UNITED ARAB EMIRATES
MINISTRY OF CLIMATE CHANGE
& ENVIRONMENT

UAE National Air Emissions Inventory Project

2nd Air Quality Pollutant Emissions Inventory

2023

www.moccae.gov.ae

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Acknowledgements

A multidisciplinary team was involved in developing the 2019 UAE National Air Emissions Inventory. MOCCAE would like to thank all individuals and organisations for their active participation and contribution to this report.

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Ajman Municipality
Ajman Transport Authority
Dubai Municipality
Environment Agency – Abu Dhabi
Fujairah Environment Authority
Fujairah Municipality
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Advamix Building Materials Trading LLC
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Abu Dhabi National Oil Company (ADNOC)
Abu Dhabi National Paper Mill
Abu Dhabi Waste Mangement Center - Tdweer
Abu Dhabi Port Co.
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Aiwa Plastic Products Industry L.L.C
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Al Azani Readymade Concrete Manuf Mix
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Citrol Oil Refinery
Dubai Cable Company
Ecomar Energy Solutions FZC
Emarat General Petroleum
Emirates Global Aluminium
Emirates National Oil Company
Emirates Sembcorb Water and Power Company
Emirates Steel Industries Co. PJSC
Emirates Western Oil Well Drilling & Maint. Co. LLC
Enerco Contracting Company LLC
ENOC Retail
EPCO International Limited
Fireclay Factory LLC
Fujairah Asia Power Company
Fujairah Cement Industries PJSC
Fujairah Oil Terminal
Fujairah Rockwool Factory
Fujairah Tank Terminals Ltd
General Mineral Industries L. L. C
Guardian Zoujaj International Float Glass Co. LLC
GTI Fujairah FZC
Gulfcryo Emirates Industrial Gases Co
Gulf Fluor
Gulf Petrochem Oil Terminal
Gulf Cement Company
Hasell Limited
Henkel International Lubricants Industry LCC
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The Fireclay Factory LLC
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Union International Bitumen
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2023 UAE National Air Emissions Inventory Project

Foreword

Considered one of the greatest environmental risks to health, ambient air pollution has been an area of concern across the globe for many years. Prolonged exposure to fine particulate matter, ground ozone and high concentrations of harmful air pollutants can have devastating effects on our health and impact our quality of life in the UAE. For this reason, the UAE has placed significant priority and strategic focus on improving air quality and decreasing the concentration of air pollutants nationally, with intent to supporting our collective good and bettering health and environmental sustainability for us all.

In 2017, the government of the UAE launched the Air Emissions Monitoring Project and in 2018 produced the UAE Air Emissions Inventory Methodology, aimed at guiding and articulating our local processes for monitoring air emissions across the UAE. One year later in 2019, we successfully developed our first UAE National Air Emissions Inventory as a means to capture and catalogue air emissions of a range of pollutants across several sectors and activities in the country. Recognising the need for continual improvement and enhancement in safeguarding our environmental health and preserving our way of life, the UAE Air Quality Strategy 2021 – 2031 was developed to frame high-level goals and ensure strategic actions are taken to protect our livelihoods, minimize our exposure to harmful pollutants and to promulgate a cohesive, multi-sectoral approach to reducing harmful emissions and their resultant negative health impacts.

In this vein, we continued to prioritize the wellbeing of the UAE citizens and residents over the years, and through the cooperation of Federal and local entities and institutional partners, we can finally share with you, our 2nd National UAE Air Emissions Inventory – highlighting our progress in reducing air pollutant emissions in sectors such as Energy and Transport while shedding light on areas needed for further action – as we move one step closer to achieving our air quality and climate goals.

I extend a heartfelt thank you to all contributors of the latest National UAE Air Emissions Inventory. Through these important partnerships and the meaningful and resolute contributions from various Federal and local stakeholders, we continue on our journey, persistent and unwavering, to meeting and exceeding our national air quality and climate goals, safeguarding our health and the environment, and forging a path forward for sustainable and quality living in the UAE.

Mariam bint Mohammed Almheiri

Minister of Climate Change and Environment

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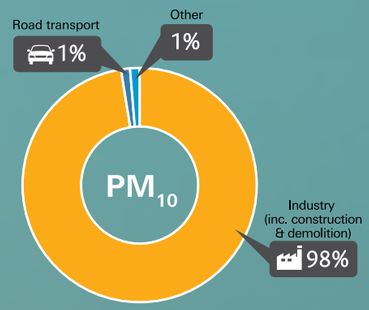
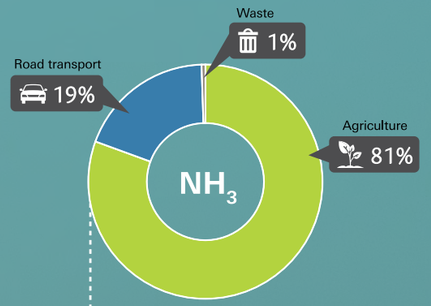
List of acronyms and abbreviations

ADNOC	Abu Dhabi National Oil Company
CO	Carbon monoxide
EAD	Environment Agency – Abu Dhabi
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
FCSC	Federal Competitiveness and Statistics Centre
GHG	Greenhouse gas
IPPU	Industrial processes and product use
IMO	International Maritime Organization
LPG	Liquid petroleum gas
LTO	Landing and take-off (aviation)
MOCCAE	UAE Ministry of Climate Change and Environment
MOEI	Ministry of Energy and Infrastructure
MSW	Municipal solid waste
N	Nitrogen
NFR	Nomenclature for Reporting
NH3	Ammonia
NMVOC	Non-methane volatile organic compounds
NOX	Nitrogen oxides
PM10	Particulate matter less than 10 micrometres in diameter
PM2.5	Particulate matter less than 2.5 micrometres in diameter
POPs	Persistent organic pollutants
RAK	Ras Al-Khaimah
SOX	Sulphur oxides
SO2	Sulphur dioxide
t	Tonne
TSP	Total suspended particles
UAE	United Arab Emirates
UAQ	Umm Al-Quwain

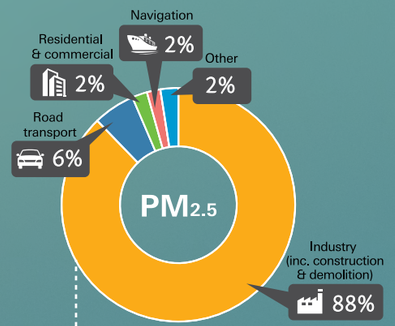
Main sources of air pollution in the UAE for the year 2019





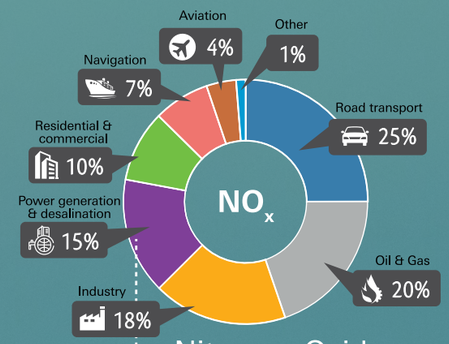
Ammonia

Irritating and poisonous. It is a precursor for $PM_{2.5}$, causing asthma, lung cancer, cardiovascular issues, birth defects, and premature death in humans'



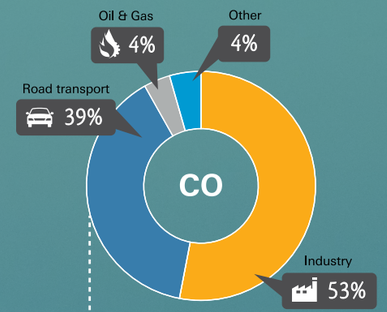
$PM_{2.5}$ & PM_{10}

Particulate matter of maximum 2.5 & 10 micrometers: tiny particles that can get deep into lungs and embedded in the organs shortening lifespan.



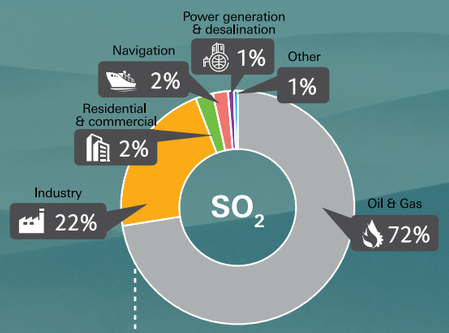
Nitrogen Oxides

Worsens allergies, respiratory infections, & lung/heart conditions.



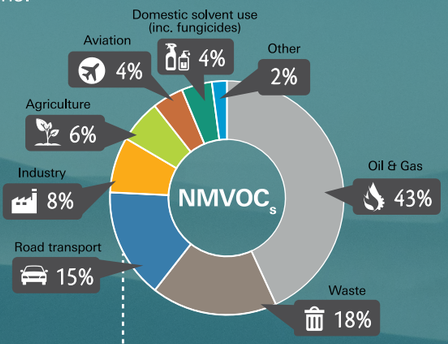
Carbon Monoxide

Reduces oxygen supply in the blood; harms the heart & brain.



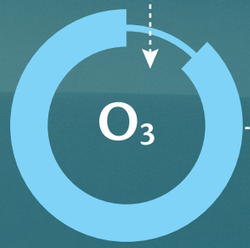
Sulfur Dioxide

Triggers asthma, respiratory problems, & breathing difficulties. It is also very damaging of the ecosystems.



Non-methane volatile organic compounds:

Causes respiratory inflammation & cancer.



Ozone

NOx reacts with NMVOCs and other air pollutants in the presence of sun light to produce ground level ozone. Ozone affects the respiratory tract & triggers respiratory illnesses

Executive summary

The UAE has long recognized the important role air quality plays in supporting an overall healthy and sustainable life for its inhabitants as this was recognized in the UAE's Centennial 2071 Plan objectives, which place a strong emphasis on a high quality of life and a sustainable economy. In July 2017, the Ministry of Climate Change and Environment (MOCCAE) launched the Air Emissions Monitoring Project to develop the first national level inventory for air pollutant emissions in the UAE. In 2019, the first national air pollutant inventory, which provided estimates for 2015, was published.

The inventory identified key sources of air pollutants and as a result the National Air Quality Agenda was formulated to make improvements. To evaluate the progress of air pollution emission reductions, the National Emissions Inventory needs to be undertaken frequently. This report provides an updated air pollutant emissions inventory for the year 2019 and provides amended estimates for 2015 where improvements could be made and includes estimates of ammonia for the first time. In addition, emission maps for each pollutant have been produced.

This report provides the project's methodology and results. The following pollutants are included:

- Carbon monoxide (CO)
- Nitrogen oxides (NO_x)
- Sulphur dioxide (SO_2)
- Particulate matter of 10 micrometres or less (PM_{10})
- Particulate matter of 2.5 micrometres or less ($PM_{2.5}$)
- Non-methane volatile organic compounds (NMVOCs)
- Ammonia (NH_3)

The methodology for compilation of the national inventory follows the EMEP[1] / European Environment Agency (EMEP/EEA) 2019 guidebook, internationally recognised for compiling air pollutant emission inventories (EEA, 2019). In this inventory, emissions are classified into the following sectors:

- Energy
- Transport[2]
- Industrial processes & product use (IPPU)
- Agriculture
- Waste

For each sector, the guidebook provides three methodologies with varying levels of complexity. In some cases, due to data availability, the simplest methodology has been used. Where possible, however, more detailed methods have been used, resulting in higher levels of accuracy and improvements have been made since the 2015 inventory in this regard.

Priority was given to local and national official data sources. Where data was not available, estimates or assumptions were incorporated. Recommendations have therefore been made to improve the completeness and accuracy of the emission estimates in the next inventory compilation cycle. Of note is the lack of completeness for the industry sector, both in terms of combustion and process emissions. Therefore, collecting activity data to enhance this sector will be a key priority going forward.

