants for energy production

This activity covers emissions from large combustion plants. The emissions considered are released by a controlled combustion process (boiler emissions, furnace emissions, emissions from gas turbines or stationary engines) and are mainly characterised by the types of fuels used. Furthermore, a characterisation of the combustion sources may be developed according to the size and type of plants as well as from primary or secondary reduction measures. For example, solid, liquid or gaseous fuels are used and there are a range of emission abatement measures (for example PM, SO_2 and NO_x control). Figure 16 and Figure 17 below provide a schematic approach of the power plants currently found in the Regional Unit of Florina.

Figure 16 Process scheme for power plant in Meliti-Achada, adapted from IPCC Figure 2.2 in the energy industries chapter

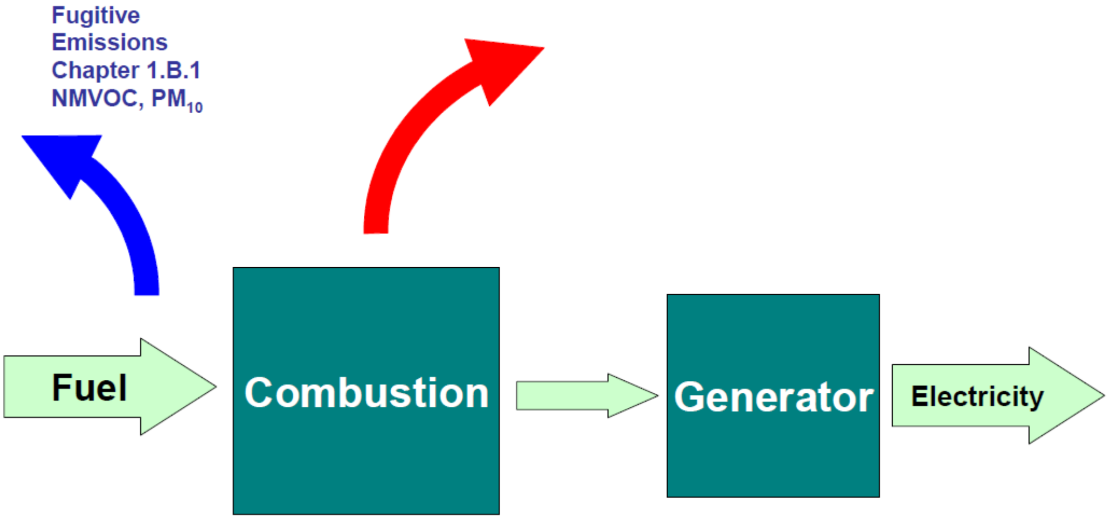
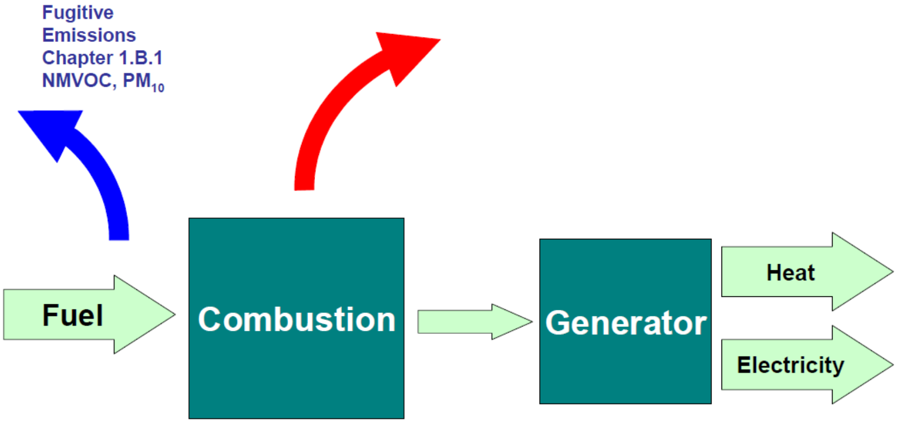


Figure 17 Process scheme for Amyntaio (provides also teleheating, i.e. combined power and heat plant), adapted from IPCC Figure 2.2 in the energy industries chapter



Combustion of coal and other solid mineral fuels

Coal is largely burnt as a pulverised fuel with corner (tangential), wall or downfired furnaces. The dry bottom boiler (DBB) has typical combustion temperatures of 900 up to 1 200 °C leading to dry ash discharge from the combustion chamber due to combustion temperatures from. This type of boiler is mainly used for the combustion of hard coal and brown coal/lignite and is applied all over Europe.

Sulphur oxides

In the absence of flue gas desulphurisation (FGD) technology, the emissions of sulphur oxides (SO_x) are directly related to the sulphur content of the fuel. The sulphur content of refined natural gas is negligible. The majority of SO_x is sulphur dioxide (SO_2) although small proportions of sulphur trioxide (SO_3) can arise.

Nitrogen oxides

Emissions of nitrogen oxides (nitric oxide and nitrogen dioxide — NO_x) arise from nitrogen in the fuel (mainly relevant to solid and liquid fuels) and from reaction of atmospheric nitrogen. Combustion control can provide a high degree of NO_x emission control (low NO_x burner technology) and this may be supplemented by use of selective catalytic reduction (SCR) or selective non-catalytic reduction techniques (SNCR).

Non-methane volatile organic compounds (NMVOC)

Emissions of non-methane volatile organic compounds (NMVOC), e.g. olefins, ketones, aldehydes, result from incomplete combustion. Furthermore, unreacted fuel compounds such as ethane (C2H6) can be emitted. The relevance of NMVOC and CH_4 emissions from boilers, which are often reported together as VOC, is very low for large-sized combustion plants. VOC emissions tend to decrease as the plant size increases (Rentz et al, 1993).

Carbon monoxide (CO)

Carbon monoxide (CO) appears always as an intermediate product of the combustion process and in particular under sub-stoichiometric combustion conditions. However, the relevance of CO released from combustion plants is not very high compared to CO_2. The formation mechanisms of CO and VOC are similarly influenced by combustion conditions. Substantial emissions of CO can occur if combustion conditions are poor.

Ammonia (NH_3)

Emissions of ammonia (NH_3) are not generally associated with a combustion process; emissions can result from incomplete reaction of NH_3 additive in NO_x abatement systems — selective catalytic and non-catalytic reduction (SCR and SNCR).

Particulate matter

Particulate matter (PM) emissions from large combustion installations (> 50 MW) burning solid fuels are often lower than emissions from smaller plants (per unit of energy input); the physical and chemical characteristics of the PM also differ. This is because different combustion and abatement techniques are applied.

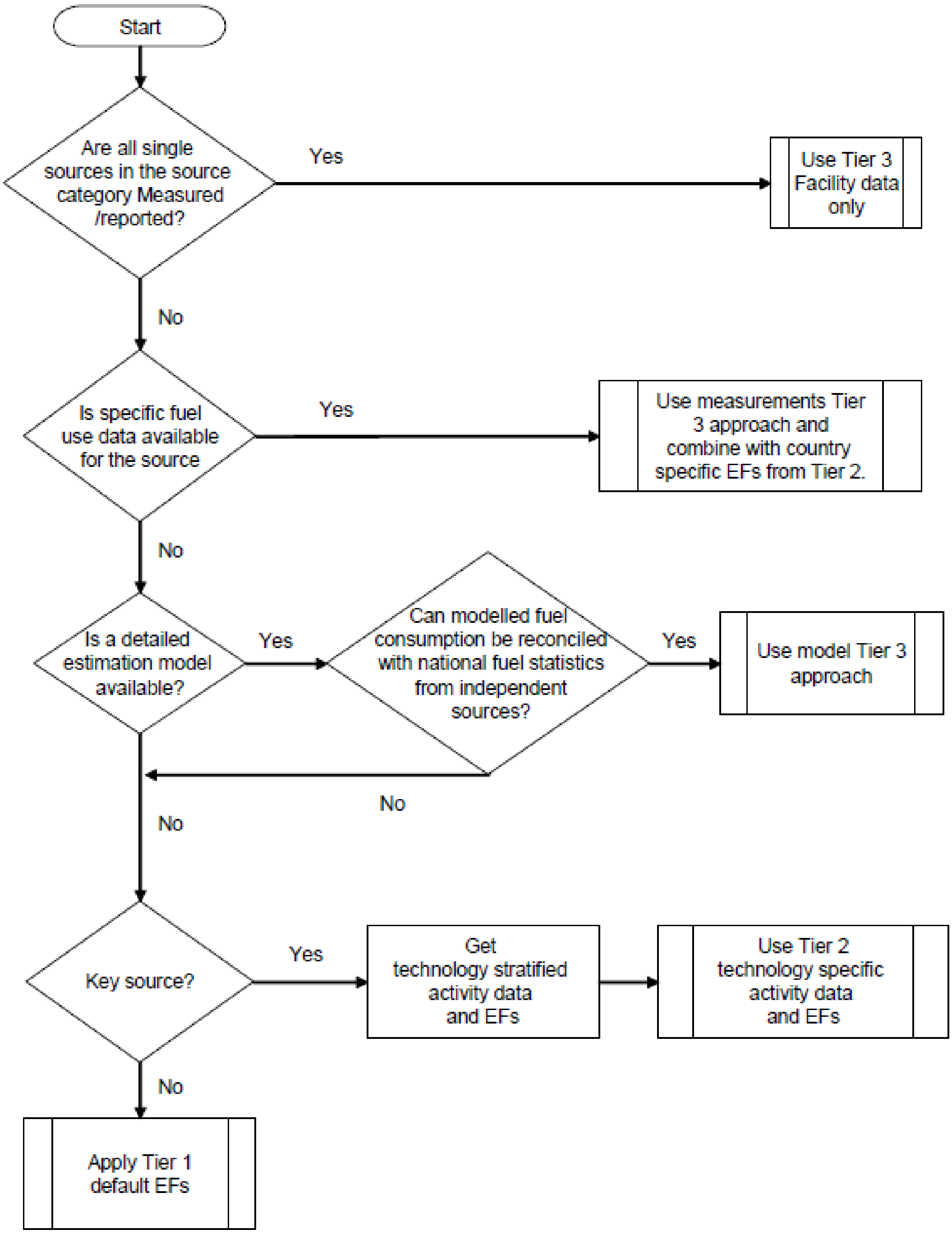
Combustion of fuels can generate solid residues which may be deposited within combustion chambers (furnace bottom ash) within the furnace, boiler surfaces or ducting (fly ash) or on heat exchanger surfaces (soot and fly ash). Coal and other fuels with significant ash content have the highest potential to emit PM. Suspended ash material in exhaust gases may be retained by particulate abatement or other emission abatement equipment (abatement residues). Material which remains in the flue gases beyond the abatement equipment and passes to the atmosphere is primary PM. Secondary PM is formed by chemical and physical processes after discharge to atmosphere and is NOT considered here.

A number of factors influence the measurement and determination of primary PM emissions from activities and, the quantity of PM determined in an emission measurement depends to a large extent on the measurement conditions. This is particularly true of activities involving high temperature and semi-volatile emission components – in such instances the PM emission may be partitioned between a solid/aerosol phase and material which is gaseous at the sampling point but which can condense in the atmosphere. The proportion of filterable and condensable material will vary depending on the temperature of the flue gases and in sampling equipment.

A range of filterable PM measurement methods are applied around the world typically with filter temperatures of 70-160°C (the temperature is set by the test method). Condensable fractions can be determined directly by recovering condensed material from chilled impinger systems downstream of a filter – note that this is condensation without dilution and can require additional processing to remove sampling artefacts. Another approach for total PM includes dilution where sampled flue or exhaust gases are mixed with ambient air (either using a dilution tunnel or dilution sampling systems) and the filterable and condensable components are collected on a filter at lower temperatures (but depending on the method this can be 15-52°C). The use of dilution methods, however, may be limited due to practical constraints with weight and/or size of the equipment.

The PM emission factors (for TSP, PM10 and PM2.5) can represent the total primary PM emission, or the filterable PM fraction. The basis of the emission factor is described (see individual emission factor tables).

