STATE OF ISRAEL

Israel's First National Inventory Report, 2022

2025

הלשכה המרכזית לסטטיסטיקה
Central Bureau of Statistics
دائرة الإحصاء المركزية

ISRAEL'S FIRST INVENTORY REPORT to the United Nations Framework Convention on Climate Change.

This report was prepared and edited by the Central Bureau of Statistics – April 2025

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Abstract

Background

This report presents the inventory of greenhouse gas emissions in Israel for 2022, prepared as part of Israel's National Inventory Report (NIR) to the United Nations Framework Convention on Climate Change (UNFCCC). The report contains background and explanations for each source of emission, a description of the methods of calculation, and a presentation of the greenhouse gas emission estimates for 2022. Estimates for the following previous years are also presented: 1996, 2000, and 2003–2021.

This report is the first prepared by Israel and was compiled in accordance with the latest reporting guidelines of the UNFCCC, formulated at the 26th Conference of the Parties to the Convention (COP26). The inventory was calculated according to the calculation guidelines of the Intergovernmental Panel on Climate Change (IPCC) for 1996, and, in some cases, according to the 2006 guidelines. The calculation of Israel's emissions involves a constant process of improvement and adapting the international calculation methods to Israel and their implementation.

The inventory of greenhouse gas emissions was calculated for the first time at the Ministry of Environmental Protection, for the years 1996 and 2000. The first inventory calculated at the Central Bureau of Statistics (CBS) was for 2003, and it has been calculated by the CBS every year since then.

Inventory of Greenhouse Gas Emissions

Total emissions of greenhouse gases in Israel came to 81.1 million tons[1] of carbon dioxide equivalent (CO_2eq) in 2022, compared to 78.4 million tons in 2021, an increase of 2.7 million tons (3.4%). In the period 2010–2022, emissions increased by 5.4%.

Greenhouse Gas Emissions, by Source, Selected Years

Thousand tons of carbon dioxide equivalent

Year / Source of Emission	2000	2003	2005	2008	2010	2015	2020	2021	2022
Total	**67,925**	**70,397**	**71,364**	**77,738**	**76,883**	**80,713**	**79,481**	**78,369**	**81,063**
Energy	59,045	60,743	60,662	63,986	63,194	64,126	61,199	60,807	62,853
Industrial processes and product use	2,740	2,270	2,560	4,527	3,986	6,065	7,634	6,619	6,968
Agriculture	2,340	2,291	2,392	2,563	2,474	2,330	2,325	2,389	2,419
Land use change and forestry	-213	-286	-376	-347	-411	-141	-260	-294	-286
Waste and wastewater	4,013	5,379	6,125	7,007	7,640	8,333	8,584	8,849	9,108

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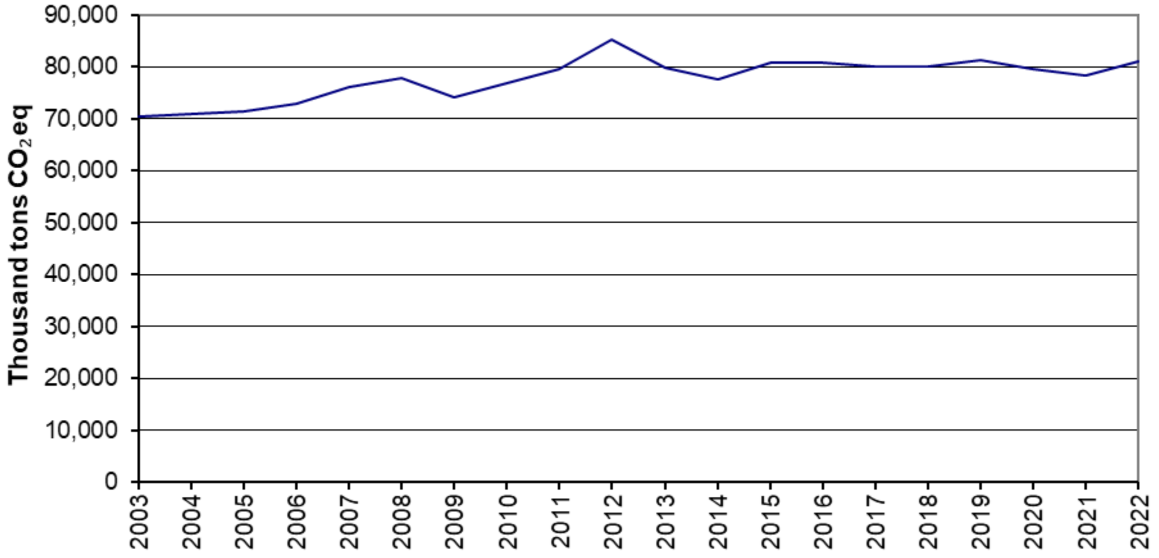
[1] The term "ton", throughout this publication, refers to metric ton, i.e., 1000 kg.