Figure i below presents a summary of the results. Particulate matter emission estimates have been included for the first time for the construction and demolition sector, and as seen below this gives rise to significant emissions of this pollutant. Petroleum refining comprises a large proportion of the NOx emissions, with road transport and power generation also contributing significant amounts. For SO_2, flaring and petroleum refining are the dominant sources. For CO however, the IPPU sector is an important source followed by petrol fuelled passenger cars and light duty vehicles. The agriculture and waste sectors play a minor role, and these are more significant sectors in terms of greenhouse gas emissions. Of note, however, is the estimated NMVOC emissions from municipal solid waste disposal on land and the contribution of the agriculture sector to NH_3 emissions.

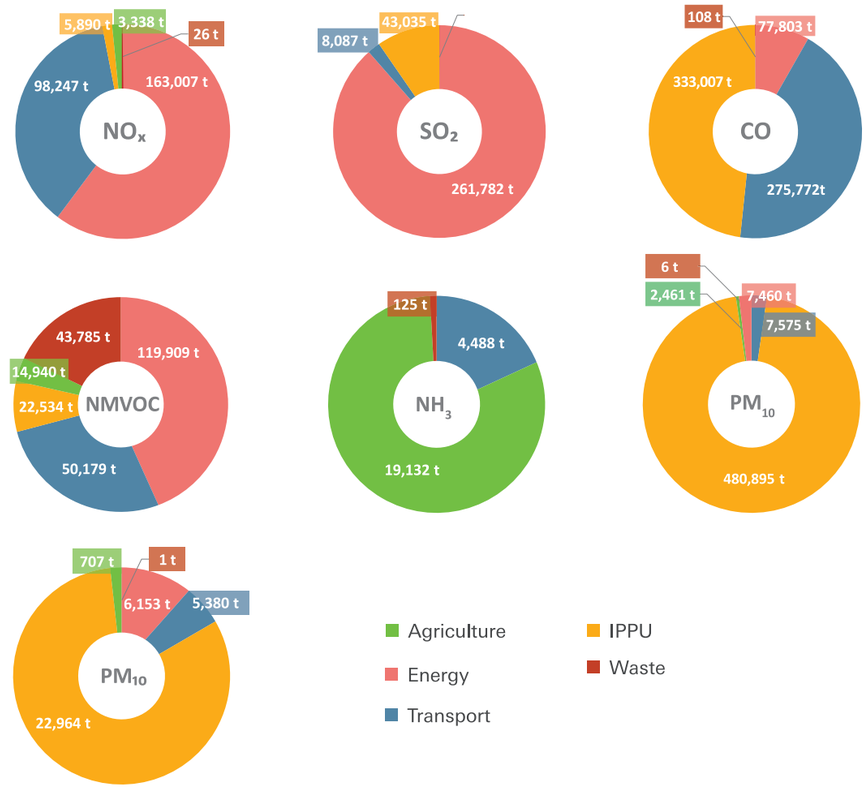


Figure i: Overview of UAE emissions by pollutant and sector, 2019 (in tonnes)

[1] Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe, more commonly known as European Monitoring and Evaluation Programme, or EMEP.

[2] For ease of reference, this report uses 'Energy' and 'Transport', instead of 'Energy (Stationary)' and 'Energy (Mobile)'.

1 Introduction

1.1 Background

According to the World Health Organization (WHO), exposure to ambient air pollution accounts for an estimated 4.2 million deaths per year due to stroke, heart disease, lung cancer, and chronic respiratory diseases. It is thought that approximately 91% of the world's population live in places where air quality levels exceed WHO limits (WHO, 2016).

The UAE has long recognized the important role air quality plays in supporting an overall healthy and sustainable life for its inhabitants as it was recognized in the UAE's Centennial 2071 Plan objectives, which place a strong emphasis on a high quality of life and sustainable economy. One of the first steps to improving air quality is to understand the sources by compiling an emissions inventory. This provides a detailed estimate of selected pollutants and their sources, which can serve to guide policy decisions on air pollution reduction measures and where effort should be focused.

This inventory covers all seven emirates, namely Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al-Quwain (UAQ), Ras Al-Khaimah (RAK) and Fujairah.

1.2 Scope of the inventory of emissions

Emission inventories have been compiled for 2015 and 2019 for the following pollutants. Emissions of ammonia have been added for the first time in this inventory.

- Carbon monoxide (CO)
- Nitrogen oxides (NO_X)
- Sulphur dioxide (SO_2)
- Particulate matter of 10 micrometres or less (PM_{10})
- Particulate matter of 2.5 micrometres or less ($PM_{2.5}$)
- Non-methane volatile organic compounds (NMVOCs)
- Ammonia (NH_3)

Emission estimates are divided into sectors as follows:

- Energy
- Transport
- Industrial processes and product use (this covers the emissions resulting from various industrial activities that produce emissions not directly as a result of energy consumed).
- Agriculture
- Waste

Each sector is later split into individual categories (e.g. Transport) and sub-categories (e.g. road transport) and then further sub-divided into further categories where necessary (e.g. passenger vehicles).[3] Each of these categories is assigned with a Nomenclature for Reporting (NFR) code (see Figure 1) (EEA, 2019). The nomenclature is consistent with the format used for reporting of GHG emission inventories under the United Nations Framework Convention on Climate Change (UNFCCC) but expanded for particular sources of air pollution. An abridged version of NFR codes is provided in Table 1.

[3] For ease of reference, in this report, the category 'Transport' was moved to the sector level.

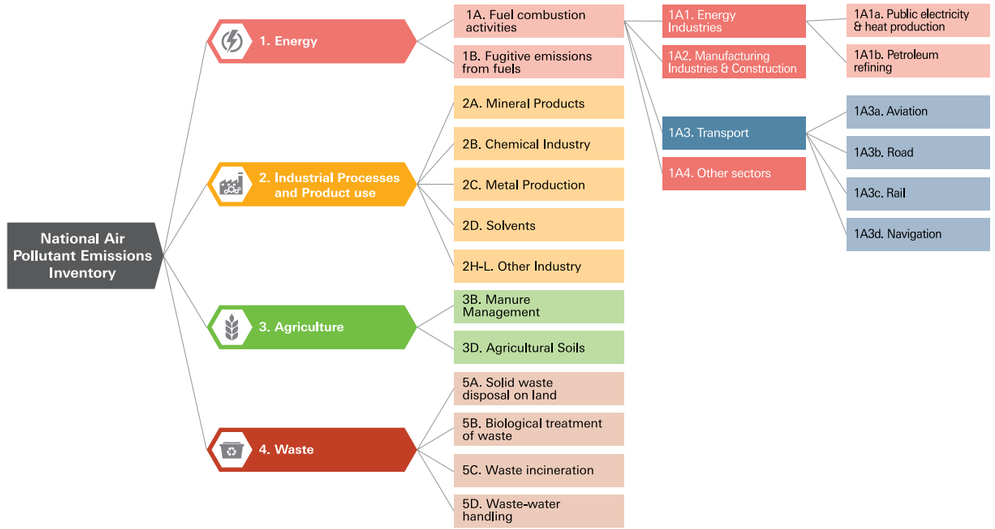


Figure 1: Synopsis of Nomenclature for Reporting (NFR) code

Table 1: An abridged guide to the Nomenclature for Reporting (NFR) code[4]

NFR Code	Source description
1	**Energy**
1A	**Fuel Combustion Activities**
1A1	Energy Industries
1A1a	Public electricity and heat production[5]
1A1b	Petroleum refining (referred to in this report as oil and gas operation)
1A1c	Manufacture of solid fuels and other energy industries
1A2	Manufacturing Industries and Construction
1A3	Transport
1A3a	Aviation
1A3b	Road Transport
1A3c	Railways
1A3d	Navigation (shipping)
1A3eii	Other
1A4	Other sectors (stationary and mobile combustion)
1A5	Other (not elsewhere specified)
1B	**Fugitive Emissions from Fuels**
1B1	Fugitive Emissions from Solid Fuels
1B2	Fugitive Emissions from Oil and Natural Gas
2	**Industrial Processes and Product Use**
2A	Mineral Products
2B	Chemical Industry
2C	Metal production
2D	Solvents
2H	Pulp and paper industry, food and beverages industry
2I	Wood Processing
2K	Consumption of POPs and heavy metals
3	**Agriculture**
3B	Manure Management
3D	Agricultural soils
5	**Waste**
5A	Solid Waste disposal on land (referred to in this report as MSW)
5B	Biological treatment of waste
5C	Waste Incineration
5D	Waste-water handling
5E	Other Waste
6	**Other**

[4] NFR code 4, which does not appear on this list, relates to 'Land Use, Land Use Change and Forestry'. This category is only applicable to greenhouse gas inventories.

[5] Referred to as 'Power generation' in this report.

2 Methodology

2.1 Process of compilation

The air quality pollutant inventory was compiled by quantifying the national estimates. The 2019 EMEP/EEA guidebook was followed throughout, abiding by the methodologies and quality assurance/quality control practices. The guidebook, widely used by many countries, was adapted – ensuring that the UAE inventory is comparable with many other inventories. In addition, the guidebook provides a transparent methodology across all relevant sectors for the UAE.

2.1.1 Emissions estimation and 'Tier' methodology

Given the complexities and impracticalities of undertaking direct measurements of the emissions from each source identified in the UAE, it is necessary to estimate emissions through an indicator that describes the **source activity** and an **emission factor** that is specific for the typology of the source. In general, anthropogenic (human-produced) emissions of air pollutants are estimated by multiplying emission factors with activity data for each source:

$$\textbf{Estimated emissions}_{\text{pollutant}} = \textbf{Emission factor}_{\text{pollutant}} \times \textbf{Activity data}$$

where the emission factor is the average emission rate of a given pollutant from a given source, relative to the intensity of a specific activity, and the activity data is a measure of the scale of activity providing the emissions.

Emissions can be estimated at different levels expressed in three tiers of increasing complexity. The 'Tier 1' is a simple method using already available default emission factors only. The 'Tier 2' method uses either country-specific emission factors, or default emission factors over a range of different technologies. The 'Tier 3' method uses emission factors that are not only country-specific but also differentiated by technology and operating conditions. Tier 3 is the most accurate and complex methodology, while it is easiest to obtain data for Tier 1.

The methodological choice for a particular source and in a particular country depends on the importance of that source to the level and trend of emissions in that country, as well as on the resources available to prepare the emissions inventory.

2.1.2 Data management

Activity data for 2015 and 2019 was provided directly from Federal related entities, local municipalities, environmental authorities, transport operators and industrial sites through specifically designed questionnaires. In some cases, international datasets were used as well as expert judgement from discussions with local and national experts (see Figure 2).

Throughout the inventory compilation process, the sector experts applied the 2019 EMEP/EEA guidebook precepts on good practice to review and incorporate data gathered in a consistent and accurate manner.

2.1.3 Compilation spreadsheets

The inventories were compiled in Excel spreadsheets. In general, there is a spreadsheet for each sector and within this file each tab contains the calculations for one or more than one NFR category, depending on the complexity of the calculation and method used. For the simpler calculations (Tier 1 and 2), default emission factors were obtained from the 2019 EMEP/EEA guidebook and combined with an activity statistic to estimate the annual emissions.

2.2 Stakeholder consultation

A launch event for the inventory project was held in December 2021. This provided the background to the project and presented the data collection forms and the study approach. Attendees included UAE federal authorities, local Municipalities, local Environmental Authorities, transport and industrial organisations.