Figure 18 Decision tree for combustion in energy transformation industries



The Tier 1 approach (selected using decision tree-Figure 18) for process emissions from combustion uses the general equation:

$$E_{\text{pollutant}} = AR_{fuel\ consumption} \times EF_{pollutant}$$

Where:

$E_{pollutant}$: annual emission of pollutant

$EF_{pollutant}$: emission factor of pollutant

$AR_{fuel\ consumption}$: activity rate by fuel consumption

Fuel used: Lignite (fuel classification: Brown coal)

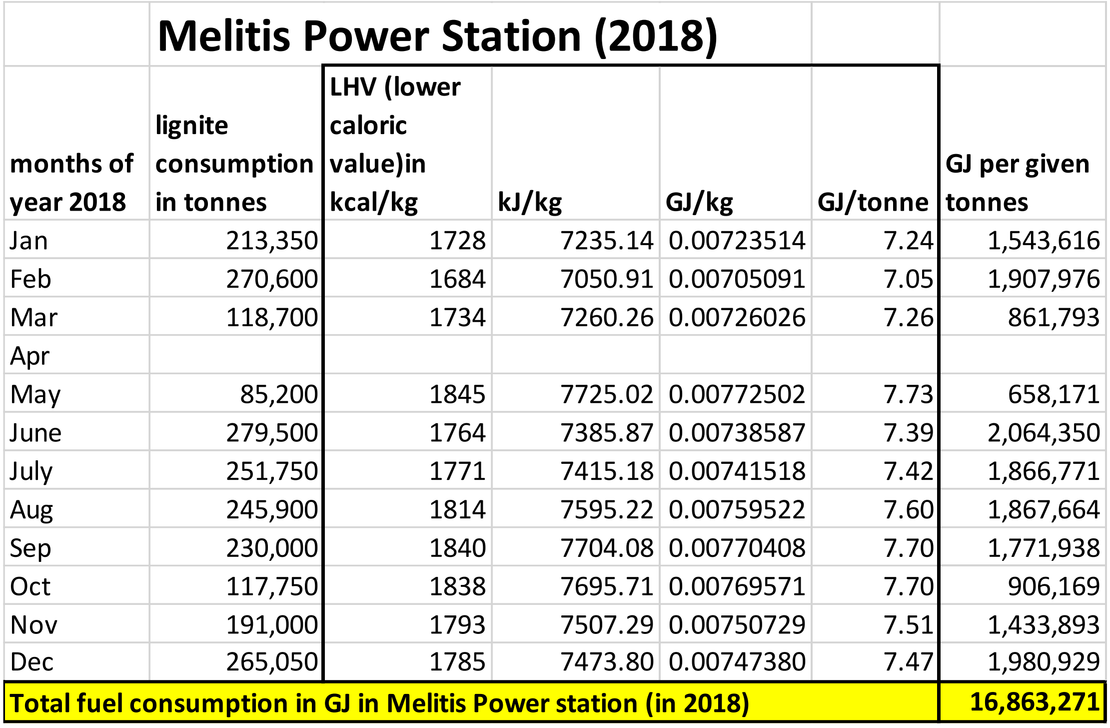
The emission factors are given in Table 16.

Table 16 Tier 1 emission factors for source category 1.A.1.a using brown coal

Emission factors	Value (g/GJ)	
NOx	247	
CO	8.7	
NMVOC	1.4	
SOx	1680	The factor for SOx assumes no SO2 abatement and is based on 1 % mass sulphur content using EF calculation from subsection 3.4.2.2 of the present chapter; 95 % confidence intervals calculated using range from Table C-1 in Appendix C.
TSP	11.7	The TSP, PM10 and PM2.5 emission factors represent filterable PM emissions and are based on an ash content of 5%.
PM10	7.9	
PM2.5	3.2	

Activity rate: The activity should refer to the energy input of the emission sources considered (net or inferior fuel consumption in [GJ]). PPC maintains 3 Power Stations in the Regional Unit of Florina. Table 17, 18 and 19 give the calculations of the fuel consumption in each one for the year 2018, while table 20 the total consumption.

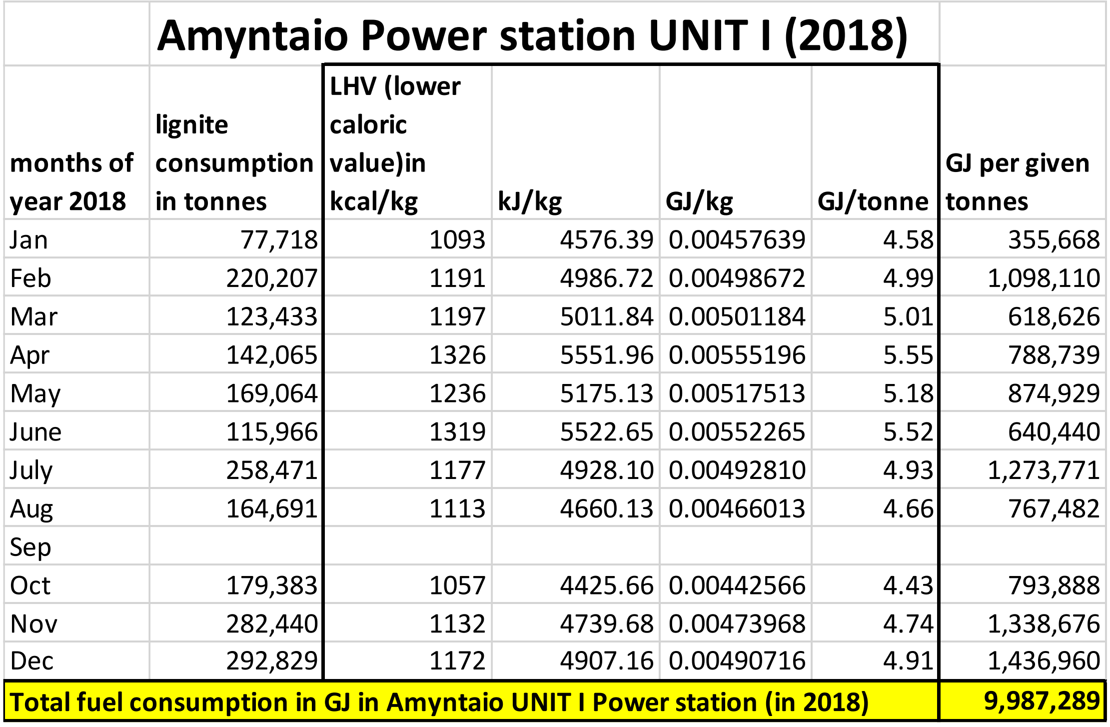
Table 17 Calculation of fuel consumption (activity rate) in Melitis Power Station



Melitis Power Station (2018)

months of year 2018	lignite consumption in tonnes	LHV (lower caloric value)in kcal/kg	kJ/kg	GJ/kg	GJ/tonne	GJ per given tonnes
Jan	213,350	1728	7235.14	0.00723514	7.24	1,543,616
Feb	270,600	1684	7050.91	0.00705091	7.05	1,907,976
Mar	118,700	1734	7260.26	0.00726026	7.26	861,793
Apr						
May	85,200	1845	7725.02	0.00772502	7.73	658,171
June	279,500	1764	7385.87	0.00738587	7.39	2,064,350
July	251,750	1771	7415.18	0.00741518	7.42	1,866,771
Aug	245,900	1814	7595.22	0.00759522	7.60	1,867,664
Sep	230,000	1840	7704.08	0.00770408	7.70	1,771,938
Oct	117,750	1838	7695.71	0.00769571	7.70	906,169
Nov	191,000	1793	7507.29	0.00750729	7.51	1,433,893
Dec	265,050	1785	7473.80	0.00747380	7.47	1,980,929
Total fuel consumption in GJ in Melitis Power station (in 2018)						**16,863,271**

Table 18 Calculation of fuel consumption (activity rate) in Amyntaio Power Station UNIT I



Amyntaio Power station UNIT I (2018)

months of year 2018	lignite consumption in tonnes	LHV (lower caloric value)in kcal/kg	kJ/kg	GJ/kg	GJ/tonne	GJ per given tonnes
Jan	77,718	1093	4576.39	0.00457639	4.58	355,668
Feb	220,207	1191	4986.72	0.00498672	4.99	1,098,110
Mar	123,433	1197	5011.84	0.00501184	5.01	618,626
Apr	142,065	1326	5551.96	0.00555196	5.55	788,739
May	169,064	1236	5175.13	0.00517513	5.18	874,929
June	115,966	1319	5522.65	0.00552265	5.52	640,440
July	258,471	1177	4928.10	0.00492810	4.93	1,273,771
Aug	164,691	1113	4660.13	0.00466013	4.66	767,482
Sep						
Oct	179,383	1057	4425.66	0.00442566	4.43	793,888
Nov	282,440	1132	4739.68	0.00473968	4.74	1,338,676
Dec	292,829	1172	4907.16	0.00490716	4.91	1,436,960
Total fuel consumption in GJ in Amyntaio UNIT I Power station (in 2018)						**9,987,289**

Table 19 Calculation of fuel consumption (activity rate) in Amyntaio Power Station UNIT II

	Amyntaio Power station UNIT II (2018)					
months of year 2018	**lignite consumption in tonnes**	**LHV (lower caloric value)in kcal/kg**	**kJ/kg**	**GJ/kg**	**GJ/tonne**	**GJ per given tonnes**
Jan	256,074	1060	4438.22	0.00443822	4.44	1,136,513
Feb	76,180	1133	4743.87	0.00474387	4.74	361,388
Mar	165,800	1246	5217.00	0.00521700	5.22	864,979
Apr	20,883	1252	5242.12	0.00524212	5.24	109,471
May	212,344	1251	5237.94	0.00523794	5.24	1,112,244
June	73,313	1407	5891.11	0.00589111	5.89	431,895
July	171,303	1204	5041.15	0.00504115	5.04	863,564
Aug	256,074	1158	4848.55	0.00484855	4.85	1,241,587
Sep	38,504	1180	4940.66	0.00494066	4.94	190,235
Oct	34,319	1053	4408.91	0.00440891	4.41	151,309
Nov	191,464	1184	4957.41	0.00495741	4.96	949,165
Dec	275,676	1074	4496.84	0.00449684	4.50	1,239,670
Total fuel consumption in GJ in Amyntaio UNIT II Power station (in 2018)						**8,652,021**

Table 20 Calculation of total fuel consumption (activity rate) in the Power Stations located in the Regional Unit of Florina

PPC Power stations in the Regional Unit of Florina	**Fuel (lignite) consumption in the year 2018 (in GJ)**
Melitis	16,863,271
Amyntaio Unit I	9,987,289
Amyntaio Unit II	8,652,021
TOTAL	**35,502,580**

The total emissions are calculated in Table 21.

Table 21 Pollutant emissions from the lignite-fired plants in the Regional Unit of Florina

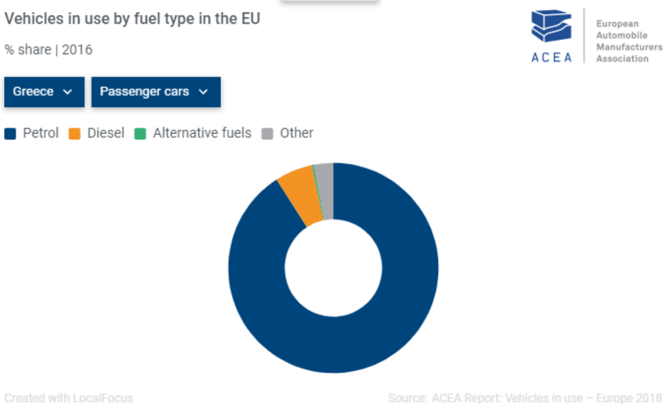
Pollutant	**$AR_{fuel\ consumption}$ (GJ)**	**Emission Factor (g/GJ)**	**$E_{pollutant}$ (tonnes)**
NOx	35,502,580	247	8,769.14
CO		8.7	308.87
NMVOC		1.4	49.70
SOx		1680	59,644.33
TSP		11.7	415.38
PM10		7.9	280.47
PM2.5		3.2	113.61

5. EMISSIONS FROM TRANSPORTATION

In Greece the collection of transport related statistical data is extremely problematic, since it is observed a significant lack of data sources regarding transportation and mobility activities. Therefore, several assumptions are provided in order to efficiently result to the Tier 1 method of EEA to be run herein.

According to European Automobile Manufacturers Association (2018) the vehicles in use by fuel type is presented to the below Figures 19, 20 and 21:

Figure 19 Vehicles in use by fuel type in EU[24]



Passenger Cars: Petrol: 91% - Diesel: 5.8% - Alternative fuels: 0.3% - Other: 3%

Petrol vehicles heavily dominate the passenger cars sector with diesel being the second most dominant source of fuel. Diesel vehicles became available to Greece's urban environments through the last 10 years and they have been extremely popular since then.