Between 2003 (the first year the inventory was calculated at the CBS) and 2022, total emissions increased by 15.2%. (Up to the year 2007, emissions from the use of substitutes for ozone-depleting substances were not included in the calculation, under the assumption that these emissions were not high). During most of the years since 2003, a general trend of fluctuating increase was observed, with stabilization since 2014.

DIAGRAM A TOTAL GHG EMISSIONS
2003–2022



Emissions, by Emission Source

Energy

In 2022, the largest source of emissions in Israel, as in most countries around the world, was the energy sector – 62.9 million tons of CO_2eq (77.3% of total greenhouse gas emissions, excluding emissions from land use change and forestry). Changes in emissions from this source over the years depend on the size of the population and increases in the standard of living and are affected by the mix of fuels used to generate energy. In 2003, the energy sector's share of all emissions was 85.9%, and it gradually decreased over the years (due to the stabilization of emissions in the energy sector and an increase in emissions from other sources), until it reached 77.3% in 2022.

The largest source of emissions was electricity generation (included in the energy industries), which accounted for 54.1% of all emissions in the energy sector. The second largest source of emissions in the energy sector was land transport – 30.7%.

Total emissions in the energy sector increased between 2003 and 2022 by 3.5% (whereas there were fluctuations in total emissions during this period), and between 2021 and 2022 they increased by 3.4%.

Industrial processes and product use

The third largest source of emissions in 2022 was industrial processes and product use – 7.0 million tons of CO_2eq, which was about 8.6% of total greenhouse gas emissions.

Greenhouse gas emissions from industrial processes and product use come primarily from two main sources: the use of substitutes for ozone-depleting substances (71.8%), mainly gases for air conditioning and refrigeration systems (HFCs) (66.3%); and the mineral industry (27.5%), mainly cement production. The changes in emissions from the use of substitutes for ozone-depleting substances were mainly affected by changes in the quantities of these gases imported over the years and the replacement of ozone-depleting substances, which were used previously.

In 2003, the share of emissions from industrial processes and product use out of all emissions was 3.2%. Between 2008 and 2022 these emissions increased by 53.9%. (In 2008, the calculation of emissions from the use of substitutes for ozone-depleting substances began.) Between 2021 and 2022 emissions from industrial processes and product use increased by 5.3%.

Agriculture

Total greenhouse gas emissions from agriculture in 2022 came to 2.4 million tons of CO_2eq. The share of emissions from agriculture out of total emissions was about 3%, a percentage that has remained stable over the years. Between 2011 and 2022, the emissions from agriculture increased by 13.6%, and between 2021 and 2022, they increased by 1.3%. In 2022, emissions of nitrous oxide (N_2O), both direct and indirect, resulting from agricultural land management, amounted to 1.0 million tons of CO_2eq – 39.9% of all emissions from agriculture. Emissions from enteric fermentation amounted to approximately 1,187,000 tons of CO_2eq (49.1% of all emissions from agriculture). Emissions from animal manure management amounted to approximately 266,100 tons of CO_2eq (11% of all emissions from agriculture – 7.2% were N_2O emissions from animal manure management and 3.8% were CH_4 emissions from this source).

Land use change and forestry

Trees absorb carbon and, therefore, an increase in forests reduces the emission of greenhouse gases. Conversely, cutting down trees results in the emission of the carbon absorbed by the trees. Most of the forests in Israel are planted forests, and their area has increased over the years. In 2022, the total net absorption of greenhouse gases from forestry was 0.3 million tons of CO_2eq. Between 2003 and 2022, the absorption from forestry fluctuated, averaging about 0.3 million tons of CO_2eq.