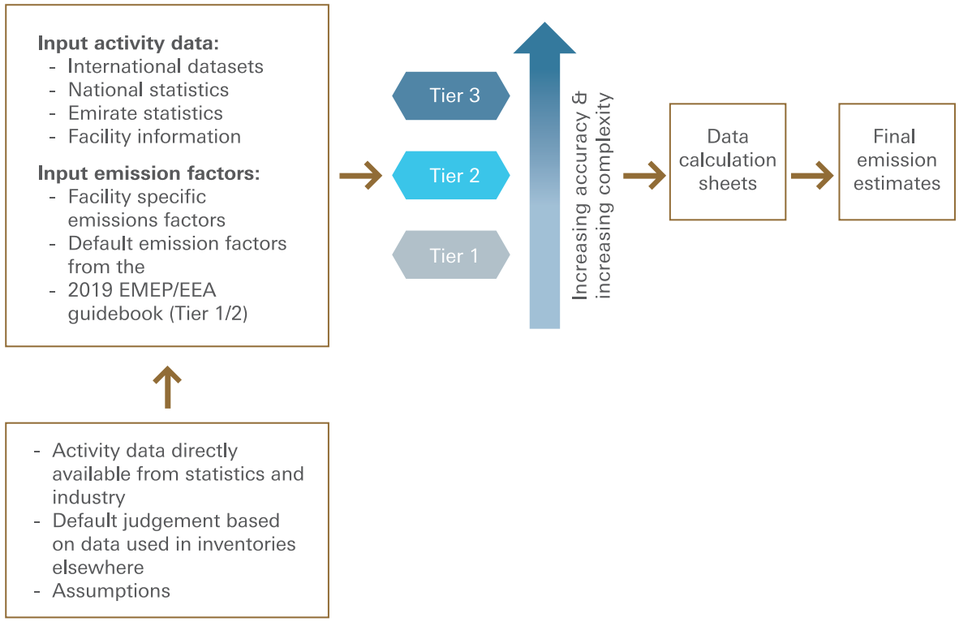


Figure 2: Overview of methodology

3 Summary of results

3.1 Estimates of emissions

A summary of the total emission estimates by pollutant and sector is shown in Figure 3, Figure 4, and Table 2. Particulate matter emission estimates have been included for the first time for the construction and demolition sector, and as seen below this gives rise to significant emissions of this pollutant. Also, particularly noticeable is the dominant source of ammonia emissions in the agriculture sector.

Overall, an increase was estimated in emissions for most of the pollutants between 2015 and 2019, which has been driven primarily by increases in activity levels. The exception to this is NO_x and SO_2 for which a decline in emissions has been estimated.

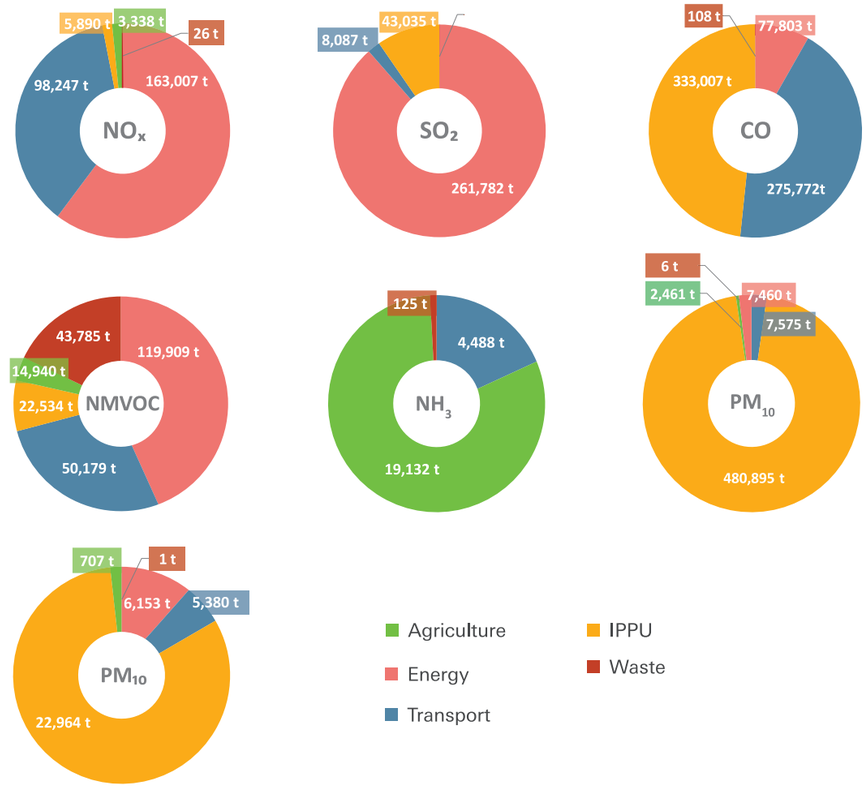


Figure 3: Overview of UAE emissions by pollutant and sector, 2019 (in tonnes)

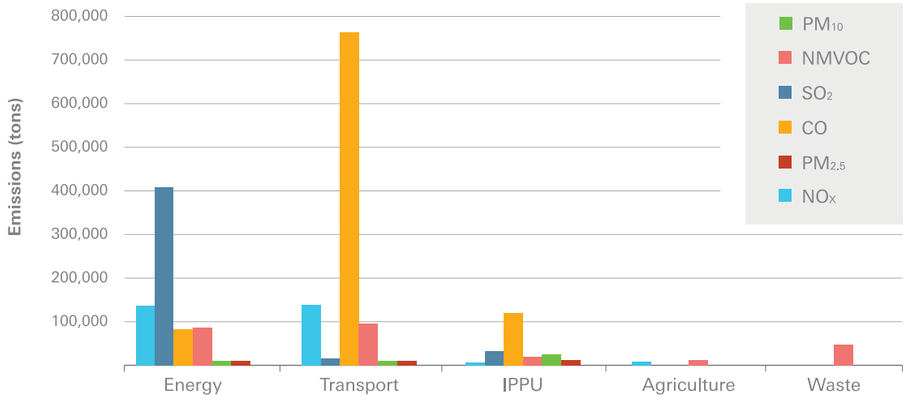


Figure 4: Estimated emissions by pollutant per sector, 2019 (in tonnes)

Table 2: Summary of total UAE air pollutant emissions per pollutant by sector, 2015 and 2019 (in tonnes)

Sector	Emissions						
	NO_x	SO_2	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
Energy 2015	145,014	410,234	81,682	82,458	NE	6,986	5,997
Energy 2019	163,007	261,782	77,803	119,909	NE	7,460	6,153
Transport 2015	122,039	22,500	356,998	43,936	3,852	5,105	4,060
Transport 2019	98,247	8,087	275,772	50,179	4,488	7,575	5,380
IPPU 2015	4,102	29,636	119,341	19,014	NE	352,929	42,648
IPPU 2019	5,890	43,035	333,007	22,534	NE	480,895	57,734
Agriculture 2015	3,153	NA	NE/NA	14,002	17,346	2,335	681
Agriculture 2019	3,338	NA	NE/NA	14,940	19,132	2,461	707
Waste 2015	5	0.3	323	44,308	381	6	1
Waste 2019	26	1	108	43,785	125	6	1
Total 2015[2]	274,314	462,370	558,345	203,719	21,579	367,362	53,387
Total 2019[2]	270,508	312,906	686,690	251,347	23,745	498,398	69,974

Note: Emission estimates for 2015 have been updated in this inventory where more accurate or more detailed data was available which allowed a higher methodology Tier to be used. Therefore, there may be differences between the values presented in the table above and that presented in the 2015 inventory report.

[1] NA – Not applicable (emissions of this pollutant do not arise from this source)

[2] The sum of the component parts may not exactly equal the total shown as a result of rounded off figures.

3.2 Key category analysis

A source of emissions is denoted as a key category if it has a significant influence on the country's total emissions in terms of the absolute level of emissions of a given pollutant. By highlighting these categories, the inventory compilation team were able to better assess the prioritisation for the improvement of data gathering and methodologies. Other users of the inventory can also clearly identify those categories that may be more applicable for other purposes such as mitigation to reduce air quality pollutant emissions.

In accordance with the 2019 EMEP/EEA guidelines, a key category analysis was carried out highlighting the more significant categories for each pollutant. This was performed using a simple Excel spreadsheet tool. Only an absolute level assessment has been undertaken and the inventory categories are sorted from large to small in terms of emissions for a single year and all categories that contribute to 80% of the total emissions are highlighted to identify the vital few from the trivial many. Table 3 summarises the key categories in the inventory.

Table 3: Sectors identified by the key category analysis, 2019

NFR category		Pollutant	Percentage of emissions (%)
2C3	Aluminium production	CO	43.6
1A3bi	Road transport: Passenger cars	CO	24.2
1A3bii	Road transport: Light duty vehicles	CO	10.9
2C1	Iron and Steel Production	CO	4.8
3Da2a	Animal manure applied to soils	NH_3	19.0
1A3bi	Road transport: Passenger cars	NH_3	15.6
3B4gii	Manure Management - Broilers	NH_3	14.4
3Da3	Urine and dung deposited by grazing animals	NH_3	12.7
3B4h	Manure Management - Camels	NH_3	12.2
3B2	Manure Management - Sheep	NH_3	4.9
3B4d	Manure Management - Goats	NH_3	4.6
1B2ai	Fugitive emissions from exploration, production and transport	NMVOC	31.3
5A	Solid waste disposal on land	NMVOC	17.3
1A3bi	Road transport: Passenger cars	NMVOC	5.9
1B2av	Fugitive emissions from distribution of oil products	NMVOC	5.8
1B2c	Fugitive emissions from flaring	NMVOC	4.8
1A3ai(i)	International aviation LTO (civil)	NMVOC	4.3
2D3a	Domestic solvent use including fungicides	NMVOC	4.2
1A3bv	Road transport: gasoline evaporation	NMVOC	4.2
2B	Chemical Industries	NMVOC	3.6
1A1b	Oil and gas operations *	NO_x	19.1
1A3biii	Road transport: heavy duty vehicles and buses	NO_x	16.6
1A1a	Power Generation	NO_x	15.4
1A4	Small scale combustion	NO_x	9.5

NFR category		Pollutant	Percentage of emissions (%)
1A3dii	National navigation (shipping)	NO_x	7.1
1A3bi	Road transport: Passenger cars	NO_x	6.6
1A2b	Non-ferrous metals	NO_x	5.6
1A2f	Non-metallic minerals	NO_x	4.0
2A5a	Construction and demolition	PM_{10}	89.0
2A5a	Construction and demolition	$PM_{2.5}$	63.8
2A1	Cement Production	$PM_{2.5}$	6.4
2B	Chemical Industries	$PM_{2.5}$	5.3
1A2f	Non-metallic minerals	$PM_{2.5}$	4.1
2C3	Aluminium production	$PM_{2.5}$	2.5
1B2c	Fugitive emissions from flaring	SO_2	38.6
1A1b	Oil and gas operations *	SO_2	33.8
1A2f	Non-metallic minerals	SO_2	7.5

* Although the term 'oil and gas operations' has been used here, NFR code 1A1b technically refers only to petroleum refineries. See sections 4.2.2 and 4.2.5 for further information.

The results show that construction and demolition comprise the vast majority of particulate matter emissions. Oil and gas operations comprises a large proportion of the NOx emissions, with heavy-duty vehicles and power generation also contributing significant amounts. For SO2, fugitive emissions from flaring is the dominant source, while aluminium production and passenger cars comprise the majority of CO emissions. For NMVOC, fugitive emissions and waste disposal on land are the most important sources. Lastly for NH3, agriculture is the dominant source.

4 Energy

4.1 Overview of emissions

Stationary combustion comprises burning of fuels to provide energy in power stations to generate electricity and desalinate water, in oil and gas operations, and in other industries. This sector also includes fugitive emissions from extraction, processing, and delivery of fossil fuels. These activities result in emissions of all the pollutants considered within the scope of this inventory and include some of the most significant sources of the air pollutants covered in the inventory.