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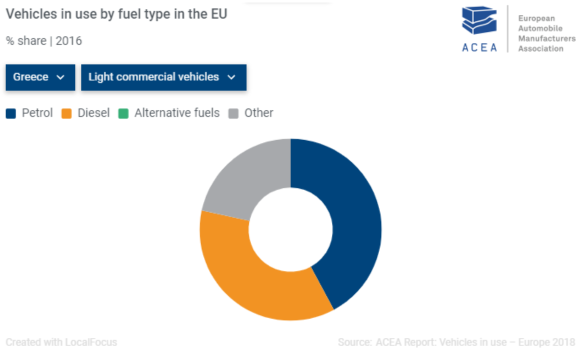
[24] *Automobile Manufacturers Association (2018)*

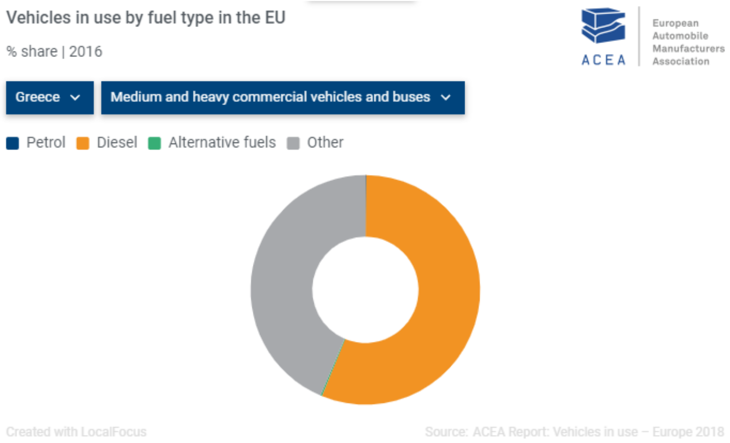
Figure 20 Vehicles in use by fuel type in Greece (% share) for the Light commercial vehicles[25]



Light commercial vehicles Petrol: 42.1% Diesel: 36.3% Other: 21.6%

Light commercial vehicles or else Light Duty Vehicles meet a high diversity of fuel sources. In this case petrol vehicles dominate the sector but diesel is extremely popular as well, due to the larger size of vehicles and their respective need in fuel consumption. Finally, other fuel sources such as LPG are widely used especially during the last 10-15 years where such vehicle alternations became available through after market solutions.

Figure 21 Vehicles in use by fuel type in Greece (% share) for the medium and heavy commercial vehicles and buses



Automobile Manufacturers Association (2018)

Medium and heavy commercial vehicles and buses Diesel: 56.1% - Other: 43.6% Petrol: 0.1% - LPG/Natural gas: 0.2%

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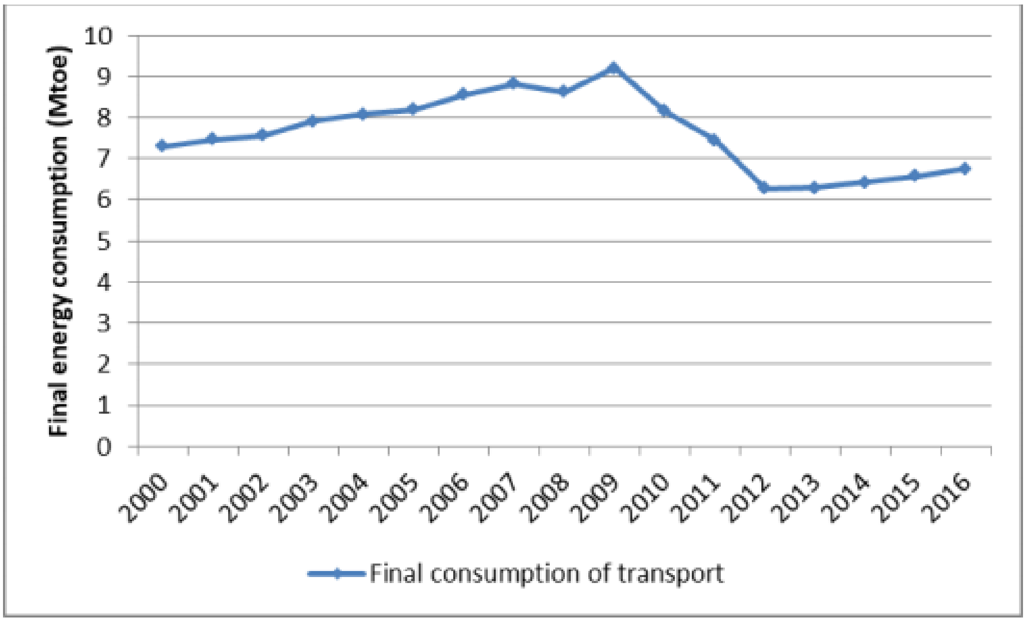
[25] *Automobile Manufacturers Association (2018)*

The energy consumption in Transport during the year 2016 was almost 6,8 Mtoe in Greece (see Figure 22). Using the population of Greece as indicator, in the Regional Unit of Florina (population 51,414 habitants) and the total population of Greece (10,8 million) – based on the Last census – so the assumption that is made regarding the energy consumption in transport is that the regional unit of Florina results to a fuel consumption of almost 0.0324 Mtoe (2016).

Figure 22 Energy Consumption in Transport in Greece[26]



Road transport (see Figure 23) has a share of 88% and obviously constitutes the bigger part of the final energy consumption through transport in Greece (2016).

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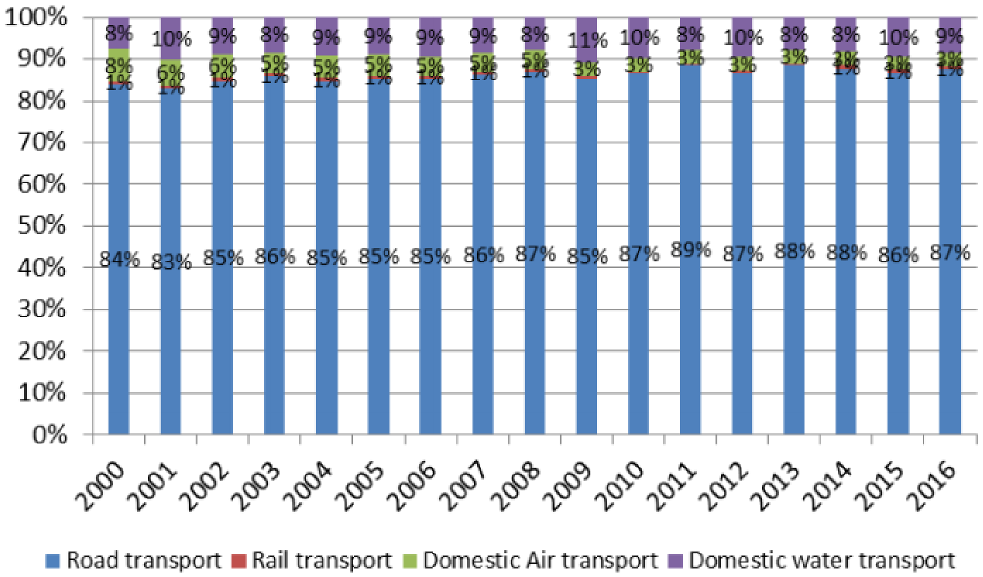
[26] *CRES/ENERGY SOURCES AND SAVING (2018)*

Figure 23 Share by mode in Transport 2000-2016[27]



Consequently, the total energy consumption in road transportation in the Regional Unit of Florina is 0.0285 Mtoe. In addition, regarding the mass of fuel consumption, and according to the National Inventory Report of Greece (2017), the fuel consumption from road transportation during 2015 was almost 2.300.000 tons of gasoline (petrol) and more specifically 1,800,000 from passenger cars, 240.000 from LDVs and 250.000 from motorcycles. Moreover, almost 2.120.000 tons of diesel, 1.070.000 tons from HDVs, 480.000 tons from LDVs, 290.000 tons from PCs, and 280.000 tons from buses. For Florina's Regional Unit case, assumingly the fuel consumption from road transport is approximately 6,545 ton of gasoline(petrol) and more specifically 4,788 from PCs, 1,393 from LCVs and 364 from motorcycles.

The aforementioned information is presented in Table 22.

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[27] *CRES/ENERGY SOURCES AND SAVING (2018)*

Table 22 Calculation of the fuel consumption in the Regional Unit of Florina

	PCs	**LCV***	**HDV****	**Motorcycles (L-category)**
Vehicles in Greece* **	5,282,695	672,031	698,420	1,583,491
Vehicles in the Regional Unit of Florina* **	14,053	3,900	3,978	2,303
Percentage of Regional Unit of Florina (share)	0.27%	0.58%	0.57%	0.15%
Petrol consumption in Greece (tons)	1,800,000	240,000	0	250,000
Diesel consumption in Greece (tons)	290,000	480,000	1,350,000	0
Petrol consumption in the Regional Unit of Florina (tons)******	4,788	1,393	0	364
Diesel consumption in the Regional Unit of Florina (tons)******	771	2,789	7,689	0
LPG consumption in the Regional Unit of Florina (tons)******	190	21	0	0

*Assuming (because of the lack of data) that 50% of total trucks are LDV

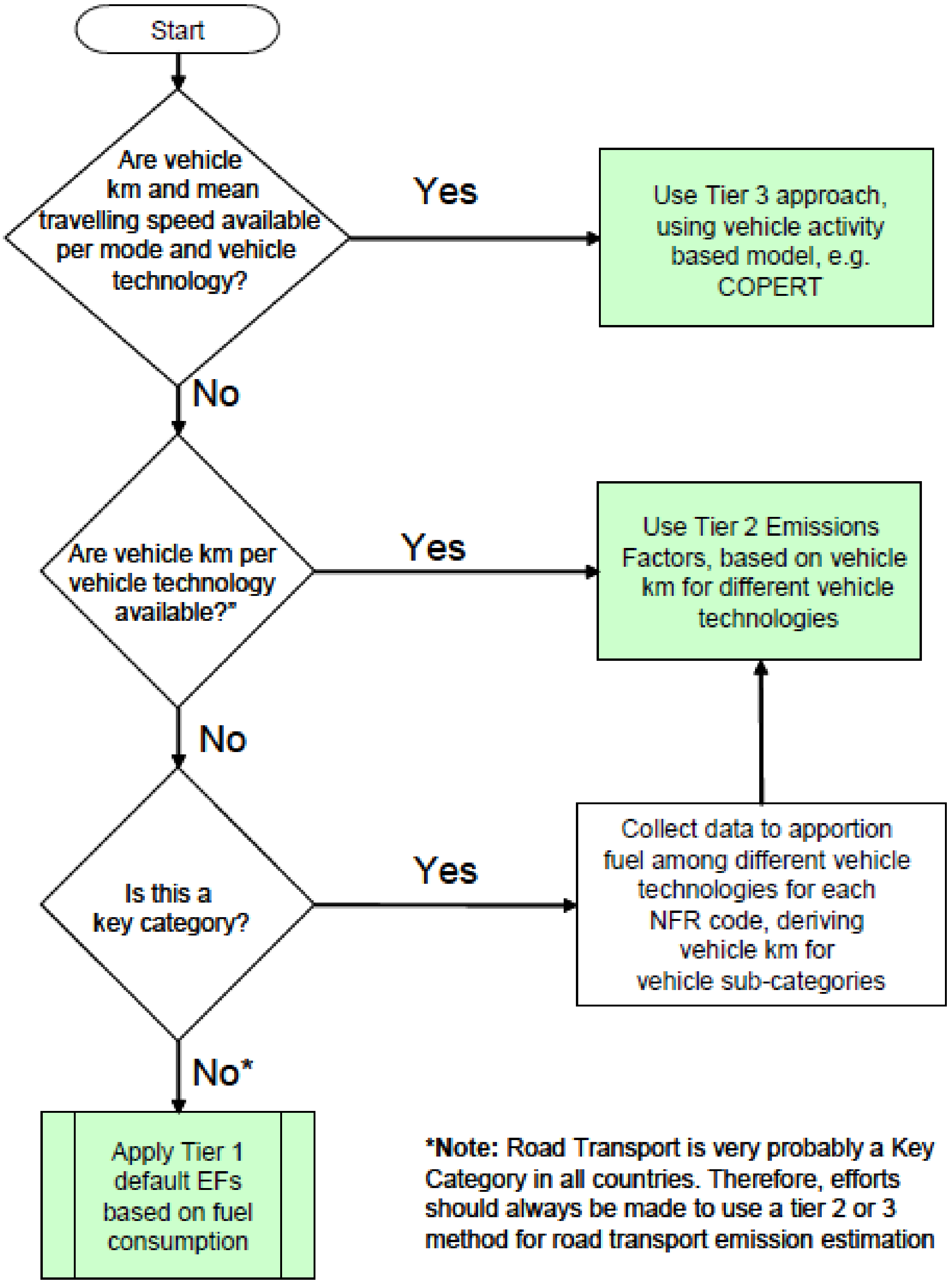
**If the total HDVs are the 50% of total tracks plus the buses