Waste and wastewater

In 2022, total emissions of greenhouse gases from waste and wastewater amounted to 9.1 million tons of CO_2eq, 11.2% of all emissions in Israel (the second-largest source of emissions). Emissions from waste and wastewater in Israel come from waste management (approximately 75% of urban waste goes to landfill) and management of domestic and industrial wastewater.

Emissions from waste and wastewater increased between 2003 and 2010 by 42.0%. Between 2011 and 2022, this upward trend moderated, and emissions increased by only 15.3%.

Emissions, by Gas

In 2022, carbon dioxide (CO_2) emissions constituted 79.3% of all emissions (excluding emissions from land use change and forestry), coming predominantly from the energy sector. Methane (CH_4) emissions constituted 12.8% of all emissions, mainly originating from waste and wastewater management, particularly the disposal of waste as landfill. The share of emissions of gases used for air conditioning and refrigeration (HFCs) (which are included in the industrial processes and product use sector) out of total emissions increased from 1.0% in 2008 to 5.7% in 2022. Nitrous oxide (N_2O) emissions, which come mainly from the agriculture sector, constituted about 2% over the course of the years.

Key Source Categories

The assessment of the relative contributions of the emission sources is carried out by means of two examinations: one to ascertain the relative contribution of the emission source to the total **absolute level of emissions**, and the other to examine the effect of the emission source on the **trend in emissions** over the course of the years.

An analysis of the relative contributions of the emission sources to the total **absolute level of emissions** shows that the following were the main emission sources in 2022: electricity generation (41.5%), transportation (22.4%), disposal of waste as landfill (9.8%), fuel combustion in the manufacturing and construction industries (7.1%), substitutes for ozone-depleting substances - air conditioning and refrigeration system (HFCs) (5.3%), petroleum refining (3.2%), cement Production (2.2%), and enteric fermentation in the digestive system of animals emissions (1.4%).

Over the course of the years, electricity generation has been the largest primary source of emissions. The share of emissions from the use of substitutes for ozone-depleting substances has increased substantially over the years.

The relative contributions of the emission sources to the **trend in emissions** is analyzed relative to a base year. From this analysis it is possible to learn what the primary emission sources were that affected the emissions trend in 2022. In order to isolate other influences on the trend analysis, 2011 was chosen as the base year in Israel, and since that year the emissions have been calculated in similar fashion.

Electricity generation (42.2%), transportation (18.2%) and emissions of gases used for air conditioning and refrigeration (HFCs) (15.7%) are the primary emission sources that influenced the trend in emissions. Electricity generation and transportation influenced the trend due to their large share in emissions, with even slight changes in this source affecting the trend. Emissions of gases used for air conditioning and refrigeration influenced the trend due to a sharp increase in emissions from this source over the years.

1. Chapter 1: National circumstances, institutional arrangements and cross-sectorial information

1.1. Background information on greenhouse gas (GHG) emissions inventories

1.1.1. International agreements on the reporting of GHG emissions inventories

As part of efforts to reduce global warming and its effects, the United Nations Framework Convention on Climate Change (UNFCCC) was signed. The convention entered into force in 1994, and Israel ratified it in 1996. One of the principal commitments made by the ratifying parties under the convention was to develop, publish and regularly update the national emissions inventory of greenhouse gases.

In 1997, the Kyoto Protocol was adopted as an addendum to the convention. It determines detailed instructions for reducing emissions in developed countries. Israel signed the protocol in 1998, but at that time it was not considered a developed country, and therefore was not included in the countries that were obliged to meet the reduction targets set by the protocol.

At the UN Climate Conference held in Copenhagen in December 2009, the President of Israel stated that Israel will reduce its GHG emissions by 20% by 2020, compared to a "business as usual" scenario. In November 2010, according to Israel's commitment, the government approved Government Resolution No. 2508: "Formulation of a national plan to reduce GHG emissions in Israel".