The emission estimates for stationary combustion show that different sectors are responsible for the largest share of emissions for different pollutants (see Figure 5 and Table 4).

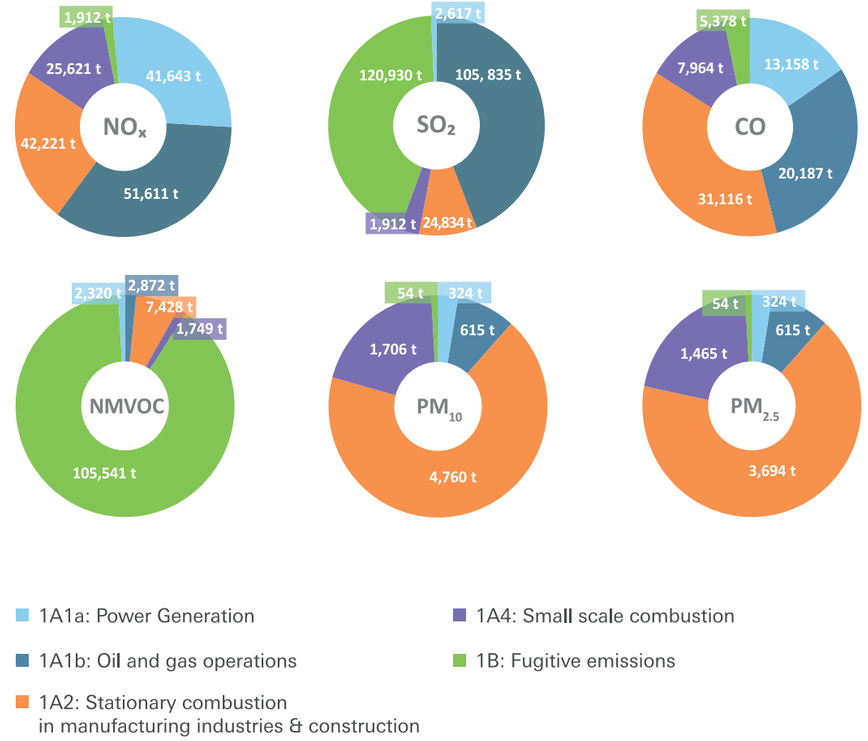


Figure 5: Estimated emissions from the energy sector by pollutant, 2019 (in tonnes)

Table 4: Estimated emissions from the energy stationary sector by pollutant, 2015 and 2019 (in kilotonnes)

Sector / category		Emissions						
		NO_x	SO_2	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
1A1a	**Power generation 2015**	42.3	9.3	12.2	2.2	NE	0.7	0.6
1A1a	**Power generation 2019**	41.6	2.6	13.2	2.3	NE	0.3	0.3
1A1b	**Oil and gas operations 2015**	39.2	165.9	16.7	2.0	NE	0.1	0.1
1A1b	**Oil and gas operations 2019**	51.6	105.8	20.2	2.9	NE	0.6	0.6
1A2	**Stationary combustion in manufacturing industries and construction 2015**	35.9	33.5	40.9	4.7	NE	4.8	4.1
1A2	**Stationary combustion in manufacturing industries and construction 2019**	42.2	24.8	31.1	7.4	NE	4.8	3.7
1A4	**Small-scale combustion 2015** [1]	21.0	5.7	6.9	1.4	NE	1.3	1.1
1A4	**Small-scale combustion 2019**	25.6	7.6	8.0	1.7	NE	1.7	1.5
1B	**Fugitive emissions 2015**	6.6	195.8	5.1	72.2	NE	0.1	0.1
1B	**Fugitive emissions 2019**	1.9	120.9	5.4	105.5	NE	0.1	0.1
Total 2015 [2]		145.0	410.2	81.7	82.5	NE	7.0	6.0
Total 2019 [2]		163.0	261.8	77.8	119.9	NE	7.5	6.2

Note: Emission estimates for 2015 have been updated in this inventory where more accurate or more detailed data was available which allowed a higher methodology Tier to be used. Therefore, there may be differences between the values presented in the table above and that presented in the 2015 inventory report.

[1] Refers to commercial and residential sectors.

[2] The sum of the component parts may not exactly equal the total shown as a result of rounded off figures.

NOx emissions are produced from all combustion processes and all fuels, and in 2019 the oil and gas operations sector was the largest single source of NOx emissions, followed by that from stationary combustion in industry & construction, and power generation and desalinisation. For SO_2, oil and gas operations make the largest share, with stationary combustion in manufacturing industries and construction also contributing a significant amount.

For CO, emissions from solid fuel combustion in cement manufacture were the largest sources.

For NMVOC, fugitive emissions from oil and gas operations were a significant source and are a key category in the inventory.

For PM, the only major source and key category amongst stationary combustion activities was combustion of solid fuels in cement manufacture.

4.2 Overview of methodology

4.2.1 1A1a – Power generation and desalination

In the UAE, electricity production and water desalination is fuelled by the burning of natural gas in normal conditions, and diesel and residual fuel oil as backup. Desalination tends to occur at the same sites as electricity generation, and as one fuel consumption figure is often reported for the two activities combined, they are treated as a single activity in this inventory. The most common technology in operation in 2019 was gas turbine generation, although some generation in steam turbines also occurred.

Tier 3 emissions estimates mainly based on continuous emissions monitoring data were provided by Dubai, Abu Dhabi and Fujairah Emirates for NOx, SO_2 and CO. These estimates covered most plants in the emirates, so were used directly where appropriate. For plants owned by ECPC and AMPC in Abu Dhabi no CEMS data was provided for 2019. Instead, emissions for NOx, and SO_2 were taken directly from Chapter 6.2 of the Statistical Yearbook of Abu Dhabi Emirate.

Estimates of NMVOC and PM in Dubai, Abu Dhabi and Fujairah Emirates, and of all pollutants in other emirates, were based on data on fuel consumption by fuel type and type of generation technology in 2019 which were provided by all four electricity and water authorities in UAE.

Between 2015 and 2019, emissions of NOx, NMVOC and CO remained relatively constant. In contrast, emissions of SO_2 and PM fell substantially, due to significantly smaller quantities of light and heavy fuel oil consumption (which have high associated PM and SO_2 emissions compared with natural gas) being used by SEWA's stations in Sharjah Emirate.

4.2.2 1A1b[6] – Oil and gas operations

In the NFR reporting structure, 1A1b is technically referred to as 'petroleum refineries'. However, it has been renamed in this report as 'oil and gas operations' to more closely reflect what the sector comprises of.

This sub-sector includes emissions arising from exploration and production, oil refineries and gas processing. In 2015 and 2019, there were four oil refineries in the UAE and multiple gas processing plants. These operations take place in the emirates of Abu Dhabi, Dubai and Fujairah.

With respect to Abu Dhabi Emirate, emission estimates for NO_X, SO_2, CO and NMVOCs were provided directly by the Abu Dhabi National Oil Company (ADNOC) and they were considered to be a combination of Tier 2 and Tier 3 methods. For particulate matter, a Tier 1 approach was applied, using activity data provided by ADNOC and emission factors from the 2019 EMEP/EEA guidebook.

In the case of the Dubai Emirate refineries, emission estimates for all pollutants reported have been provided directly by Dubai Municipality and are thought to be based on stack monitoring and thus also considered to be a Tier 3 method. In accordance with the 2019 EMEP/EEA guidebook, it has been assumed that for this sector:

Total suspended particles (TSP) = PM_{10} = $PM_{2.5}$

For Fujairah Emirate, the amount of fuel combusted, the combustion process, sulphur fuel content and abatement efficiency was provided by the refinery directly for 2015 and 2019. This allowed a Tier 2 standard to be used using emission factors from the 2019 EMEP / EEA Guidebook.

Emissions from this sector are dominated by ADNOC operations. The upward trend in NOx, NMVOC and CO and downward trend in SO_2 reflects lower emissions reported by ADNOC, whereas the high PM estimates in 2019 compared with 2015 may partly relate to a methodological shift; for 2015 PM emissions were not reported by ADNOC but estimated using EMEP/EEA Tier 1 emission factors, whereas in 2019 ADNOC provided their own emissions estimate.

[6] In the NFR reporting structure, 1A1b is referred to as petroleum refineries. Exploration and production emissions would normally be accounted for in the industrial combustion sector (1A2), but have been included here so that all emissions arising from oil and gas operations are included in one sector.

4.2.3 1A2 – Stationary combustion in manufacturing and construction

The emissions included in this category result from fuel consumption in combustion to provide heat, electricity and mechanical work for manufacturing & construction. This is distinct from emissions resulting from industrial processes and product use (IPPU), which are covered in section 6. In the NFR framework, this category is subdivided into a number of different subcategories, including:

- 1A2a Iron and steel
- 1A2b Non-ferrous metals
- 1A2c Chemicals
- 1A2d Pulp, paper and print
- 1A2e Food processing, beverages and tobacco
- 1A2f Non-metallic minerals
- 1A2gviii Other stationary combustion in industry

In the UAE, key activities grouped under subcategory 1A2f (Non-metallic minerals) include manufacture of cement, asphalt, glass, plaster, ceramics and mineral wool, among others. The subcategory 1A2gviii (Other stationary combustion in industry) includes quarrying and crushing of stone, and concrete production.

Several types of fuel combustion data were available, depending on the emirate and subcategory, which necessitated a varied approach to emissions estimation.

For Dubai Emirate, usage of facility-level emissions estimates from the 2015 and 2019 Dubai industrial emission inventory was made. The activity description provided within these data were mapped to the appropriate subcategory of 1A2, and then included directly in the compilation files. The original methodology used to create the estimates was a mixture of Tier 3 measured emissions, and Tier 1 and Tier 2 estimates, depending on the facility in question.

For Abu Dhabi Emirate for 2015, a mixture of approaches was taken to align estimates as far as possible with those reported in the 2015 Abu Dhabi Air Emissions Inventory. For 2019, MOCCAE issued questionnaires to key emitters and these responses were used to derive the estimates.

For Ajman, Fujairah and Ras Al-Khaimah Emirates MOCCAE issued questionnaires to all listed industrial facilities in UAE asking for information on fuel consumption in 2015 and 2019 by industrial process or combustion technology (as well as production quantities and abatement applied). In the returned forms, the completeness of information on the combustion technology or specific process in which fuel consumption occurred, and on abatement measures applied, was inconsistent. Therefore, a Tier 1 approach was used combining fuel consumption with default EFs from the EMEP/EEA Guidebook (2019), which are averages across several combustion technologies.

If fuel consumption data from 2019 was not available but data from another year was, a scaling factor based on industry GDP in the UAE was used to scale the data between years. When facility level emissions estimates were available, they were used.

For Sharjah and Umm Al Quwain Emirates no data was available from questionnaires. Total liquid petroleum product consumption (for both emirates) and total natural gas consumption (Sharjah Emirate only) was combined with Tier 1 emission factors to give a "Total industry" emissions estimate not split by subsector.

From 2015 to 2019 NOx and SO_2 emissions increased. CO and $PM_{2.5}$ emissions showed a small decline, whereas PM_{10} remained largely consistent. The emissions estimates are to some extent dependent on the number of MOCCAE issued questionnaire responses received from listed industrial facilities.

Due to the lack of completeness, estimates of emissions from industry (both combustion and IPPU) should be interpreted as 'reported' emissions, rather than a true total.