***Based on the Hellenic Statistical Agency (2018)

****Based on the respective share

*****According to the Automobile Manufacturers Association (2018), the EU average share of PCs in other and alternative fuels is 3,3%, therefore if the total consumption in petrol and diesel is 196.460 tons (96.7% share) that means the 3.3% share of LPG is 190 tons. Assuming by the same method, the LDVs CNG consumption, (and according to the Automobile Manufacturers Association (2018) which indicates that CNG EU average share in LDVs category is 1.3%) is 21 tons. Regarding the HDVs, Florina does not have available CNG providers so no CNG consumption occurs within the regional authority

Figure 24 Decision tree for exhaust emissions from road transport[28]



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[28] *EEA Passenger cars, Light commercial trucks, Heavy-duty vehicles including buses, Mopeds & motorcycles (2018)*

The Tier 1 approach (selected using decision tree-Figure 24) for exhaust emissions uses the following general equation:

$$E_i = \sum_j \left(\sum_m (FC_{j,m} \times EF_{i,j,m})\right)$$

Where:

E_i = emission of pollutant i [g],

$FC_{j,m}$ = fuel consumption of vehicle category j using fuel m [kg],

$EF_{i,j,m}$ = fuel consumption-specific emission factor of pollutant i for vehicle category j and fuel m [g/kg].

The vehicle categories considered are passenger cars (PCs), light commercial vehicles (LCV), heavy-duty vehicles (HDV) and L-category vehicles (etc. motorcycles). The emission factors have been selected and presented in Table 23.

Table 23 Selection of emission factors for transport

Category	**Fuel**	**CO (g/kg fuel)**	**NMVOC (g/kg fuel)**	**NO_x (g/kg fuel)**	**PM (g/kg fuel)**	**N_20 (g/kg fuel)**	**NH_3 (g/kg fuel)**
PC	Petrol	84.7	10.05	8.73	0.03	0.206	1.106
	Diesel	3.33	0.7	12.96	1.10	0.087	0.065
	LPG	84.7	13.64	15.20	0.00	0.089	0.080
LCV	Petrol	152.3	14.59	13.22	0.02	0.186	0.667
	Diesel	7.4	1.54	14.91	1.52	0.056	0.038
	LPG*	84.7	13.64	15.20	0.00	0.089	0.080
HDV	Diesel	7.58	1.92	33.37	0.94	0.051	0.013
L-category	Petrol	497.7	131.4	6.64	2.20	0.059	0.05

*Assumption for LPG emissions for Light Commercial Vehicles equal to PC LPG emissions. Due to unknown emissions for LCVs and LPG vehicles specifically, we assume these emissions as the ones of LPG private cars. It has to be noted that these emissions factors in reality are larger due to the fact that LCVs are larger vehicles with significantly higher fuel consumption in relation to private cars.

Emissions from Passenger Cars

Table 24 Calculation of Passenger Cars emissions for different pollutants

Emission Factors	**Fuel**	**CO (g/kg fuel)**	**NMVOC (g/kg fuel)**	**NOx (g/kg fuel)**	**PM (g/kg fuel)**	**N20 (g/kg fuel)**	**NH3 (g/kg fuel)**	**Fuel consumption (kg)**	**Correction factor**
Passenger Cars	**Petrol**	84.7	10.05	8.73	0.03	0.206	1.106	4788000	1000
	Diesel	3.33	0.7	12.96	1.1	0.087	0.065	771000	1000
	LPG	84.7	13.64	15.2	0	0.089	0.08	190000	1000
Pollutants (kg)		**CO (kg)**	**NMVOC (kg)**	**NO_x (kg)**	**PM (kg)**	**N_20 (kg)**	**NH_3 (kg)**		
Passenger Cars	**Petrol**	405,544	48,019	41799	144	986	5,296		
	Diesel	2,544	540	9,992	848	67	50		
	LPG	16,093	2,592	2,888	0	17	15		

Table 25 Road transport emissions from Passenger cars in the Regional Unit of Florina (2015)

Pollutants (tn)		**CO (tn)**	**NMVOC (tn)**	**NO_x (tn)**	**PM (tn)**	**N_20 (tn)**	**NH_3 (tn)**
Passenger Cars	Petrol	405.5	48	41.8	0.14	0.99	5.3
	Diesel	2.5	0.54	9.9	0.85	0.067	0.05
	LPG	16	2.6	2.9	0	0.017	0.015
	Total	434	51.1	54.6	0.99	1.07	5.37

Emissions from Light Commercial Vehicles

Table 26 Calculation of Light Commercial Vehicles emissions for different pollutants

Emission Factors	**Fuel**	**CO (g/kg fuel)**	**NMVOC (g/kg fuel)**	**NO_x (g/kg fuel)**	**PM (g/kg fuel)**	**N_20 (g/kg fuel)**	**NH_3 (g/kg fuel)**	**Fuel consumption (kg)**	**Correction factor**
LCV	Petrol	152.3	14.59	13.22	0.02	0.186	0.667	1393000	1000
	Diesel	7.4	1.54	14.91	1.52	0.056	0.038	2789000	1000
	LPG	84.7	13.64	15.2	0	0.089	0.08	21000	
Pollutants (kg)		**CO (kg)**	**NMVOC (kg)**	**NO_x (kg)**	**PM (kg)**	**N_20 (kg)**	**NH_3 (kg)**		
LCV	Petrol	212,154	20,324	18,415	28	259	929		
	Diesel	20,639	4,295	41,584	4,239	156	106		
	LPG	1,779	286	319	0	1.9	1.7		

Table 27 Road transport emissions from Commercial vehicles in the Regional Unit of Thessaloniki (2015)

Pollutants (tn)		**CO (tn)**	**NMVOC (tn)**	**NO_x (tn)**	**PM (tn)**	**N_20 (tn)**	**NH_3 (tn)**
LCV	**Petrol**	212	20.3	18.4	0.03	0.26	0.93
	Diesel	20.6	4.3	41.6	4.2	0.16	0.11
	LPG	1.8	0.29	0.32	0	0.002	0.002
	Total	234.4	24.89	60.32	4.23	0.42	1.04

Emissions from Heavy-duty Vehicles

Table 28 Road transport emissions from Heavy-duty Vehicles in the Regional Unit of Thessaloniki (2015)

Emission Factors	**Fuel**	**CO (g/kg fuel)**	**NMVOC (g/kg fuel)**	**NOx (g/kg fuel)**	**PM (g/kg fuel)**	**N20 (g/kg fuel)**	**NH3 (g/kg fuel)**	Fuel consumption (kg)	Correction factor
HDV	**Diesel**	152.3	14.59	13.22	0.02	0.186	0.667	7689000	1000
Pollutants (kg)		**CO (kg)**	**NMVOC (kg)**	**NO_x (kg)**	**PM (kg)**	**N_20 (kg)**	**NH_3 (kg)**		
HDV	**Diesel**	1,171,035	112,183	101,649	154	1430	5,129		

Table 29 Road transport emissions from Heavy Duty vehicles in the Regional Unit of Thessaloniki (2015)

Pollutants (tn)		CO (tn)	NMVOC (tn)	NO_x (tn)	PM (tn)	N_20 (tn)	NH_3 (tn)
HDV	Diesel	1171	112	101.6	0.15	1.4	5.1
	Total	1171	112	101.6	0.15	1.4	5.1

Note: Table 29 presents the diesel produced emissions from HDVs which result to the total emissions as well. CNG consumption is unavailable within Florina's regional authority but a small percentage of LPG HDV's may be in circulation but such data were not available.

Emissions from L-category vehicles

Table 30 Road transport emissions from L-category in the Regional Unit of Thessaloniki (2015)

Emission Factors	**Fuel**	**CO (g/kg fuel)**	**NMVOC (g/kg fuel)**	**NO_x (g/kg fuel)**	**PM (g/kg fuel)**	**$N_2$0 (g/kg fuel)**	**NH_3 (g/kg fuel)**	Fuel consumption (kg)	Correction factor
L-category	**Petrol**	497.7	131.4	6.64	2.2	0.059	0.05	364000	1000
Pollutants (kg)		**CO (kg)**	**NMVOC (kg)**	**NO_x (kg)**	**PM (kg)**	**$N_2$0 (kg)**	**NH_3 (kg)**		
L-category	**Petrol**	181,163	47,830	2,417	801	21.5	18.2		

Table 31 Road transport emissions from L-category in the Regional Unit of Thessaloniki (2015)

Pollutants (tn)		**CO (tn)**	**NMVOC (tn)**	**NO_x (tn)**	**PM (tn)**	**$N_2$0 (tn)**	**NH_3 (tn)**
L-category	Petrol	181.1	47.8	2.4	0.8	0.022	0.018
	Total	181.1	47.8	2.4	0.8	0.022	0.018

Table 32 below presents summary information on emissions through vehicles of all previously identified categories such as passenger cars, light commercial vehicles, heavy duty vehicles and motorcycles. Moreover, total emissions per factor are attributed to the area's square kilometers in order to calculate the total emissions in tones per km^2. Accordingly, Florina's regional unit area is 1,924km^2.

Table 32 Road transport emissions from all categories in the Regional Unit of Florina (2015)

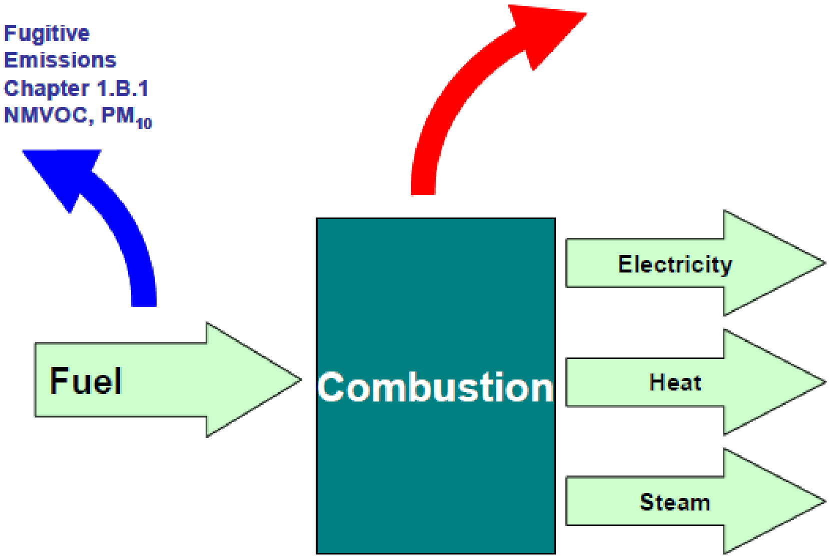
Pollutants (tn)	**CO (tn)**	**NMVOC (tn)**	**NO_x (tn)**	**PM (tn)**	**N_20 (tn)**	**NH_3 (tn)**
Passenger Cars	434	51.1	54.6	0.99	1.07	5.37
Light Commercial Vehicles	234.4	24.89	60.32	4.23	0.42	1.04
Heavy-duty Vehicles	1171	112	101.6	0.15	1.4	5.1
L-category	181.1	47.8	2.4	0.8	0.022	0.018
Total	**2,021**	**235.8**	**218.9**	**6.2**	**2.9**	**11.5**
Total emissions (tn/km^2)	1.05	0.12	0.11	0.003	0.0015	0.0059

6. EMISSIONS FROM RESIDENTIAL BUILDING HEATING

Emissions from smaller combustion installations are significant due to their numbers, different type of combustion techniques employed, and range of efficiencies and emissions. See process scheme in Figure 25. Many of them have no abatement measures nor low efficiency measures. In some countries, particularly those with economies in transition, plants and equipment may be outdated, polluting and inefficient. In the residential sector in particular, the installations are very diverse, strongly depending on country and regional factors including local fuel supply.