At the climate conference that convened in December 2015 in Paris, a global and binding agreement was signed to combat climate change (the Paris Agreement). Ahead of the conference, Israel committed in September 2015 to reduce GHG emissions to 7.7 tons of carbon dioxide equivalent (CO_2eq) per capita by 2030, a decrease of 26% from the level of emissions per capita in 2005. The national target for reducing GHG emissions in Israel was submitted to the Secretariat of the UNFCCC in September 2015.

The State of Israel signed the agreement on April 22, 2016 and ratified it on November 14, 2016.

In April 2016, Government Resolution No. 1403 was approved: "National plan for the implementation of the goals for reducing GHG emissions and energy efficiency," with the aim of achieving the national goal.

The climate conference held in Glasgow in 2021 was the 26th gathering of the parties committed to the framework convention as a continuation of the climate conference in Paris in 2015. Before the conference, the countries that signed the convention were required to submit to the Secretariat of the UNFCCC their Nationally Determined Contribution (NDC) to reduce GHG emissions in accordance with the decisions of the climate conference in Paris in 2015. In 2021, the State of Israel submitted Israel's NDC to the Secretariat of the UNFCCC.

1.1.2. Government resolutions

The following are selected sections from the main government resolutions regarding the reduction of GHG emissions in Israel and Israel's adaptation to climate change.

Government Resolution No. 474: "Israel's adaptation to climate change - preparation and readiness for climate change and reduction of GHG emissions" (June 25, 2009) (Hebrew only)

A committee of directors headed by the Director of the Ministry of Environmental Protection should be established, for readiness and adaptation to climate change and reduction of GHG emissions (mitigation).

The directors committee is tasked with formulating a recommendation for a national action plan to reduce GHG emissions in Israel, which will determine, among other things, the following issues: national goals for reducing GHG emissions; criteria according to which the reduction goals will be calculated, including the base year for the calculation; reduction measures and methods of implementation; timetables and milestones; economic and budgetary aspects arising from the implementation of the mitigation measures; determination of output and result indicators to meet the goals of the national action plan. Working teams will be appointed to formulate a recommendation for policies and plans for the reduction of GHG emissions, in the following areas, among other things: energy conservation and efficiency and optimization of electricity generation processes, construction and housing, transportation, agriculture, waste, land use, water and renewable energies.

Additionally, the committee will formulate a recommendation for a national action plan for the preparation and adaptation of the State of Israel to climate change. The committee will appoint work teams to prepare a recommendation for a national plan for preparing and adapting to climate change, among other things, in the following areas: changes in the demand for energy for cooling and heating, water resources, agriculture, construction, public health, coastal infrastructure, drainage and erosion, economy and insurance, geo-strategic aspects, biodiversity and natural habitats and tourism.

Government Resolution No. 1504: "Formulation of a national plan to reduce GHG emissions" (March 14, 2010) (Hebrew only)

The steering committee, established to formulate a national plan to reduce GHG emissions, will formulate recommendations to reduce GHG emissions in Israel, with the aspiration of bringing about a reduction of 20% of the total expected emissions in 2020 compared with the "business as usual" scenario. The committee will examine the economic consequences of reducing emissions on the Israeli economy and will propose the most effective policy tools. The committee will examine possible actions to reduce GHG emissions, identify barriers to their implementation in the economy and propose policy measures, economic tools and allocation of resources at the level of the economy.

Government Resolution No. 2508: Formulation of a national plan to reduce GHG emissions in Israel (November 28, 2010) (Hebrew only)

The steering committee, established to formulate a national plan to reduce GHG emissions, will examine additional policy measures to reduce GHG emissions, including in the field of renewable energies, with the aspiration of bringing about a 20% reduction in total emissions expected in 2020 by the "business as usual" scenario. The resolution allocates a total amount of NIS 2.2 billion for the period of 2011–2020 to implement the action plan of reducing GHG emissions. The Minister of Environmental Protection is tasked with carrying out supervision and follow-up on the reduction of GHG emissions in the economy as a result of the implementation of this decision and to report on it to the government. The relevant government ministries are tasked with carrying out actions to promote the reduction of GHG emissions, including: regulations, updating the standard, education and outreach activities, plans to support investments to reduce GHG emissions, establishing a plan to support conducting energy surveys, reducing taxes.