4.2.4 Small-scale combustion [1A4]

Small-scale combustion emissions correspond to the combustion of fuels in the commercial and residential sectors. For 2019, data on the total amount of fuel consumed in the commercial and residential sectors by Emirate was made available by MOEI. Data on the breakdown by fuel type was also provided at the national level. Therefore, an assumption was made that the proportion of fuel consumed in the residential and commercial sectors at the national level also applied to each Emirate. For 2015, the total amount of fuel combusted in the residential and commercial sectors was extracted from the Energy Annual Statistical Report 2016; however, no information was available on the type of fuel combusted or the split between Emirates. Therefore, the 2015 national totals were allocated on the basis of the 2019 data. Default emission factors from the 2016 EMEP/EEA guidebook were applied.

Emission estimates have increased between 2015 and 2019. Whilst fuel consumption in the residential sector has declined during this period, this is more than offset by the amount of fuel combusted in the commercial sector which has increased. This combined with the fact that in most cases emission factors are higher for the commercial sector than in the residential sector leads to an increase in the estimated emissions.

4.2.5 1B – Fugitive emissions from fuels

Intentional or unintentional releases of air pollutants may occur during the extraction, processing and delivery of fossil fuels to the point of final use. These are known as fugitive emissions for which estimates are subject to a high level of uncertainty.

Emissions arising from the following categories have been estimated:

- **1B2ai – Fugitive emissions oil: exploration, production and transport.** This includes fugitive emissions from production platforms, storage tanks, tanker loading, and losses during transport in marine tankers and pipelines. The estimates for this category have been compiled for Dubai, Fujairah and Abu Dhabi Emirates. This activity is not thought to occur in other emirates.
- **1B2aiv – Fugitive emissions oil: refining and storage.** Fugitive emissions arising from this category are assumed to be included in those emirates with refineries in the 1A1b (oil and gas operations) sector.
- **1B2av – Distribution of oil products.** This covers emissions arising from gasoline distribution in each of the emirates for which estimates are based on the amounts of fuel sold.
- **1B2c – Venting and flaring.** The UAE has a zero routine flaring policy in all of its oil and gas operations and compared to the year 1995, some of the largest oil and gas companies have managed to achieve a 76% reduction of hydrocarbon flaring. However, flaring sometimes does occur for safety and operational reasons. The 2019 emissions data provided by ADNOC included estimates for fugitive sources and this was used directly. For 2015, ADNOC provided fugitive emission estimates as part of their total emission estimates and therefore an estimate of the combustion / fugitive emissions split was made based on the 2019 proportion. There is therefore uncertainty in the 2015 fugitive emission estimate for Abu Dhabi Emirate. However, the total combustion plus fugitive estimate will be accurate. The amount of fuel flared in the Fujairah Emirate refinery was provided for 2015 and this was assumed to be the same in 2019. For Dubai Emirate, estimates were taken directly from information provided by Dubai Municipality apart from for NMVOCs for which no data was provided and therefore an estimate based on the amount of fuel flared was derived. Default emission factors were then applied in accordance with the 2019 EMEP/EEA guidebook.

Overall emissions of all pollutants (apart from NMVOCs) have decreased between 2015 and 2019 due to a reduction in the amount of flaring taking place. However, NMVOC emissions are estimated to have increased over this period due to increasing amounts of gasoline being consumed in the road transport sector. In addition, an increase has been estimated from flaring taking place in Abu Dhabi Emirate; however as noted above this may be an artefact of the data.

5 Transport

5.1 Overview of emissions

This sector covers aviation, road transport, railways, and shipping. Railway emissions are included for the first time in the 2019 inventory because Etihad Rail began operating in 2016 and there was no activity in this sector prior to this date in the UAE.

Emission estimates for non-road mobile machinery are not explicitly included as a separate source, due to a lack of activity data (which is also common across many other countries).

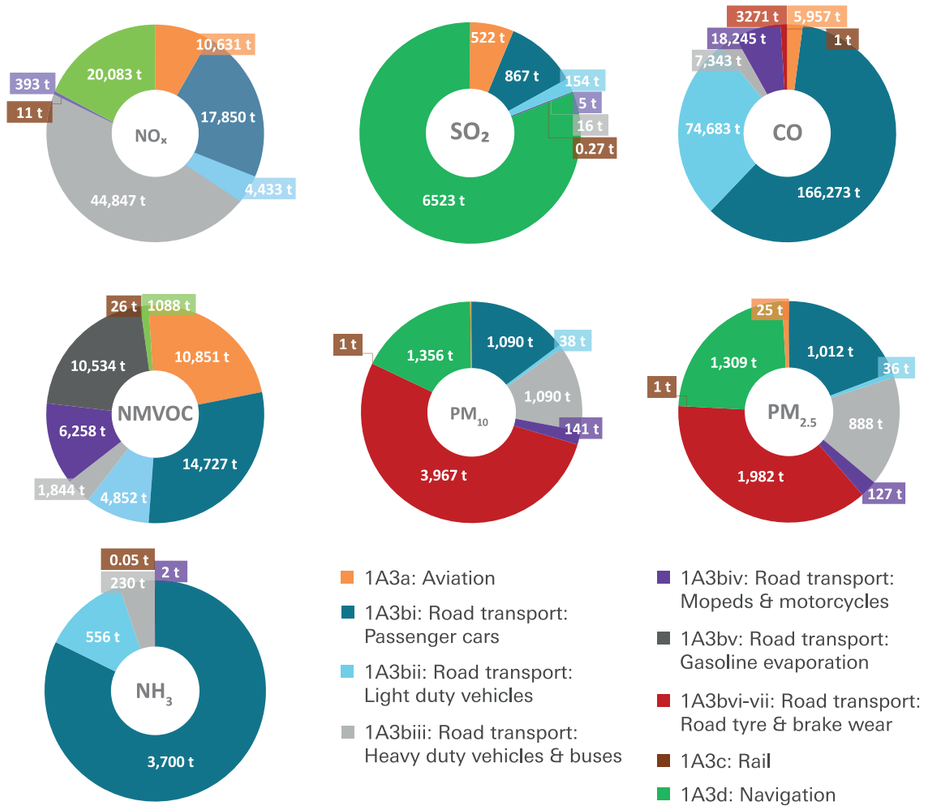


Figure 6: Estimated emissions from the energy mobile sector by pollutant, 2019 (in tonnes)

The emission estimates show that both passenger cars and heavy-duty vehicles dominate the NO_x emissions for this sector (see Figure 6 and Table 5). The aviation and navigation sectors also contribute to the total transport emissions across all pollutants.

Table 5: Estimated emissions from the energy mobile sector by pollutant, 2015 and 2019 (in tonnes)

Sector		Emissions						
		NO_x	SO_2	CO	NMVOC	PM_{10}	$PM_{2.5}$	NH_3
1A3a	Aviation 2015	11,774.4	581.0	6,449.1	12,110.4	28.9	28.9	NE
1A3a	Aviation 2019	10,630.9	522.2	5,956.7	10,851.0	25.3	25.3	NE
1A3bi	Road transport: passenger cars 2015	20,908.4	1,153.7	219,641.6	12,846.5	646.9	646.9	3,067.6
1A3bi	Road transport: passenger cars 2019	17,849.9	867.1	166,273.3	14,726.6	1,090.0	1,011.6	3,699.6
1A3bii	Road transport: light duty vehicles 2015	5,386.7	209.9	97,667.4	4,233.1	27.8	27.8	473.1
1A3bii	Road transport: light duty vehicles 2019	4,432.8	153.9	74,682.7	4,852.4	38.2	35.6	556.0
1A3biii	Road transport: heavy duty vehicles and buses 2015	54,811.3	27.4	11,173.3	1,730.8	759.4	759.4	309.9
1A3biii	Road transport: heavy duty vehicles and buses 2019	44,847.0	16.2	7,343.4	1,844.2	956.4	887.7	229.8
1A3biv	Road transport: mopeds and motorcycles 2015	287.6	6.5	17,829.1	3,109.4	50.5	50.5	1.4
1A3biv	Road transport: mopeds and motorcycles 2019	393.2	4.7	18,244.7	6,257.8	141.0	127.1	2.5
1A3bv	Road transport: gasoline evaporation 2015	NA	NA	NA	8,747.2	NA	NA	NA
1A3bv	Road transport: gasoline evaporation 2019	NA	NA	NA	10,533.9	NA	NA	NA
1A3bvi-vii	Road transport: road tyre and brake wear 2015	NA	NA	NA	NA	1,485.0	797.5	NA
1A3bvi-vii	Road transport: road tyre and brake wear 2019	NA	NA	NA	NA	2,597.6	1,291.6	NA
1A3bvi-viii	Road transport: road abrasion 2015	NA	NA	NA	NA	786.8	428.7	NA
1A3bvi-viii	Road transport: road abrasion 2019	NA	NA	NA	NA	1,369.0	690.8	NA
1A3bc	Railways	NO	NO	NO	NO	NO	NO	NO
1A3bc	Railways	10.9	0.3	0.8	25.7	1.4	1.2	0.1
1A3d	Navigation 2015	28,871.1	20,521.5	4,237.8	1,158.6	1,320.1	1,320.1	NE
1A3d:	Navigation 2019	20,082.8	6,522.9	3,270.8	1,087.9	1,356.3	1,308.8	NE
Total 2015 [2]		122,039	22,500	356,998	43,936	5,105	4,060	3,852
Total 2019 [2]		98,247	8,087	275,772	50,179	7,575	5,380	4,488

Note: Emission estimates for 2015 have been updated in this inventory where more accurate or more detailed data was available which allowed a higher methodology Tier to be used. Therefore, there may be differences between the values presented in the table above and that presented in the 2015 inventory report.

[1] NA – Not applicable (emissions of this pollutant do not occur from this source). [2] NO – Not Occurring

[2] The sum of the component parts may not exactly equal the total shown as a result of rounded off figures.

5.2 Methodology

Aviation[7]:
Emission estimates were compiled for the Landing and Take-off (LTO) element only and no emission estimates were derived for the cruise element as this sector is more important for greenhouse gas emission estimates. All flights operating are reported under 'international' as there are no commercially operated domestic flights in the UAE. There are a small number of private domestic flights and therefore emissions arising from domestic LTO are reported as 'included elsewhere'. There are no airports in Ajman or UAQ Emirates, thus emissions from these sources have been reported as 'not occurring'.

For the 2019 inventory, it was possible to use a Tier 2 standard as for all airports information was provided on the number of LTOs by aircraft type. Where this information was not available for 2015, it was assumed that the same proportion of LTOs by aircraft type occurred in 2015 as in 2019.

Emissions of all pollutants declined between 2015 and 2019. This was primarily due to a decline in the number of flight arrivals / take-offs between these years.

Road transport:
Data for 2019 on the estimated amount of total fuel consumption by fuel type in the road transport sector, along with fuel sales by sector and Emirate, were provided by the Ministry of Energy and Infrastructure. Information on the number of vehicles by type and age of the fleet in 2019 was also available for all Emirates, enabling a breakdown of emission factors by Euro standard to be inferred, which in turn facilitated the use of a Tier 2 methodology, though with the addition of some important assumptions. For 2015, information on the number of registered vehicles was also provided by MOEI. However, no information was made available on the age of the fleet for this year and therefore assumptions were made.

It is worth noting the quite large changes in estimated road transport emissions between 2015 and 2019 for some vehicle types and pollutants. 1A3biv: Mopeds and motorcycles emissions increased noticeably due to a sharp increase on the number of registered motorcycles between 2015 and 2019, which caused a disproportionate rise in emissions compared to other sectors.

Railways: In 2019 Abu Dhabi was the only emirate to have a non-electric railway line and therefore rail emissions. In 2015, there was no such railway line and therefore emissions are reported as Not Occurring (NO) for this year. Total diesel consumption for 2019 and emission estimates of CO, NOx and PM were provided by Etihad Rail. NMVOC and NH_3 emission estimates were derived using T2 emissions factors for line haul locomotives from the 2019 EMEP/EEA guidebook. For SO_2, a T1 approach outlined in EEA/EMEP guidebook 2019 has been used i.e. the sulphur content of the fuel has been used to estimate SO_2 emissions.