The small combustion installations are mainly intended for heating and provision of hot water in residential and commercial/institutional sectors (<50 kW).

Figure 25 Illustration of the main process in small combustion installations[29]



The combustion devices include:

Fireplaces

- ✓ Solid fuel fireplaces
- ✓ *Open fireplaces*
- ✓ *Partly-closed fireplaces*
- ✓ *Closed fireplaces*

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[29] *IPCC Guidelines for National Greenhouse Gas Inventories, 2006*

Stoves

- ✓ *Solid fuel stoves*
- ✓ *Conventional, traditional stoves*
- ✓ *Energy efficient conventional stoves*
- ✓ *Advanced combustion stoves*
- ✓ *Modern pellet stoves*
- ✓ *Masonry (heat accumulating) stoves*
- ✓ *Catalytic combustor stoves*
- ✓ *Liquid/gas-fuelled stoves*

Relevant pollutants are SO_2, NO_x, CO, NMVOC, particulate matter (PM), black carbon (BC), heavy metals, PAH, polychlorinated dibenzo-dioxins and furans (PCDD/F) and hexachlorobenzene (HCB). For solid fuels, generally the emissions due to incomplete combustion are many times greater in small appliances than in bigger plants. This is particularly valid for manually-fed appliances and poorly controlled automatic installations.

Emissions caused by incomplete combustion are mainly a result of insufficient mixing of combustion air and fuel in the combustion chamber (local fuel-rich combustion zone), an overall lack of available oxygen, too low temperature, short residence times and too high radical concentrations (Kubica, 1997/1 and 2003/1). The following components are emitted to the atmosphere as a result of incomplete combustion in small combustion installations: CO, PM and NMVOCs, NH_3 , PAHs as well as PCDD/F.

NH3 — small amounts of ammonia may be emitted as a result of incomplete combustion process of all solid fuels containing nitrogen. This occurs in cases where the combustion temperatures are very low (fireplaces, stoves, old design boilers). NH_3 emissions can generally be reduced by primary measures aiming to reduce products of incomplete combustion and increase efficiency.

TSP, PM_{10}, $PM_{2.5}$ — particulate matter in flue gases from combustion of fuels (in particular of solid mineral fuels and biomass) may be defined as carbon, smoke, soot, stack solid or fly ash.

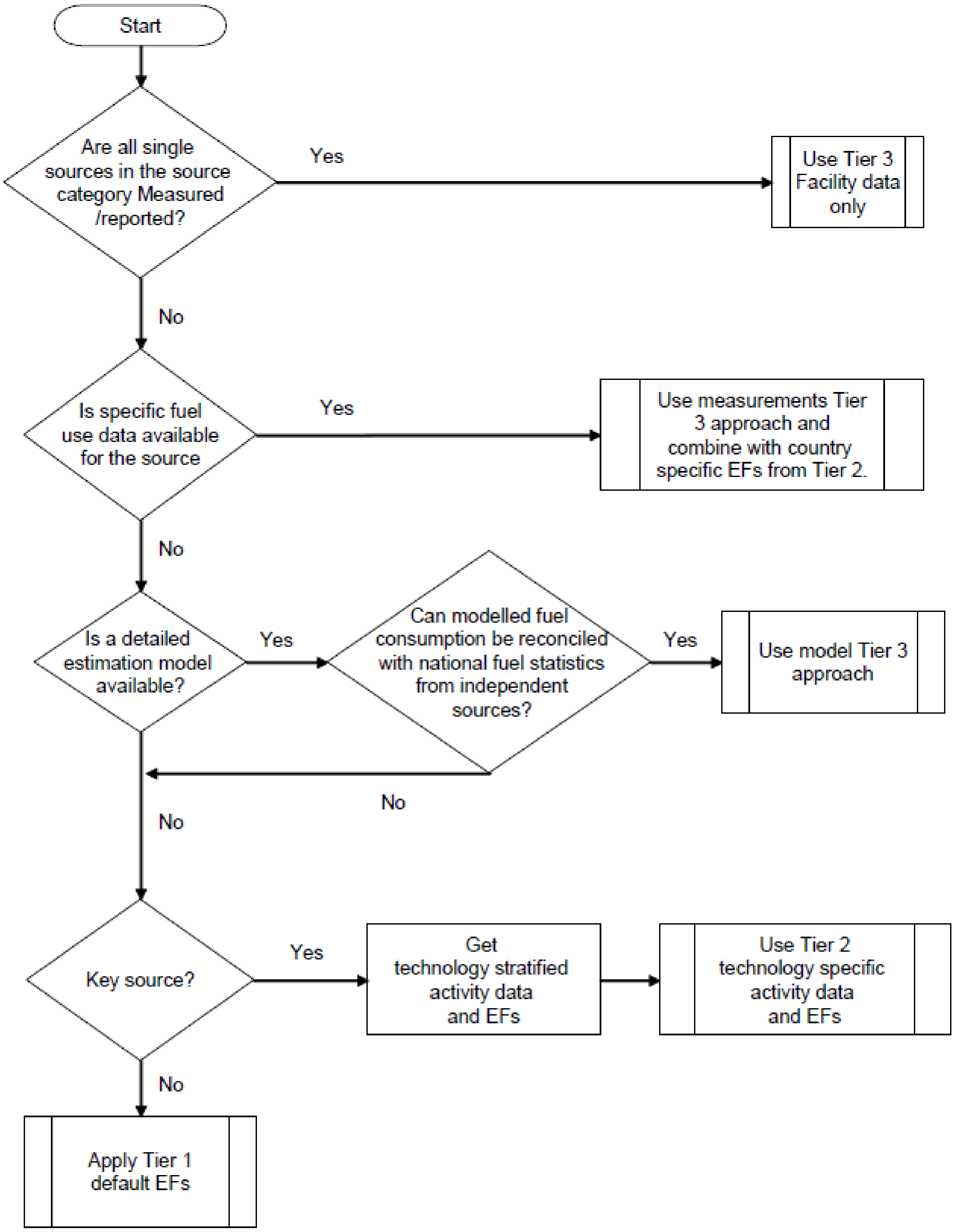
CO — carbon monoxide is found in gas combustion products of all carbonaceous fuels, as an intermediate product of the combustion process and in particular for under-stoichiometric conditions. CO is the most important intermediate product of fuel conversion to CO_2; it is oxidized to CO_2 under appropriate temperature and oxygen availability. Thus CO can be considered as a good indicator of the combustion quality. The mechanisms of CO formation, thermal-NO, NMVOC and PAH are, in general, similarly influenced by the combustion conditions. The emissions level is also a function of the excess air ratio as well as of the combustion temperature and residence time of the combustion products in the reaction zone. Hence, small combustion installations with automatic feeding (and perhaps oxygen 'lambda' sensors) offer favourable conditions to achieve lower CO emission. For example, the emissions of CO from solid fuelled small appliances can be several thousand ppm in comparison to 50–100 ppm for industrial combustion chambers, used in power plants.

NMVOC — for small combustion installations (e.g. residential combustion) emissions of NMVOC can occur in considerable amounts; these emissions are mostly released from inefficiently working stoves (e.g. wood-burning stoves). VOC emissions released from wood-fired boilers (0.510 MW) can be significant. Emissions can be up to ten times higher at 20 % load than those at maximum load (Gustavsson et al, 1993). NMVOC are all intermediates in the oxidation of fuels. They can adsorb on, condense, and form particles. Similarly as for CO, emission of NMVOC is a result of low combustion temperature, short residence time in oxidation zone, and/or insufficient oxygen availability. The emissions of NMVOC tend to decrease as the capacity of the combustion installation increases, due to the use of advanced techniques, which are typically characterized by improved combustion efficiency.

Sulphur oxides — in the absence of emission abatement, the emission of SO_2 is dependent on the sulphur content of the fuel. The combustion technology can influence the release of SO_2 with (for solid mineral fuels) higher sulphur retention in ash than is commonly associated with larger combustion plant.

Nitrogen oxides — emission of NOx is generally in the form of nitric oxide (NO) with a small proportion present as nitrogen dioxide (NO_2). Although emissions of NO_x are comparatively low in residential appliances compared to larger furnaces (due in part to lower furnace temperatures), the proportion of primary NO_2 is believed to be higher.

Figure 26 Decision tree for source category 1.A.4 Small Combustion



The Tier 1 approach (selected using decision tree-Figure 26) for process emissions from small combustion installations uses the general equation:

$$E_{\text{pollutant}} = AR_{\text{fuelconsumption}} \times EF_{\text{pollutant}}$$

Where:

$E_{\text{pollutant}}$ = the emission of the specified pollutant

$AR_{\text{fuelconsumption}}$ = the activity rate for fuel consumption

$EF_{\text{pollutant}}$ = the emission factor for this pollutant

There are three types of fuels used in the residencies in the Regional Unit of Florina: firewood, pellets & lignite

Emissions from biomass (firewood, pellets)

Table 33 Selection of the emission factors from the source category 1.A.4.b.i (Residential Plants). Fuel: Biomass

Pollutant	**Emission factor value (g/GJ)**
NO_X	50
CO	4000
NMVOC	600
SO_x	11
NH_3	70
TSP	800
PM10	760
PM2.5	740

According to the Forestry office of Florina, the Annual consumption of **firewood** for heating in residents of the Regional Unit of Florina is 40,000 tonnes (see deliverable D3.1). The calorific value of firewood is estimated according to level of moisture of the wood etc. For the purpose of this inventory, we will calculate the «calorific value of wood as equal to 16.2 Gjoules/ton of dry matter»[30]. Therefore, the **Calorific value of 40,000 tonnes firewood equals 648,000 GJ.**

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[30] http://w.astro.berkeley.edu/~wright/fuel_energy.html

According to estimations from local pellet producers and distributors, the Annual consumption of **pellets** for heating in residents of the Regional Unit of Florina in 2019 was 5,000 tonnes (see deliverable D3.1). For the purpose of this inventory, we will calculate the «calorific value of pellet as equal to 17.5 GJ/tons based on 7 % water content»[31]. Therefore, the **Calorific value of 5,000 tonnes pellet equals 87500 GJ**.

Total energy from Biomass used for Residential Heating in the Regional Unit of Florina: **735,500 GJ.** The total emissions are given in Table 34.

Table 34 Calculation of emissions for each pollutant by the residential building heating using biomass in the Regional Unit of Florina

Pollutant	**NO_X**	**CO**	**NMVOC**	**SO_x**	**NH_3**	**TSP**	**PM10**	**PM2.5**
Emission factor (g / GJ)	50	4000	600	11	70	800	760	740
AR for fuel consumption (GJ)	735,500							
Epollution (ton)	36.78	2942	441.30	8.09	51.49	588.40	558.98	544.27

Emissions form Lignite

Table 35 Selection of the emission factors for source category 1.A.4.b.i (Residential Plants). Fuel: Hard coal and brown coal

Pollutant	**Emission factor value (g/GJ)**
NO_X	110
CO	4600
NMVOC	484
SO_x	900

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[31] Danish wood pellet survey https://unstats.un.org/oslogroup/meetings/og-09/docs/day2-session7-Danish_Wood_Pellet_Survey.pdf

NH_3	0.3
TSP	444
PM10	404
PM2.5	398

According to the Forestry office of Florina, the Annual consumption of **lignite** for heating in residents of the Regional Unit of Florina (mainly in villages) in 2019 was 5,000 tonnes (see deliverable D3.1). Lignite deposits in Greece have LHV (Lower Heating Value) of 1150 kcal/kg and thus, "1 tonne of lignite gives out 4.82 GJ of energy"[32]. Therefore the **5,000 tonnes used in the Regional Unit of Florina give out 24,100 GJ of energy.** The total emissions are given in Table 36.