Government Resolution No. 542: "Reducing GHG emissions and energy efficiency in the economy" (September 20, 2015) (Hebrew only)

In order to submit a national target for reducing GHG emissions to the climate secretariat: A national target of 8.8 tons for GHG emissions per capita in 2025 and 7.7 tons for GHG emissions per capita in 2030 shall be set.

National targets should be established for the reduction and optimization of energy consumption in the economy and the generation of electricity from renewable energy sources, in order to achieve the national target for reducing GHG emissions: reducing electricity consumption by at least 17% by the year 2030, compared with the expected electricity consumption in that year according to the "business as usual" scenario, reducing 20% of the kilometers travelled by private vehicles by 2030, compared with the expected kilometers travelled that year according to the "business as usual" forecast and the trends as of 2015. Electricity generation from renewable energy will be at least 13% of the total electricity consumption in 2025 and at a rate of at least 17% of the total electricity consumption in 2030.

Government Resolution No. 1403: "National plan for the implementation of the goals for reducing GHG emissions and energy efficiency" (April 10, 2016) (Hebrew only)

The following steps shall be taken: Establish an advisory team for a program to provide state guarantees for loans for investment in energy efficiency and reducing GHG emissions in the economy, establish and operate a grant program for investments in energy efficiency, submit a detailed multi-year national plan for energy efficiency for 2030, examine and formulate steps to achieve a reduction target in electricity consumption, examine the update of the taxation policy for accelerated depreciation for energy-saving products, grant a tax benefit in the form of accelerated depreciation to business facilities with photovoltaic technology, examine measures that would establish an energy rating obligation for new residential and office buildings, formulate a detailed plan that includes measures to reduce emissions in existing and new buildings in Israel, publish a plan for achieving targets for electricity generation from renewable energy sources, establish a steering committee that will formulate recommendations for a plan to support and promote Israeli technologies in the fields of energy efficiency, renewable energy and more, formulate and implement a plan to encourage the use of public transportation, carry out actions to reduce the energy consumption of government ministries, establish a steering committee and follow-up regarding the reduction of GHG emissions.

Government Resolution No. 171: "Transition to a Low-Carbon Economy" (July 25, 2021) (Hebrew only)

Further to the government resolution regarding the reduction of greenhouse gas emissions and the optimization of energy consumption in the economy, and in order to meet Israel's commitment under the government resolution concerning the ratification of the Paris Agreement on international management of climate change:

A. The State of Israel acknowledges the importance of reaching the target of zero greenhouse gas emissions by 2050, in line with the Paris Agreement and with Israel’s international commitment, and to prevent crossing the global warming threshold of 1.5°C.

B. To update the national target for reducing greenhouse gas emissions by 2030 as set in Government Resolution 542 of 2015, such that the annual amount of GHG emissions in 2030 will be reduced by at least 27% compared to the annual amount measured in 2015, which was 79 million tons. Accordingly, the annual GHG emissions in 2030 will be approximately 58 million tons.

C. To set a national target for reducing GHG emissions by 2050, namely, that the annual amount of GHG emissions in 2050 will be reduced by at least 85% compared to the annual amount measured in 2015. Accordingly, the annual GHG emissions in 2050 will be approximately 12 million tons.

Government Resolution No. 208: "Transition to Green Energy and Amendment of Government Resolution" (August 1, 2021) (Hebrew only)

Further to a previous government resolution to promote renewable energy in the electricity sector and the government resolution to transition to a low-carbon economy, and in accordance with Israel's international commitments to reduce emissions, action will be taken toward optimizing the use of land, which is a limited resource, and increasing the use of clean energy. This is aimed at encouraging a transition to alternative fuels consumption, as well as increasing private investment due to the COVID-19 crisis.