Shipping[8]:
The approach taken varied by Emirate, depending on activity data available. For Abu Dhabi Emirate (2015 only) and Dubai Emirate (2015 and 2019), emission estimates were taken directly from the respective Emirate inventories, assumed to have been compiled using a Tier 3 approach as detailed in the EMEP/EEA Guidebook. It is worth noting that both inventories only cover in-port emissions. For Abu Dhabi and Fujairah Emirates, additional emissions reported by ADNOC attributable to shipping were added onto the estimates generated by other means. Abu Dhabi Ports provided aggregate level port call statistics for 2019. 2019 emissions estimates were estimated by scaling 2015 emissions by the overall trend in port activity taken from SCAD.

For Ajman, Fujairah, RAK and UAQ Emirates, information on vessel-by-vessel port callings including arrival and departure times was available for at least one of the years. This was used to implement a Tier 3 approach from the EMEP/EEA Guidebook 2019. Where the required data was only available for one of the years (true for Ajman, Fujairah and RAK Emirate), aggregate trends in vessel calls or goods movement from published statistics were used as a proxy to scale the Tier 3 emissions estimates for the other year. It is worth noting that Tier 3 inventories only cover in-port emissions.

For Sharjah Emirate, no port call data was available, so a Tier 1 approach has been used, combining the estimated fuel consumed in this sector (provided by MOEI) with default emission factors from the EMEP/EEA Guidebook 2019. There is therefore an inconsistency in the methodology used across the Emirates and this item has been added to the list of recommendations.

Estimated emissions from navigation were relatively stable between 2015 and 2019 for NOx and NMVOC. SO_2 emissions decreased by around 40%, mostly relating to a large reduction in the SO_2 emission estimates thought to be linked to the low sulphur regulations imposed by the IMO.

Non-road mobile machinery:
It is assumed that the emissions arising from the combustion of fuel in mobile machinery is included in the road transport emission estimates, as the fuel data provided did not allow emission estimates to be made for these specific sources.

[7] Emissions arising from ground support equipment at airports and ports are not reported in these categories and would be reported under "Other" (1A5). However, no information was available to allow direct estimates made for these sources and it has been assumed that they are accounted for in the road transport sector.

[8] Emissions arising from ground support equipment at airports and ports are not reported in these categories and would be reported under 'Other' (1A5). However, no information was available to allow direct estimates made for these sources. It was assumed that they are accounted for in the road transport sector.

6 Industrial processes and product use (IPPU)

6.1 Overview of emissions

Emissions accounted for in this category are those associated with industrial processes and product use (see Figure 7 and Table 6), and exclude combustion related emissions.

Emissions from industrial processes in the UAE most significantly arise from metal and mineral industries, while those from metal industries are predominantly from primary and secondary aluminium production, and iron and steel production. Emissions from mineral industries are predominantly from cement production, quarrying and mining.

Across the country, emissions from product use are generally not estimated due to data limitations. Domestic solvent use (which includes cosmetics and toiletries, car care products, and household products), the largest estimated category for product use, has been estimated using a default per capita value.

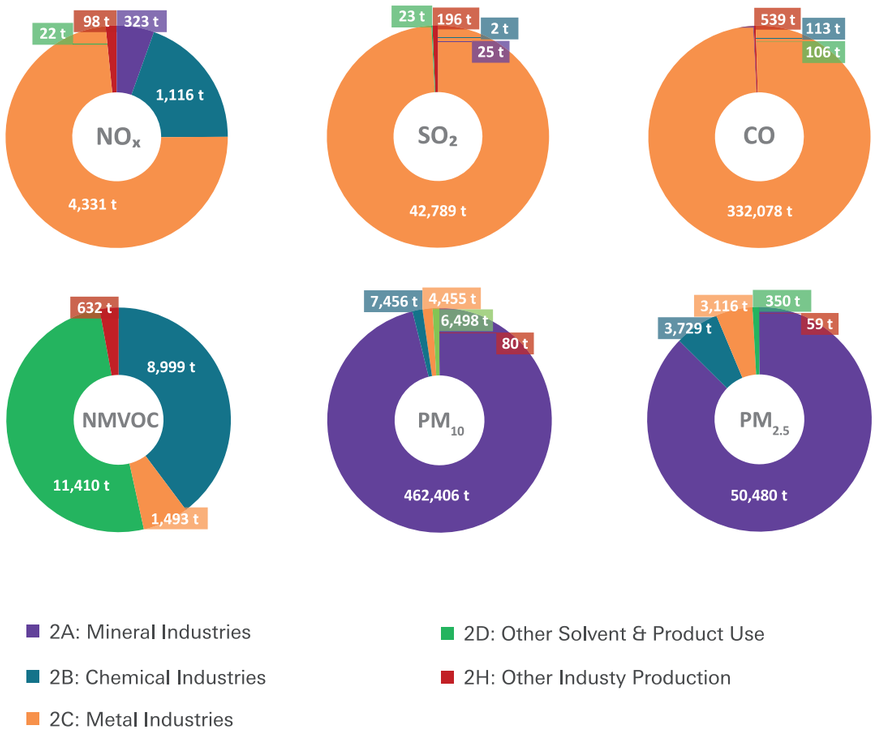


Figure 7: Estimated emissions from the IPPU sector by pollutant, 2019 (in tonnes)

Table 6: Estimated emissions from the IPPU sector by pollutant, 2015 and 2019 (in tonnes)

Sector / category		Emissions					
		NO_x	SO_2	CO	NMVOC	PM_{10}	$PM_{2.5}$
2A	Mineral industries 2015	707.5	14.1	333.2	NE	342,043	37,762
2A	Mineral industries 2019	323.1	25.4	172.2	NE	462,406	50,480
2B	Chemical industries 2015	1,118.8	1.4	112.4	7,548.3	3,723.3	2,787.8
2B	Chemical industries 2019	1,116.4	1.6	112.2	8,998.6	7,455.8	3,729
2C	Metal industries 2015	2,140.3	29,383	118,341	1,090.0	2,692.4	1,844.9
2C	Metal industries 2019	4,330.5	42,788.8	332,077.8	1,492.7	4,455.5	3,116.5
2D	Other solvent and product use 2015	23.8	12.0	14.1	10,159	4,039.8	194.4
2D	Other solvent and product use 2019	21.7	23.3	105.6	11,410.5	6,497.9	349.6
2H	Other industry production 2015	111.6	224.7	540.1	216.7	430.3	58.6
2H	Other industry production 2019	98.4	195.9	538.9	632.4	79.7	58.8
2I	Wood processing 2015	0.1>	0.1>	0.1>	0.1>	0.1>	NA
2I	Wood processing 2019	IE	IE	IE	IE	IE	NA
2J	Production of persistent organic pollutants (POPs) 2015	NA	NA	NA	NA	NA	NA
2J	Production of persistent organic pollutants (POPs) 2019	NA	NA	NA	NA	NA	NA
2K	Consumption of POPs and heavy metals 2015	NA	NA	NA	NA	NA	NA
2K	Consumption of POPs and heavy metals 2019	NA	NA	NA	NA	NA	NA
2L	Other production 2015	NA	NA	NA	NA	NA	NA
2L	Other production 2019	NA	NA	NA	NA	NA	NA
Total 2015 [2]		4,102	29,636	119,341	19,014	352,929	42,648
Total 2019 [2]		5,890	43,035	333,007	22,534	480,895	57,734

Note: Emission estimates for 2015 have been updated in this inventory where more accurate or more detailed data was available which allowed a higher methodology Tier to be used. Therefore, there may be differences between the values presented in the table above and that presented in the 2015 inventory report.

[1] NA – Not applicable (emissions of this pollutant do not occur from this source).

[2] The sum of the component parts may not exactly equal the total shown as a result of rounded off figures.

6.2 Methodology

For Abu Dhabi and Dubai Emirates, whilst efforts were made to use a bottom-up approach to compilation, in some cases it was necessary to extrapolate emission estimates from the respective inventories previously used for 2015 and supplement this with individual facility survey returns where relevant. For other Emirates, in general a bottom-up approach has been taken to estimating emissions. Input data was largely acquired from questionnaires distributed to individual facilities throughout the UAE. An additional data base compiling all the received data was created. This approach means that emission estimates are only as complete as data received, and therefore completeness remains an issue for the IPPU sector across the UAE. Where available, international data sets were used to complement facility data to improve completeness. Where required extrapolation using GDP as a proxy was used to gap fill for missing data. This occurred across sectors where facility data which was made available for the inventory compiled for the year 2015 was not available for 2019 in order to ensure completeness of the estimates and comparability across the emission years.

Either a tier 1 or 2 approach was taken to estimate emissions from each facility dependent on the level of detail in the information provided by the facility. In some cases, data from continuous monitoring of facilities could be used to apply a Tier 3 methodology. Otherwise, emissions were calculated based on methodologies taken from the EMEP/EEA 2019 Guidebook.

Emissions have increased across all pollutants in the IPPU sector between 2015 and 2019. Whilst efforts were made to ensure that this was not driven by improvements in completeness, the nature of the methodology for the IPPU sector means that individual facility reports, or the increase in the number of facilities reporting, can have significant impact on the trend of emissions as there are few compiled and/or aggregated national statistics for the sector.

7 Agriculture

7.1 Overview of emissions

Emissions from the agriculture sector are of minor significance for all air quality pollutants included in this inventory. SO_2 and CO emissions are not applicable for the agriculture sector and are therefore not included in this section (see Figure 8 and Table 7). It should be noted that the primary air pollutant from the agriculture sector is NH_3, which has been included for the first time in the 2019 inventory.

The main activity that causes emissions is manure management. The term manure refers to excrement from agricultural livestock that is used as a fertiliser.

NO_X, NH_3 and NMVOC emissions arise from the excreta of agricultural livestock that are deposited in and around buildings, and collected as liquid slurry, solid manure or litter-based farmyard manure. Emissions of particulate matter (PM) are mainly from feed, bedding, and feathers which occur from buildings used to house livestock.

The majority of NMVOC and PM_{10} emissions from manure management are due to farmed cattle and poultry. A much larger proportion of $PM_{2.5}$ emissions are due to camels, which have approximately the same contribution as dairy and non-dairy cattle to $PM_{2.5}$ emissions from manure management. Negligible emissions of NMVOC, PM_{10} and $PM_{2.5}$ are estimated from crop production and agriculture soils (3D).