Table 36 Calculation of emissions for each pollutant by the residential building heating using lignite in the Regional Unit of Florina

Pollutant	**NO_X**	**CO**	**NMVOC**	**SO_x**	**NH_3**	**TSP**	**PM10**	**PM2.5**
Emission factor (g / GJ)	110	4600	484	900	0.3	444	404	398
AR for fuel consumption (GJ)	24,100							
Epollution (ton)	2.65	110.86	11.66	21.69	0.01	10.70	9.74	9.59

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[32] Tsakalakis, Ioakeim, "Power generation methods using conventional fossil fuels", April 2020

7. EMISSIONS FROM AGRICULTURE

According to chapter **3.D Crop production and agricultural soils** of the “EMEP/EEA air pollutant emission inventory guidebook 2019”, there are many sections of agriculture that can cause emissions into the atmosphere. Those include:

- Emissions that arise during and after the application of inorganic N fertilisers to land
- Emissions from application of organic matter to the soils, i.e. livestock manure, sewage sludge, digestate, compost, crop residues.
- Urine and dung deposited by grazing livestock
- Indirect emissions resulting from the deposition of N emitted from managed soils
- Farm-level agricultural operations including storage, handling and transport of agricultural products
- Off-farm storage, handling and transport of bulk agricultural products
- Ammonia emissions arising from standing or ‘cultivated’ crops. This source is distinct from emissions of NH_3 that arise from the application of fertiliser to crops.

The main four sources of emissions from crop production and agricultural soils are the following

- mineral N fertiliser, livestock manure and organic waste application (NH_3);
- soil microbial processes (NO);
- crop processes (NH_3 and NMVOCs);
- soil cultivation and crop harvesting (PM).

Ammonia NH_3

NH3 volatilisation occurs when NH_3 in solution is exposed to the atmosphere. The extent to which NH3 is emitted depends on the chemical composition of the solution (including the concentration of NH_3), the temperature of the solution, the surface area exposed to the atmosphere and the resistance to NH_3 transport in the atmosphere.

Although N fertilisers are normally applied as solids, there is usually sufficient moisture in the soil or air for the fertiliser to dissolve. High pH favours the volatilisation of NH3 from many N fertilisers, so if the soil is acidic (i.e. pH values of less than 7), the degree of volatilisation will tend to be small. In contrast, if the soil is alkaline, the potential for volatilisation will tend to be larger. In general, NH_3 emissions will increase with increasing temperature. Direct emissions of NH_3 occur from only fertilisers containing N as ammonium (NH4+) or if, as for urea, the fertiliser is rapidly decomposed to NH3. Those fertilisers containing N as only nitrate (NO3–) are not direct sources of NH3 but may increase NH_3 emissions via crop foliage.

NH3 emissions that occur in the 7 to 10 days after N fertiliser application include some emissions from the crop canopy, because of the increase in the concentration of N in the leaves of crops after the addition of fertiliser N. Emissions from the crop canopy that occur at this time cannot be distinguished from emissions that take place directly from applied N fertiliser and are included with N fertiliser emissions. Once direct NH3 emissions after N fertiliser application have ceased, there may be a net emission of NH3, or net deposition, depending on many factors, including the N status of the plant; the crop or plant growth stage; stresses such as drought and disease; the time of day; and the ambient NH3 concentration. Later in the season, during grain filling and senescence, net NH3 emissions from standing crops can occur. The emission of NH_3 from crops is a complex process as it is influenced by both the concentration of NH_3 in the air and environmental conditions. NH3 emissions occur when organic manures (livestock manure, sewage sludge and other organic wastes) are applied to land. As for N fertilisers, these emissions occur because a proportion of the N is present as ammonium in the liquid fraction.

NH3 emissions may also be emitted from crop residues as they senesce and break down. The degradation of proteins within the residues leads to the formation of NH4+. Senesced residues, such as cereal straw, are not considered to be sources of NH3 emissions.

The difficulty in the estimation of NH3 flux from standing crops and crop residues is increased by limited measurements of NH3 flux, especially in field environments and for whole seasons or years. As a consequence, it has not yet been possible to develop a robust and usable methodology to calculate these emissions.

Nitric Oxide NO

In agricultural soils, where pH is likely to be maintained above 5.0, nitrification is considered to be the dominant pathway of NO emission. Nitrification is the process by which microorganisms oxidise NH4+-N to NO3–-N. The main determinants of NO production during crop production and in agricultural soils are mineral N concentration, temperature, soil carbon (C) concentration and soil moisture.

Increased nitrification is likely to occur after the application of fertilisers containing NH4+, soil cultivation and the incorporation of crop residues. Activities such as tillage and incorporation are considered to increase NO emissions by a factor of four, for periods of between 1 and 3 weeks.

The 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 2006) account for indirect N2O emissions, i.e. those that result from the deposition of N emitted as NH3 from N fertilisers, organic wastes, urine and dung N deposited on land grazed by livestock; N in crop residues (above and below ground), including N-fixing crops and forage/pasture renewal returned to soils; and N mineralisation associated with loss of soil organic matter resulting from change of land use or management on mineral soils. Since NO is produced as an intermediate product of nitrification and denitrification, indirect emissions should be accounted for here. However, it has not yet been possible to develop a methodology.

Non-methane volatile organic compounds NMVOCs

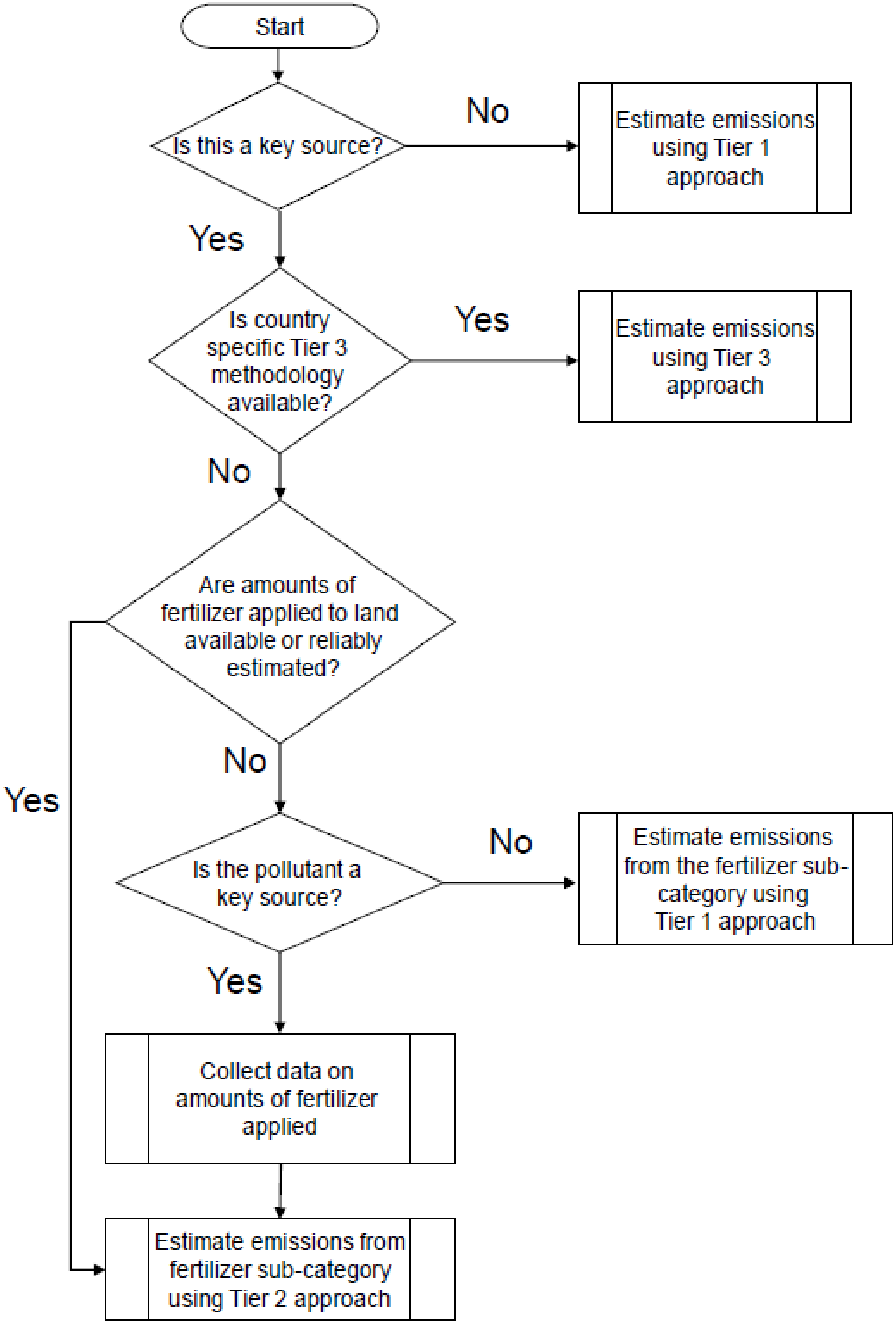
Emissions from crops may arise to attract pollinating insects, eliminate waste products or as a means of losing surplus energy. The NMVOCs emitted have proven difficult to quantify in atmospheric samples. Factors that can influence the emission of NMVOCs include temperature and light intensity, plant growth stage, water stress, air pollution and senescence.

Particulate matter PM

The main sources of PM emissions from soil result from soil cultivation and crop harvesting, which together account for > 80 % of total PM10 emissions from tillage land (CEIP, 2015). These emissions originate at the sites at which the tractors and other machinery operate, and are thought to consist of a mixture of organic fragments from the crop and soil mineral and organic matter. There is considerable settling of dust close to the sources and washing out of fine particles by large particles. Field operations may also lead to the re-suspension of dust that has already settled (re-entrainment). Emissions of PM are dependent on climatic conditions, and in particular the moisture of the soil and crop surfaces. Emissions of PM vary according to the following:

- the type of crop;
- the physical properties of the particles;
- the origin of the particles, i.e. soil, plant or machinery;
- the meteorological conditions of the soil and/or produce before and during the operation (wind speed, temperature, rain fall, humidity);
- the type of operation;
- the parameters of the machinery (working speed, working capacity, working surface).

Figure 27 Decision tree for source category 3.D Crop production and agricultural soils



At this inventory we will use Tier 1 methodology (selected using decision tree-Figure 27) to estimate NH_3, NO, NMVOC and PM emissions from crop production and agricultural soils.

NH_3 and NO emissions from crop production and agricultural soils

The Tier 1 approach for NH3 and NO emissions from crop production and agricultural soils uses the general equation:

$$E_{pollutant} = AR_{N\_applied} \times EF_{pollutant}$$

where:

$E_{pollutant}$ = amount of pollutant emitted (kg a^{-1}),

$AR_{N\_applied}$ = amount of N applied in fertiliser or organic waste (kg a^{-1}),

$EF_{pollutant}$ = EF of pollutant (kg kg^{-1}).

We have estimated the amount of N applied in fertiliser (kg a^{-1}) in the land of the Regional Unit of Florina in Tables 37, 38, 39 below.

Table 37 Calculation of kg of N fertilizer per stremma per year for the Fruit and berry plantations of temperate climate in the Regional Unit of Florina

FRUIT AND BERRY PLANTATIONS OF TEMPERATE CLIMATE in the Regional Unit of Florina			
Type of trees	**Number of trees**[33]	**%**	**Kg of N fertilizer per stremma per year (range)**
Peaches - Nectarines	663,566	84%	15-20 kg
Apples	411,520		15-20 kg
Cherries	171,440	13%	5-13 kg
Pears	28,039	3%	10-15 kg[34]
Apricots	7,233		10-15 kg
TOTAL	1,281,798	100%	
kg of N fertilizer per stremma per year: 16.25 (84% x 17.5 + 13% x 9 + 3% x 12.5)			

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[33] 2016 Farm Structure Survey of the Hellenic Statistical Authority

[34] http://www.humofert.gr/el/component/eshop/catalog/item/kalliergeies/epaggelmaties/31-miloeidi/343-ahladia.html

Table 38 Calculation of kg of N fertilizer per stremma per year for the Fruit and berry plantations-nuts in the Regional Unit of Florina

FRUIT AND BERRY PLANTATIONS – NUTS in the Regional Unit of Florina			
	Number of trees in the Regional Unit of Florina[35]	%	Kg of N fertilizer per stremma per year (range)
walnuts	58,837	37.3%	14-16 kg[36]
almonds	57,285	36.3%	12-15 kg[37]
chestnuts	38,352	24.3%	9-12 kg[38]
Hazelnuts	2,854	1.8%	10-12 kg[39]
pomegranates	346	0.22%	9-13.5 kg[40] (90 trees per stremma[41], 100-150 gr per tree per year)
Figs for fresh figs	80	0.05%	3.6-7.2 kg[42] (35-37 trees per stremma[43], 100-200gr per tree per year)
TOTAL	157,754	100%	
kg of N fertilizer per stremma per year: **13.27** (37.3% x 15 + 36.3% x 13.5 + 24.3% x 10.5 + 1.8% x 11 +0.22% x 11.25 +0.05% x 5.4)			