Government Resolution No. 542: "Promotion of Clean and Low-Carbon Transport" (October 24, 2021) (Hebrew only)

In accordance with the National Energy Efficiency Program published by the Ministry of Energy in December 2020 – which stated that Israel will work toward establishing the nation's energy independence and reducing the economy's reliance on oil and polluting fuels – and as part of Israel's preparations for energy efficiency, the fight against climate change, and transitioning to a low-emissions economy by 2050, national targets for the introduction of clean transportation to Israel were set. These targets include: Starting in 2035 at the latest, 50% of vehicles over 3.5 tons imported to Israel by commercial importers will be clean vehicles or vehicles using fuels that reduce GHG emissions by 80% compared to diesel. In addition, in order to set a target for non-urban clean buses, pilot programs for operating such buses will be promoted, and based on the results of the pilot, targets for 2030 will be set for the transition to importing clean buses.

Government Resolution No. 1282: "National Plan for the Prevention and Reduction of Air Pollution and Greenhouse Gas Emissions in Israel – Implementation Plan" (March 14, 2022) (Hebrew only)

To advance the economy toward meeting the national GHG emissions reduction targets, as approved by the government in Resolution No. 171 of July 25, 2021, "Transition to a Low-Carbon Economy," along with additional reduction measures needed to fully meet the targets. Furthermore, in order to implement Israel's commitment, as submitted to the UN Secretariat of the UNFCCC as part of implementing the Paris Agreement, a national plan for the prevention and reduction of air pollution and GHG emissions is presented. This national plan is part of Israel's response to the climate crisis, and its purpose, among other things, is to fulfill some of Israel's commitments under the Paris Agreement and the Glasgow Climate Conference, including government efforts toward meeting the target to reduce GHG emissions in the economy by 2030.

1.1.3. Emission gases

This report presents the calculation of the emissions and sinks of greenhouse gases in Israel resulting from human activity, according to the main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6).

The report to the Secretariat of the Climate Convention also includes the indirect greenhouse gases: carbon monoxide (CO) and nitrogen oxides (NO_X). In addition, sulfur dioxide (SO_2) emissions are reported, because they participate in the generation of aerosols and affect global warming. The calculation of emissions of non-methane volatile organic compounds (NMVOCs) was discontinued in 2011.

Gases that have various effects on global warming are included in the emissions calculation. To enable a comparison between the gases, the Global Warming Potential (GWP) was defined; it weighs the relative influence of the various gases (according to their ability to absorb radiation and the time they remain in the atmosphere). According to this index, the Global Warming Potential of CO_2 is defined as 1, and the other gases – in proportion to it.

The report presents the emissions of each of the greenhouse gases in CO_2eq according to Global Warming Potential coefficients for a period of 100 years, as published in the IPCC Fifth Assessment Report (AR5). The Global Warming Potential coefficient of CH_4 is 28, and that of N_2O – 265. The coefficients of greenhouse gases containing fluorine (HFCs, PFCs, SF_6) vary among the different types of gases.

1.1.4. Sources of emissions

GHG emissions[1] were grouped into five emission sectors defined in IPCC 1996 for reporting. These sectors represent the main human activities that contribute to the emissions and sinks of greenhouse gases.

These are the emission sectors:

- Energy
- Industrial processes and product use
- Agriculture
- Land use change and forestry
- Waste and wastewater

1.1.5. Year of Reporting

The last reporting year in this report during which the emissions were generated is 2022, and in addition, emissions from previous years are presented for comparison and analysis.

The emissions calculation is based on administrative information (such as fuel consumption and number of animals) and dedicated surveys (such as a survey of imports of gases containing fluorine) on activity in the economy that occurred between 1 Jan. 2022 and 31 Dec. 2022.

1.1.6. Structure of the Report

This report is the first that Israel has prepared and it is written in accordance with the latest reporting guidelines of the UNFCCC, established at the 26th Conference of the Parties to the Convention (COP26):

"Transparency decision from COP26, Decision – 'CMA.3, Annex V' – Outline of the national inventory document, pursuant to the modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement".

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[1] The emissions inventory also includes sinks, but their part is extremely small.

The report presents estimates of the emissions inventory generated in Israel in 2022, and identifies trends in emissions for each of the emission sources and for the main greenhouse gases. The report provides comprehensive information on the calculation methods and background on the inventory preparation processes.