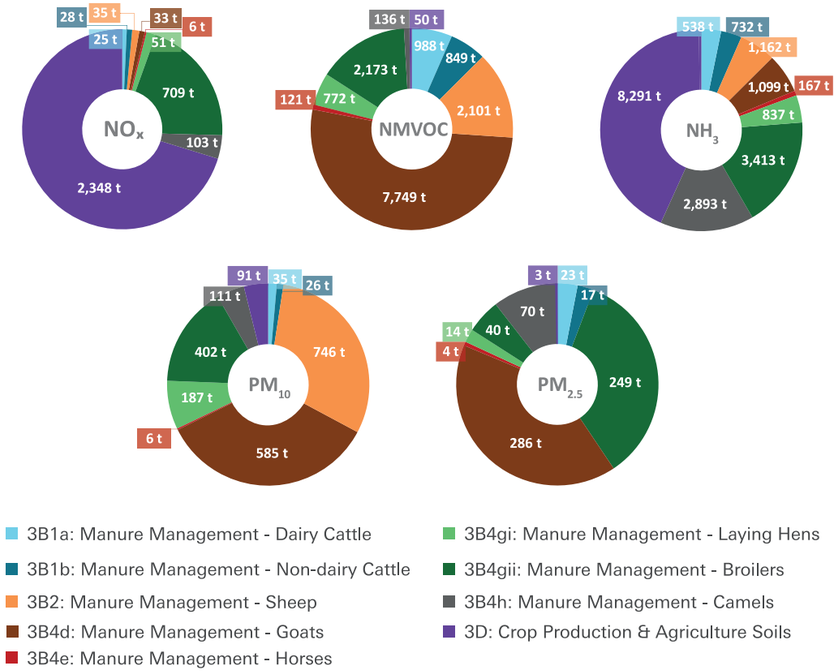


Figure 8: Estimated emissions from the agriculture sector by pollutant, 2019 (in tonnes)

Table 7: Estimated UAE emissions from the agricultural sector by pollutant, 2015 and 2019 (in tonnes)

Sector / category		Emissions						
		NO_x	SO_2	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
3B1a	Manure management – Dairy cattle 2015	21.9	NA1	NA	860.0	468.2	30.2	19.7
3B1a	Manure management – Dairy cattle 2019	25.1	NA	NA	988.1	538.0	34.7	22.6
3B1b	Manure management – Non-dairy cattle 2015	22.6	NA	NA	689.5	594.5	20.9	13.9
3B1b	Manure management – Non-dairy cattle 2019	27.9	NA	NA	849.3	732.4	25.8	17.2
3B2	Manure management – Sheep 2015	36.4	NA	NA	2,194.2	1213.2	779	259.7
3B2	Manure management – Sheep 2019	34.9	NA	NA	2101.4	1161.9	746	248.7
3B4d	Manure management – Goats 2015	31.2	NA	NA	7337.9	1040.6	812.3	270.8
3B4d	Manure management – Goats 2019	33.0	NA	NA	7748.8	1098.9	857.8	285.9
3B4e	Manure management – Horses 2015	6.0	NA	NA	121.4	167.2	6.2	4.0
3B4e	Manure management – Horses 2019	6.0	NA	NA	121.4	167.2	6.2	4.0
3B4gi	Manure management – Laying hens 2015	25.4	NA	NA	385.2	417.5	93.4	7.0
3B4gi	Manure management – Laying hens 2019	51.0	NA	NA	772.2	836.9	187.2	14.0
3B4gii	Manure management – Broilers 2015	734.5	NA	NA	2251.6	3536.5	417.0	41.7
3B4gii	Manure management – Broilers 2019	708.8	NA	NA	2172.8	3412.8	402.4	40.2
3B4h	Manure management – Camels 2015	89.7	NA	NA	118.3	2510.9	96.0	61.1
3B4h	Manure management – Camels 2019	103.3	NA	NA	136.2	2893.1	110.6	70.4
3D	Crop production and agricultural soils 2015	2,185.7	NA	NA	44.2	7397.4	80.2	3.1
3D	Crop production and agricultural soils 2019	2,347.6	NA	NA	50.0	8291.0	90.7	3.5
Total 2015 [2]		3,153.4	NA	NA	14,002.3	17,346.1	2,335.2	680.9
Total 2019 [2]		3,337.5	NA	NA	14,940.3	19,132	2,461.5	706.5

Note: Emission estimates for 2015 have been updated in this inventory where more accurate or more detailed data was available which allowed a higher methodology Tier to be used. Therefore, there may be differences between the values presented in the table above and that presented in the 2015 inventory report.

[1] NA – Not applicable (emissions of this pollutant do not occur from this source).

[2] The sum of the component parts may not exactly equal the total shown as a result of rounded off figures.

7.2 Methodology

All emission estimates have been made using the Tier 1 method. No emissions of SO_2 or CO occur from the agriculture sector.

The bulk of data on livestock population and the area of agricultural soils and crops was available from the Federal Competitiveness and Statistics Centre (FCSC). The area utilised for fruit trees, vegetable crops and field crops have been included; fallow land has not been included as it is understood as land without productive use. Where available, data supplied by individual Emirates was used in preference to UAE-level data, if this was judged to be more accurate. Other additional information such as the rate of application of fertilisers was sourced from international datasets and was allocated to Emirates based on national crop area statistics, as it was not available at the Emirate level. Default Tier 1 emission factors from the EMEP/EEA 2019 Guidebook are utilised throughout, although some have been modified to be more representative of conditions in UAE (rather than Western Europe, which is the basis for most), using default parameters on animal weight, nitrogen excretion and time spent in housing for the Middle East region from the IPCC 2019 Refinement. For allocation of manure to different types of storage, in the absence of information specific to the UAE (except to indicate no manure is burned), the default allocation for the Middle East region from the IPCC 2019 Refinement was used. Emission estimates for the agriculture sector can be treated as being uncertain for this reason. Collecting better activity data on manure management practices and the amount of fertiliser (organic and inorganic) applied within each Emirate would reduce this uncertainty.

For manure management, emissions of all pollutants have remained relatively stable between 2015 and 2019. Where larger changes have been observed, these are due to increases or decreases in animal numbers, as emission factors and other assumptions (such as the share of manure managed in different ways) are assumed to remain the same in both years (in the absence of real UAE-specific data).

The increase in NH_3 and NOx emissions between 2015 and 2019 from agricultural soils is related to the increase in animal manure applied to soils and deposited by grazing animals, in turn driven by the overall increase in animal numbers described above. No new data on synthetic nitrogen fertiliser application was available for 2019, so emission levels are assumed to have remained the same as in 2015.

8 Waste

8.1 Overview of emissions

Emissions from the waste sector are of minor significance for all air quality pollutants included in this inventory, except for NMVOC emissions from MSW[9] disposal on land, which is identified as a key category (see Figure 9 and Table 8). It should be noted that some waste disposal activities can give rise to other pollutants, particularly heavy metals and persistent organic pollutants (POPs) that are not yet included in the inventory. Small amounts of carbon monoxide emissions from composting were estimated.

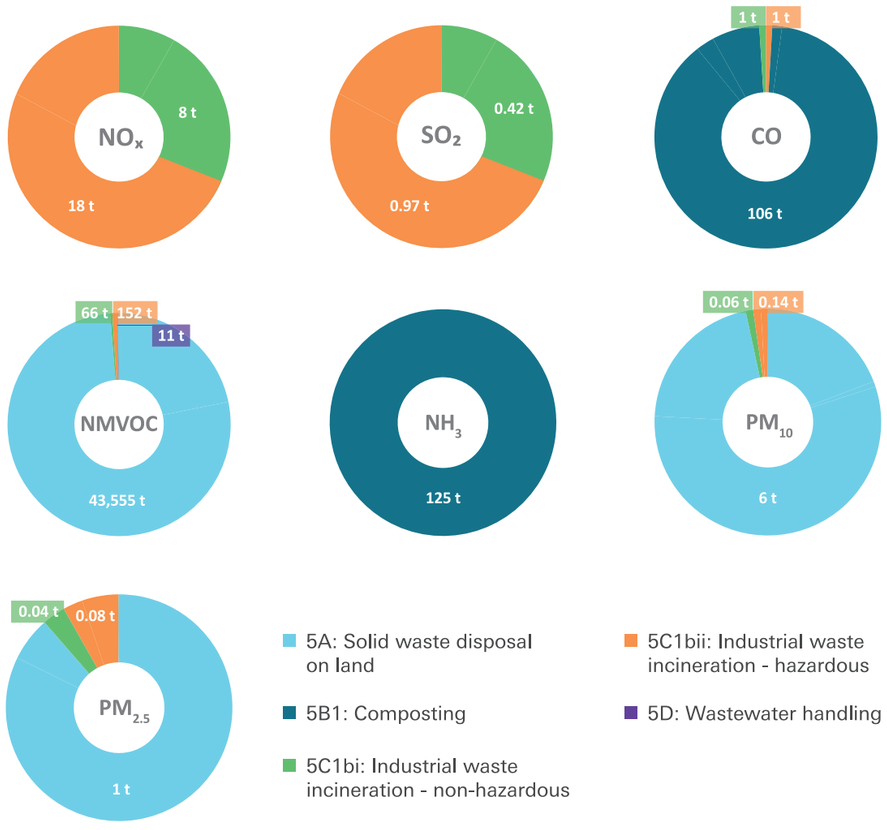


Figure 9: Estimated emissions from the waste sector by pollutant, 2019 (in tonnes)

[9] The bulk of MSW originates from households, although similar wastes from sources, such as commerce, offices, public institutions, and selected municipal services are also included. MSW also includes bulky waste, but excludes waste from municipal sewage networks, and municipal construction and demolition waste.

Negligible emissions of all pollutants are estimated from the incineration of hazardous waste in clinical waste incinerators. The incineration of hazardous waste is limited mostly to Abu Dhabi and Dubai Emirates. Wastewater is treated and collected in all the emirates. The practice gives rise to insignificant emissions of NMVOC.

Table 8: Estimated UAE emissions from the waste sector by pollutant, 2015 and 2019 (in tonnes)

Sector		Emissions						
		NO_x	SO_2	CO	NMVOC	PM_{10}	$PM_{2.5}$	NH_3
5A	**Municipal solid waste disposal on land 2015**	NA[1]	NA	NE	44,254.7	NA	6.2	0.9
5A	**Municipal solid waste disposal on land 2019**	NA[1]	NA	NE	43,555.4	NA	6.1	0.9
5B1	**Composting 2015**	NE[2]	NA	322.9	NE	380.6	NE	NE
5B1	**Composting 2019**	NE[2]	NA	105.8	NE	124.7	NE	NE
5C1b	**Industrial waste incineration – Hazardous 2015**	5.0	0.3	0.4	42.9	NE	0.01	0.02
5C1b	**Industrial waste incineration – Hazardous 2019**	17.9	1.0	1.4	152.0	NE	0.1	0.08
5C1b	**Industrial waste incineration – non Hazardous 2015**	NE	NE	NE	NE	NE	NE	NE
5C1b	**Industrial waste incineration – non Hazardous 2019**	7.8	0.4	0.6	66.1	NE	0.06	0.04
5D	**Wastewater handling 2015**	NA	NA	NA	10.9	NE	NE	NE
5D	**Wastewater handling 2019**	NA	NA	NA	11.3	NE	NE	NE
Total 2015[3]		5.0	0.3	323.3	44,308.5	380.6	6.3	1.0
Total 2019[3]		25.6	1.4	107.9	43,784.8	124.7	6.3	1.0

Note: Emission estimates for 2015 have been updated in this inventory where more accurate or more detailed data was available which allowed a higher methodology Tier to be used. Therefore, there may be differences between the values presented in the table above and that presented in the 2015 inventory report.

[1] NA – Not applicable (emissions of this pollutant do not occur from this source).

[2] NE – Not estimated (emissions of this pollutant are likely to occur from this source, but there are no default emission factors available in the EMEP/EEA guidebook).

[3] The sum of the component parts may not exactly equal the total shown as a result of rounded off figures.

8.2 Methodology

The majority of activity data for the waste sector has been obtained from the Federal Competitiveness and Statistics Centre (FCSC) Waste Statistics 2015 and 2019. This provides totals of solid waste disposal routes by Emirate, including waste disposal on land (5A), composting (5B1) and industrial waste incineration (5C1b).

Similarly, to solid waste, data on the volume of collected and treated wastewater by Emirate was available from the Emirates directly or FCSC Wastewater Statistics 2019.

Default Tier 1 emission factors are utilised throughout, except for composting (5B1) where it is assumed that 'windrow' composting is practiced. This allows for a Tier 2 methodology to be applied for carbon monoxide and ammonia.

For waste disposal on land there is minimal change in the estimated NMVOC emissions between 2015 and 2019. The largest change occurs in the composting sector for which a marked decrease is estimated between these years. This is as a result of an overall large decrease in composting activity, particularly in Abu Dhabi Emirates due to a low demand for the compost generated.