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[35] 2016 Farm Structure Survey of the Hellenic Statistical Authority

[36] https://www.fytorio-olympos.gr/el/kalliergeia-karydias

[37] http://www.agroekfrasi.gr/kaliergeia-amygdalias/

[38] https://core.ac.uk/download/pdf/132822138.pdf

[39] http://www.imathiotikigi.gr/index.php/kalliergies/item/2544-fountoukia-odigos-kalliergeias-kai-poikilies

[40] http://www.naevias.gr/files8/Η%20ΚΑΛΛΙΕΡΓΕΙΑ%20ΤΗΣ%20ΡΟΔΙΑΣ(ΠΑΠΑΚΩΣΤΑΝΤΙΝΟΥ).pdf

[41] shorturl.at/imASZ

[42] http://nestor.teipel.gr/xmlui/bitstream/handle/123456789/14081/STEG_THEKA_00301_Medium.pdf?sequence=1

[43] https://www.sykabrantitsas.com/%CE%B7-%CF%83%CF%85%CE%BA%CE%B9%CE%AC/

Table 39 Calculation of amount of N applied in fertilizer per year for all cultivations in the Regional Unit of Florina

Cultivations	**Area (stremma)**[44]	**Kg of N fertilizer per stremma per year (range available in bibliography)**	**kg of N fertilizer per stremma per year**	**amount of N applied in fertiliser per year (kg a^{-1})**
CEREALS FOR THE PRODUCTION OF GRAIN	229,290	12-16 kg[45]	14 kg	3,210,060 kg
PULSES FOR THE PRODUCTION OF GRAIN	17,021	beans 5-15 kg Lentils 6kg chickpeas 4-6 kg [46]	10 kg (as beans is the most widespread)	170,210 kg
POTATOES	3,361	20-30kg	25 kg	84,025 kg
SUGAR BEET	1,776	8-14 kg[47]	11 kg	19,536 kg
INDUSTRIAL PLANTS	23,756	cotton 12-16 kg[48]	14 kg	332,584 kg
FORAGE PLANTS	112,118	oat 5kg barley 8-11 Kg[49]	5 kg (as oat is the most widespread)	560,590 kg
OTHER ARABLE LAND CROPS	206	Same as cereals	14 kg	2,884 kg
OLIVE PLANTATIONS	33	4-12 kg	8 kg	264 kg
FRUIT AND BERRY	18,694		16.25 kg (see table above)	303,777.50 kg

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[44] 2016 Farm Structure Survey of the Hellenic Statistical Authority

[45] https://www.yara.gr/threpsi-lipansi/lipansi-sitari/vasiki-lipansi-sitari/

[46] https://www.afs.edu.gr/dyn/userfiles/files/book_%CE%BF%CC%81%CF%83%CF%80%CF%81%CE%B9%CE%B1_low.pdf

[47] http://nefeli.lib.teicrete.gr/browse/steg/fp/2005/PapageorgiouKonstantinos/attached-document/2005Papageorgiou.pdf

[48] https://www.ypaithros.gr/ekdoseis/odigos-lipansis-fytoprostasias-9-kalliergion/#two

[49] https://www.ypaithros.gr/ekdoseis/kalliergeia-ktinotrofika-fita-zootrofes/

PLANTATIONS OF TEMPERATE CLIMATE				
FRUIT AND BERRY PLANTATIONS - NUTS	4,570		13.27 kg (see table above)	60,643.90 kg
VINEYARDS	10,760	25 kg[50]	25 kg	
TOTAL	**421,585**			**5,013,574.40 kg**

The emission factors are given in Table 40 and the total calculation in Table 41.

Table 40 Tier 1 EFs for source category "3.D Crop production and agricultural soils" (NH_3, NO)

Pollutant	**Emission Factor (kg kg^{-1})**
NH_3 from N fertilizer	0.05 kg NH3 kg^{-1} fertiliser N applied
NO from N applied in fertilizer, manure and excreta	0.04 kg NO2 kg^{-1} fertiliser and manure N applied

Table 41 Emissions from agriculture (NH_3 & NO) in the Regional Unit of Florina

Pollutant	**$AR_{N\_applied}$ (kg a^{-1})**	**Emission Factor (kg kg^{-1})**	**$E_{pollutant}$ (kg per year)**	**$E_{pollutant}$ (tn per year)**
NH_3 from N fertilizer	5,013,574.4	0.05 kg NH3 kg^{-1} fertiliser N applied	250,679	250.68
NO from N applied in fertilizer, manure and excreta		0.04 kg NO2 kg^{-1} fertiliser and manure N applied	200,543	200.54

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[50] https://bit.ly/2xABuk5

NMVOCs and PM emissions from crop production and agricultural soils

The Tier 1 approach for NMVOC and PM emissions from crop production and agricultural soils uses the general equation:

$$E_{pollutant} = AR_{area} \times EF_{pollutant}$$

where:

$E_{pollutant}$ is the amount of pollutant emitted (in kg a–1);

AR_{area} is the area covered by crop (in ha);

$EF_{pollutant}$ is the EF of pollutant (in kg ha–1 a–1).

The emission factors as giver in Table 42 Tier 1 EFs for source category EMEP/EEA air pollutant emission inventory guidebook 2019 are the following:

Table 42 Tier 1 EFs for source category "3.D Crop production and agricultural soils" (NMVOC, PM_{10}, $PM_{2.5}$)

Pollutant	**Emission Factor (kg ha–1)**
NMVOC from standing crops	0.86
PM_{10} from agricultural operations	1.56
$PM_{2.5}$ from agricultural operations	0.06

The value of ARarea is equated to the utilised agricultural area (UAA), which includes all cropland, permanent pasture and rough grazing land. According to the 2009 census of the Hellenic Statistical Authority in agriculture and livestock, **the area covered by crop (in ha) (utilised agricultural area (UAA), which includes all cropland, permanent pasture and rough grazing land) in the Regional Unit of Florina is 49,100 ha.** Total emissions are given in Table 43.

Table 43 Emissions from agriculture (NMVOCs & PM) in the Regional Unit of Florina

Pollutant	**AR_{area} (ha)**	**Emission Factor (kg ha–1)**	**$E_{pollutant}$ (kg per year)**	**$E_{pollutant}$ (tn per year)**
NMVOC from standing crops	49,100	0.86	42,226	42.23
PM10 from agricultural operations		1.56	76,596	76.6
PM2.5 from agricultural operations		0.06	2,946	2.95

8. EMISSIONS FROM LIVESTOCK

Ammonia (NH3) emissions lead to the acidification and eutrophication of natural ecosystems. Ammonia may also form secondary particulate matter (PM). Nitric oxide (NO) and non-methane volatile organic compounds (NMVOCs) are involved in the formation of ozone, which near the surface of the Earth can have an adverse effect on human health and plant growth. Particulate emissions also have an adverse impact on human health.

Emissions of NH_3, NO and NMVOCs arise from the excreta of agricultural livestock deposited in and around buildings and collected as liquid slurry, solid manure or litter-based farmyard manure (FYM). In this chapter solid manure and FYM are treated together as solid. Those emissions take place from buildings housing livestock and outdoor yard areas, from manure stores, following land spreading of manures and during grazing. Emissions of PM arise mainly from feed, and also from bedding, animal skin or feathers, and take place from buildings housing livestock. Emissions of nitrous oxide (N_2O) also occur and are accounted where necessary for accurate estimation of NH_3 and NO, but are not reported here, being a greenhouse gas.

There are five main sources of emissions from animal husbandry and manure management:

- livestock feeding (PM)
- livestock housing and holding areas (NH_3, PM, NMVOCs)
- manure storage (NH_3, NO, NMVOCs)
- field-applied manure (NH_3, NO, NMVOCs)
- manure deposited during grazing (NH_3, NO, NMVOCs)

See the process scheme in Figure 28.

Figure 28 Process scheme for emissions resulting from livestock feeding, livestock excreta and manure management

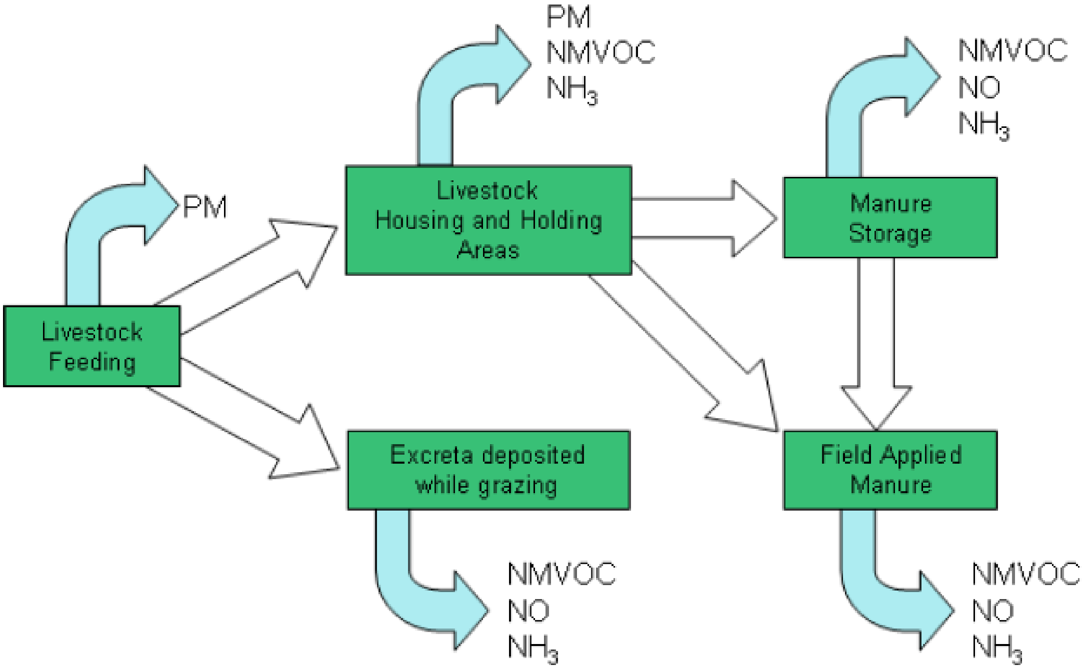
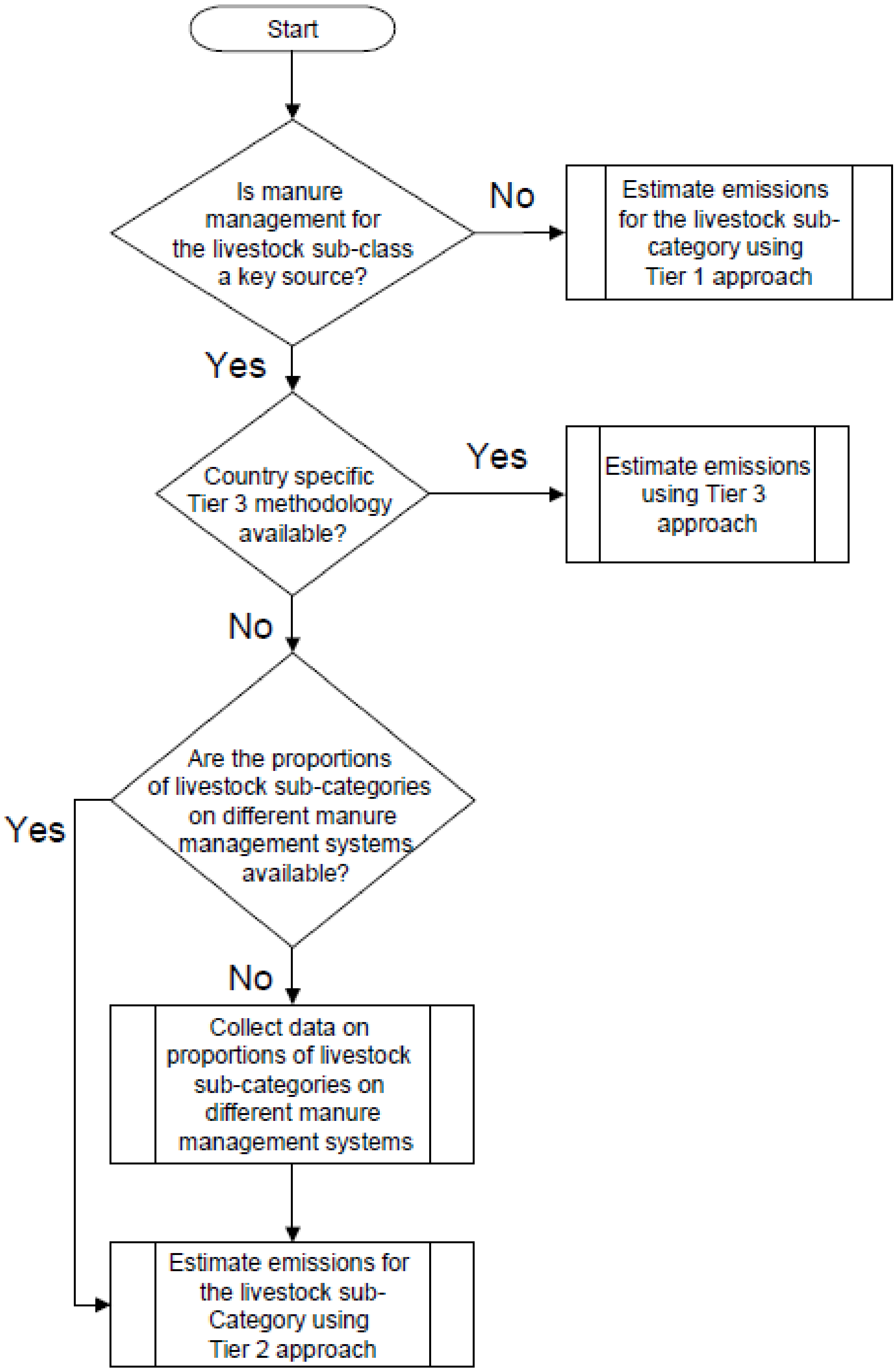


Figure 29 Decision tree for source category 3B Manure management



The Tier 1 method (selected using decision tree-Figure 29) entails multiplying the average annual population (AAP) in each livestock class; by a single default EF, expressed as kg AAP^{-1} a^{-1} NH_3. This EF includes emissions during grazing for ruminant livestock and emissions following spreading of manures for all livestock categories.

The livestock categories that identified from the inventories of the Hellenic Statistical Agency (2017) are:

- Dairy cattle
- Sheep
- Swine
- Goats

To calculate the emissions using Tier 1 methodology, the following steps are taken:

- **Step 1:** Define appropriate livestock categories and obtain the annual average number of animals in each category. The aim of this categorisation is to group types of livestock that are managed similarly.
- **Step 2:** Decide for each cattle or pig livestock category whether manure is typically handled as slurry or solid.
- **Step 3:** Find the default EF for each livestock category from subsection 3.3.2 of the guide in chapter 3B Manure Management.
- **Step 4:** Calculate the pollutant emissions ($E_{pollutant\_animal}$) for each livestock category, using the corresponding annual average population for each category (AAP_{animal}) and the relevant EF ($EF_{pollutant\_animal}$), as follows:

$$E_{pollutant\_animal} = AAP_{animal} \cdot EF_{pollutant\_animal}$$

Where AAP_{animal} = number of animals of a particular category that are present, on average, within the year.

Step 1

Four livestock categories are mainly present in the Regional Unit of Florina. The average number of animals in each category for the year 2017 was:

Number of Dairy Cattle (2017) = 4,901

Number of Sheep (2017) = 108,479

Number of Swine (2017) = 1,779

Number of Goats (2017) = 26,858

Step 2

For all categories the manure is typically handled as solid.

Step 3

Selection of emission sources in Table 44.

Table 44 Emission factors choice for each livestock category

	Emission Factors					
(Solid manure)	**NH_3 (kg a^{-1} AAP^{-1} NH_3)**	**NO_2 (kg a^{-1} AAP^{-1} NO_2)**	**NMVOC (kg AAP^{-1} a^{-1})**	**TSP (kg AAP^{-1} a^{-1})**	**PM_{10} (kg AAP^{-1} a^{-1})**	**$PM_{2.5}$ (kg AAP^{-1} a^{-1})**
Dairy cattle	26.4	0.752	8.047	1.38	0.63	0.41
Sheep	1.4	0.012	0.169	0.14	0.06	0.02
Swine	15.1	0.471	1.704	0.62	0.17	0.01
Goats	1.4	0.012	0.542	0.14	0.06	0.02

Step 4

Calculation of the pollutant emission using the following equation:

$$E_{\text{pollutant\_animal}} = AAP_{\text{animal}} \cdot EF_{\text{pollutant\_animal}}$$

Where AAP_{animal} = number of animals of a particular category that are present, on average, within the year. The total emissions are given in tables 45, 46, 47, 48, 49 and 50.

Table 45 Emissions of NH_3 from livestock manure in the Regional Unit of Florina

	AAP (2017)	**NH_3 (kg a^{-1} AAP^{-1} NH_3)**	**Emission NH_3 (kg per year)**	**Emission NH_3 (tonnes per year)**
Dairy cattle	4,901	26.4	129,386.40	129.39
Sheep	108,479	1.4	151,870.60	151.87
Swine	1,779	15.1	26,862.90	26.86
Goats	26,858	1.4	37,601.20	37.60
TOTAL Emission of NH_3 from livestock manure				**345.72 tonnes**

Table 46 Emissions of NO_2 from livestock manure in the Regional Unit of Florina

	AAP (2017)	NO_2 (kg a^{-1} AAP^{-1})	Emission NO (kg per year)	Emission NO (tonnes per year)
Dairy cattle	4,901	0.752	3,685.55	3.69
Sheep	108,479	0.012	1,301.75	1.30
Swine	1,779	0.471	837.91	0.84
Goats	26,858	0.012	322.30	0.32
TOTAL Emission of NO from livestock manure				**6.15 tonnes**

Table 47 Emissions of NMVOCs from livestock manure in the Regional Unit of Florina

	AAP (2017)	NMVOCs (kg AAP^{-1}a^{-1})	Emission NMVOCs (kg per year)	Emission NMVOCs (tonnes per year)
Dairy cattle	4,901	8.047	39,438.35	39.44
Sheep	108,479	0.169	18,332.95	18.33
Swine	1,779	1.704	3,031.42	3.03
Goats	26,858	0.542	14,557.04	14.56
TOTAL Emission of NMVOCs from livestock manure				**75.36 tonnes**

Table 48 Emissions of TSP from livestock manure in the Regional Unit of Florina

	AAP (2017)	**TSP (kg AAP^{-1} a^{-1})**	**Emission TSP (kg per year)**	**Emission TSP (tonnes per year)**
Dairy cattle	4,901	1.38	6,763.38	6.76
Sheep	108,479	0.14	15,187.06	15.19
Swine	1,779	0.62	1,102.98	1.10
Goats	26,858	0.14	3,760.12	3.76
TOTAL Emission of TSP from livestock manure				**26.81 tonnes**

Table 49 Emissions of PM_{10} from livestock manure in the Regional Unit of Florina

	AAP (2017)	**PM_{10} (kg AAP^{-1} a^{-1})**	**Emission PM_{10} (kg per year)**	**Emission PM_{10} (tonnes per year)**
Dairy cattle	4,901	0.63	3,087.63	3.09
Sheep	108,479	0.06	6,508.74	6.51
Swine	1,779	0.17	302.43	0.30
Goats	26,858	0.06	1,611.48	1.61
TOTAL Emission of PM_{10} from livestock manure				**11.51 tonnes**

Table 50 Emissions of $PM_{2.5}$ from livestock manure in the Regional Unit of Florina

	AAP (2017)	**$PM_{2.5}$ (kg AAP^{-1} a^{-1})**	**Emission $PM_{2.5}$ (kg per year)**	**Emission $PM_{2.5}$ (tonnes per year)**
Dairy cattle	4,901	0.41	2,009.41	2.01
Sheep	108,479	0.02	2,169.58	2.17
Swine	1,779	0.01	17.79	0.02
Goats	26,858	0.02	537.16	0.54
TOTAL Emission of $PM_{2.5}$ from livestock manure				**4.73 tonnes**

9. ACTIVITIES WITH NEGLIGIBLE INFLUENCE ON AIR QUALITY

There are further activities in the Regional Unit of Florina but without influencing the emission inventory or with negligible effect. Those include:

- Beekeeping, Production & Commercial Development of Honey and Bee Products
- Logging/forestry (beech, oak, walnut)
- Hunting
- Fishing
- Small manufacturing units where cooking or putrefaction is not involved, like traditional making of sweetspoons, jam and compost, as well as woven.
- Pasteurisation of milk and production of cheeses (example: FAGE Amynteou milk pasteurization factory, small cheese-making plants and DELTA milk freezer unit)
- Wastewater treatment plant of Florina
- Water bottling industries

For more information, please refer to deliverable 3.1.1.

10. TRANSBOUNDARY POLLUTION

The Regional Unit of Florina receives transboundary emissions from its adjacent Regional Units (Kastoria, Kozani, Pella), as well Albania and North Macedonia.

From adjacent Regional Units

The **management of the waste** of the Regional Unit of Florina is being taking care from the company DIADYMA S.A. (http://www.diadyma.gr/), located on the 6th km of Kozani-Ptolemaida road. The company was founded in 1996 to serve the needs for Waste Management in the area, according to the Strategic Plan approved by the Regional Council in 1997. The company's major task is the design, development & operation of the regional Integrated Waste Management System (IWMS) of Western Macedonia (61 municipalities, 300,000 residents). Shareholders are the Municipalities of Grevena, Kastoria, Florina, Kozani & Ptolemaida and the Local Unions of the municipalities of the four prefectures of the region. There is a «waste transfer station» within the Regional Unit of Florina that transfers 10,000 tonnes of waste per month to DIADYMA S.A. for further treatment. The waste treatment plant processed 120,000 tonnes of waste in 2018, where 86% were treated as biodegradable materials, exceeding the expectations of the contractors.

PPC S.A. will build a new power station named "Ptolemaida V" of 660 MW gross nominal capacity that will contribute to the air pollution together with Agios Dimitrios Plant that will remain open (both in the Municipality of Kozani).
For more details see deliverable 3.3.1.

From neighboring countries

A power plant in the "Republic of North Macedonia" and two lignite mines are located close to the borders and in great proximity with the city of Florina, i.e. approximate 20 km NE, that highly affects the air quality of the whole region. For more details please refer to deliverable 3.3.1.

11. CONCLUSIONS

Table 51 below summarizes all calculations made through this report and provides the total emissions for each pollutant in the Regional Unit of Florina.

Table 51 Analytical emissions for each polluter (tonnes) for the Regional Unit of Florina

Emission source	YEAR	NH_3	NO_x	NMVOC	TSP	PM_{10}	$PM_{2.5}$	CO	SO_x	CH_4	N_20
INDUSTRY											
Quarring											
Quartz & inert materials (sand, gravel, crashed rocks) extraction	2019				26.68	13.08	1.31				
Lime Production											
Process emissions	2019				270	105	21				
Pulp and paper											

Emissions from pulp & paper industry	2019		17.25	34.5	17.25	13.8	10.35	94.88	34.5 (SO_2)		
Food and beverages											
Process emission	2019			15							
ENERGY PRODUCTION											
Lignite mines											
Emissions from lignite mines	2019			2200	244.75	115.5	13.75			3,644.80	
Lignite-fired plants											
Emissions from lignite-fired plants	2018		8,769.14	49.70	415.38	280.47	113.61	308.87	59,644.33		
TRANSPORTATION											
Emissions PCs	2015	5.37	54.6	51.1	0.99			434			1.07
Emissions from LCVs	2015	1.04	60.32	24.89	4.23			234.4			0.42

Emissions from HDV	2015	5.1	101.6	112	0.15			1171			1.4
Emissions from L-category vehicles	2015	0.018	2.4	47.8	0.8			181.1			0.022
RESIDENTIAL BUILDING HEATING											
Emissions from biomass	2019	51.49	36.78	441.30	588.40	558.98	544.27	2942	8.09		
Emissions from residential heating using lignite	2019	0.01	2.65	11.66	10.70	9.74	9.59	110.86	21.69		
AGRICULTURE											
	2009	250.68	200.54	42.23		76.6	2.95				
LIVESTOCK											
Dairy cattle, sheep, swine & goats	2017	345.72	6.15	75.36	26.81	11.51	4.73				
TOTAL		**659.43**	**9,251.43**	**3,105.54**	**1,606.14**	**1,184.68**	**721.56**	**5,477.11**	**59,708.61**	**3,644.80**	**2.91**

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