The emission estimates for industrial waste incineration have increased between 2015 and 2019. This is a result of a substantial increase in levels of activity, particularly in Abu Dhabi and Ajman Emirates.

9 Emission maps

Emission maps for each category of pollutant within the inventory have been generated and are presented in Figures 10 to 16, featured below. These maps are detailed at a resolution of 1 kilometre. Despite the diligent efforts of the compilation team to predominantly rely on primary information for the precise identification of emission sources, certain informed assumptions were necessitated in instances where data was insufficient, notably with respect to area, line and fugitive sources. In the case of point sources, the accuracy of the allocation is subject to the availability of valid information. We anticipate that the precision of these allocations will improve with each subsequent update of the inventory.

Some of the key assumptions made during the mapping process include:

- Particulate matter emissions from construction and demolition projects were allocated to settlements in proportion to their density and available national road maps due to the absence of precise project locations.
- Emissions associated with road transport were allocated based on road carrying capacity in absence of actual vehicle counts.
- Emissions from fuel consumption from the commercial and residential sectors, as well as emission related to domestic solvent-use were allocated to settlements in proportion to their population density.
- Navigation-related emissions were estimated and allocated within a buffer zone around major ports.
- Agriculture-related emissions were allocated proportionally to identified agricultural areas within the country.
- Point sources lacking coordinates could not be included in the emission maps.

These assumptions were employed to ensure a comprehensive emission mapping process, taking into account the limitations of available data.

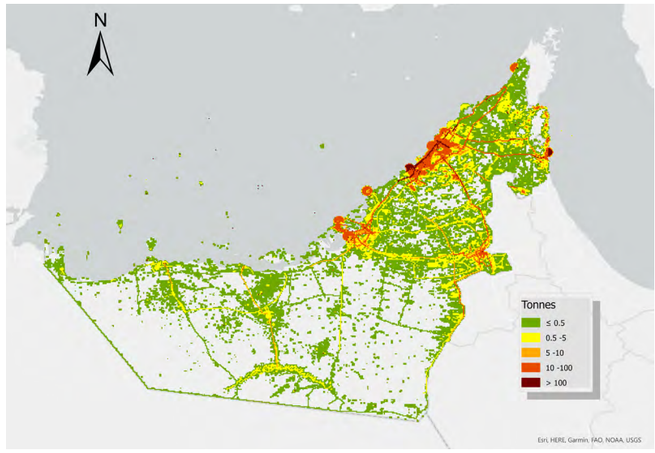


Figure 10: Estimated Nitrogen Oxides (NO_x) emissions for 2019 (tonnes) - All sectors

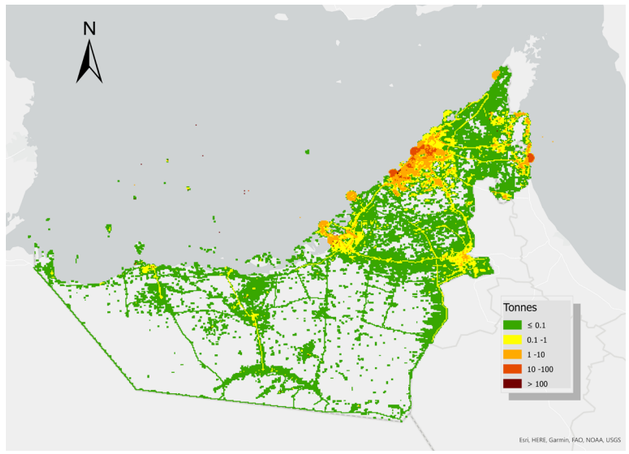


Figure 11: Estimated Sulphur Dioxide (SO_2) emissions for 2019 (tonnes) - All sectors

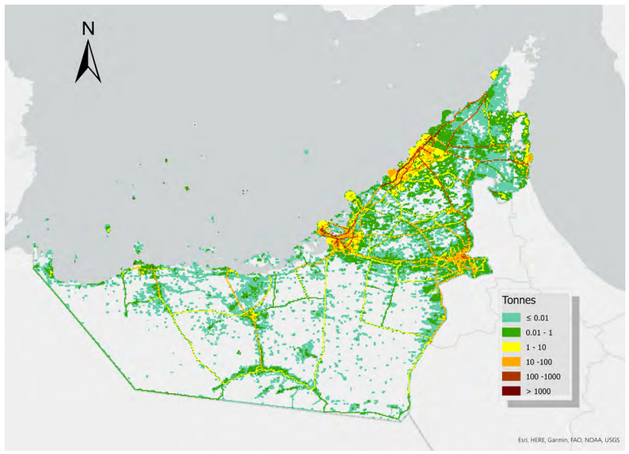


Figure 12: Estimated Carbon Monoxide (CO) emissions for 2019 (tonnes) – All sectors

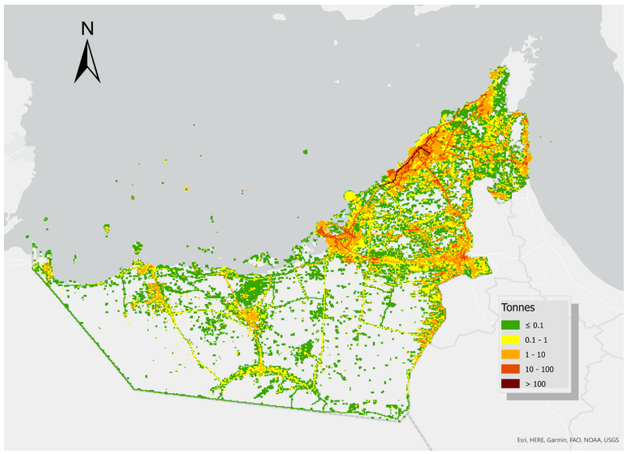


Figure 13: Estimated Non-methane volatile organic compounds (NMVOC) emissions for 2019 (tonnes) – All sectors

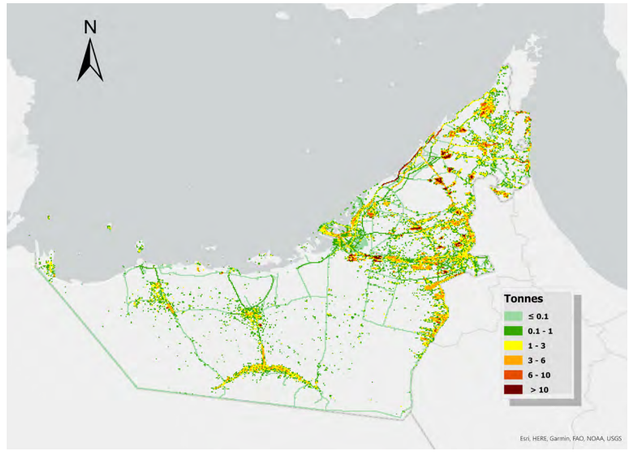


Figure 14: Estimated Ammonia (NH_3) emissions for 2019 (tonnes) – All sectors

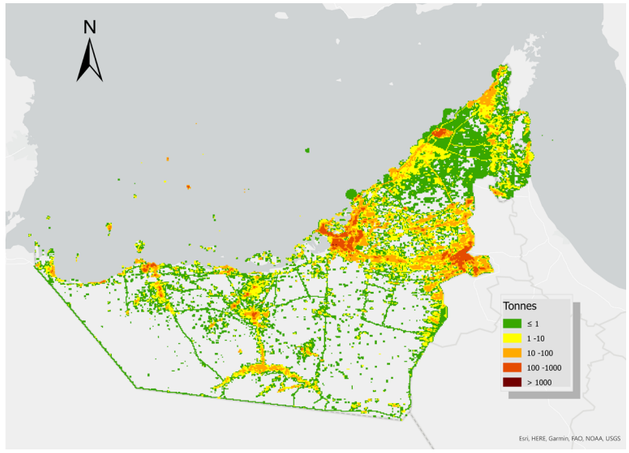


Figure 15: Particulate Matter< 10µm (PM_{10}) emissions for 2019 (tonnes) – All sectors

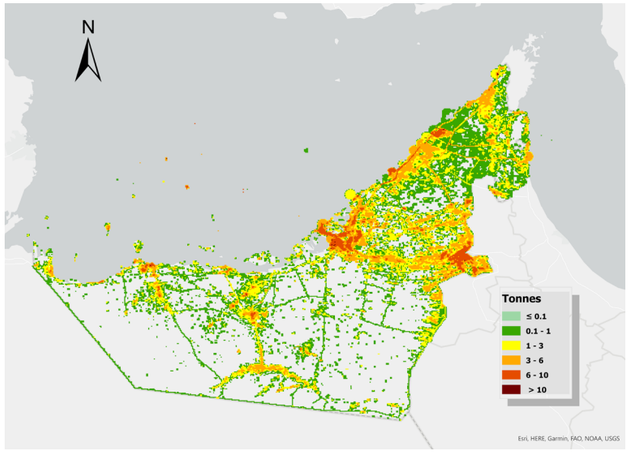


Figure 16: Particulate Matter<2.5µm ($PM_{2.5}$) emissions for 2019 (tonnes) – All sectors

10 Conclusions & recommendations

Emission estimates of seven air quality criteria pollutants have been compiled for the years 2015 and 2019 for the whole of the UAE. Emission estimates of ammonia were added in this version. Previous estimates compiled for 2015 in the preceding inventory have been updated when new activity data or better data was available, allowing a more accurate methodology to be undertaken.

Overall, an increasing trend was observed in the estimated emissions for most of the pollutants between 2015 and 2019, which has been driven primarily by increase in activity levels. The exception to this is SO_2 and NOx for which a decline in emissions has been noted.

The construction and demolition sector was included in this version, and it was found to significantly contribute to emissions of particulate matter. Oil and gas activities comprise a large proportion of the NOx emissions, with road transport and power generation also contributing substantial amounts. For SO_2, fugitive emissions from flaring are the dominant source. For CO however, aluminium production comprises most emissions with petrol fuelled passenger cars and light duty vehicles also being important sources. The agriculture and waste sectors play a minor role, and as discussed in the report, these are more significant sectors in terms of greenhouse gas emissions. Of note, however, is the estimated NMVOC emissions from solid waste disposal on land. NH_3 emissions are low but are dominated by the agriculture and to a lesser extent the transport sector.

In this second iteration of the National Inventory, the process of collecting activity was improved as there was better understanding of the emissions sources and data requirements by compilers, reviewers and data providers. As a result, data of better quality was gathered which allowed to undertake more robust methodologies for calculations in many cases. However, completeness in the industrial combustion and process sectors remains a matter of concern; and accuracy of activity data and estimations for the transport and construction and demolition sector still needs to be improved. Another important area of improvement is the consistency between the estimates of emission for the different Emirates, as each Emirate has different data availability and compilation methods.

An update to the inventory is recommended every three years. Efforts should focus on completeness and accuracy of key categories, and where improvements can be made with a low or medium level of effort. Significant improvements to the accuracy of the national inventories can be achieved with the development of country emission factors that reflect the local practices and technologies.

As part of the ongoing efforts to improve the national emissions inventory process in the medium term, MOCCAE has embarked in the implementation of a Monitoring, Reporting and Verification system for air quality and greenhouse gas emissions. The aim is to have a consistent approach between the greenhouse gas and air quality pollutants inventories and between the individual Emirate and UAE inventories, with the same data sources and activity data being used where possible. The system will cover governance, technical capacity of experts, data flows, co-ordination, systems and tools and the engagement and communication strategy. The MRV system framework would formalise the new roles, responsibilities, resources and relationships needed to deliver the system outputs. Once the MRV system is in place, it will greatly enhance the process and accuracy of compiling the air quality pollutant inventories.

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