The Enhanced Transparency Framework (ETF) of the Paris Agreement, signed at the Paris Conference, introduces a new reporting framework for all parties that aims to strengthen the availability and transparency of the information they report on. Within the framework of the ETF, all parties are required to regularly report on national GHG inventories through the use of a set of common guidelines and a system of Common Reporting Tables (CRTs), which replace reporting using the Common Reporting Format – CRF.

As of yet, Israel has not been required to report through CRTs. By 2024, an electronic reporting system (CRF) will be built, and it will replace the current system. After setting up the system, all the required tables will be filled. At this stage, the main tables (of all emissions and of each emission source) will be filled.

1.2. The legal and organizational setup of the inventory calculation

1.2.1. The legal basis for the inventory calculation

The inventory of GHG emissions in Israel was calculated for the first time by an external consultant on behalf of the Ministry of Environmental Protection, for 1996 and 2000. The Central Bureau of Statistics (CBS) calculated the first inventory for 2003, and since then it has been calculated by the CBS every year.

In consultation and cooperation with the Ministry of Environmental Protection, it was agreed that the inventory would be calculated by the CBS, since it has the best access to information and there is a mandatory obligation to report to the CBS, which enables the CBS to calculate the inventory on a regular basis.

The CBS operates by the power of the Statistics Ordinance (New Version), 5732 – 1972. The Statistics Ordinance defines the mission of the Central Bureau of Statistics, the manner in which it works, the public's obligation to provide information to the CBS, the CBS's obligation regarding the safeguarding of the confidentiality of information received, and the CBS's obligation to publish the results of its activities.

The Statistics Ordinance provides the CBS with the authority to obligate the public to provide it with the information it requires in order to conduct the statistical activities it performs. Parallel to the public's obligation to provide the CBS information, and with the aim of ensuring that no personal details be disclosed as a result, the law states that the CBS is forbidden to transmit to any other authority any datum that makes it possible to identify the individual providing it. For this reason the law obligates the CBS to safeguard every datum that it receives in absolute confidentiality.

1.2.2. Inventory calculation process

The inventory calculation process for year N begins in January of year N+1 and continues until August of year N+1. The Calculation of the previous inventory is done with a delay of two years(N+2) due to the dependence on receiving the data required for the calculation and after work at the CBS, preparations were made to bring forward the inventory calculation with a delay of only one year.

The inventory calculation is carried out using a system of Excel files.

In the first step, the file system is updated to receive the required data. Every year the previous calculation files are saved for documentation and quality assurance purposes.

After that, the updates are checked using the calculation method according to the priorities and available resources.

In the second stage, data are collected from surveys or from administrative sources – from sources within the CBS, from government ministries and companies in the economy.

Concomitantly with calculating the inventory and collecting the data and entering it, the data that are received are checked.

After the collection is completed, the data is processed and the emission tables are produced.

The inventory is calculated by one employee from the Senior Sector of Agriculture, Environment and Energy in the Senior Department of Infrastructure-Economic Statistics.

1.2.3. Quality testing process

Throughout the collection and calculation, the received data is checked and the emissions are calculated.

For each figure, its value is checked against the previous report. If discrepancies are found, the reason for this is checked by contacting the reporter. Some of the data are checked by comparison with other sources (for example, data from different sources on energy consumption).

Additionally, in the process of calculating the emissions, each emission is checked – by emission source and in the greatest possible detail – against the emissions received in the past.

Before the calculation process, an inspection is conducted with professionals (mainly from the Ministry of Environmental Protection) to detect changes that occurred in emissions that require methodological updates in the calculation.

External review of the inventory

On April 18, 2016, a technical analysis of Israel's first Biennial Update Report (BUR) was submitted. As part of the analysis, comments were presented on the emissions inventory that was calculated and submitted with the report.

Below are the main points of the comments received in the technical analysis of that report, and explanations of how they were implemented (in full or in part) in the current report:

- Comment: In the case of updates to the inventory calculation, information on the activity and relevant information explaining the updates should be provided.
  - Explanation: This report explains the updates that were made and the emission factors or calculation methods that were updated. Information on updating activity data was not provided. In the future, after filling out the CRTs tables, updates on the activity data will also be attached (subject to restrictions to maintain the confidentiality of business information).

- Comment: The emissions should be reported according to the table structure defined.
  - Explanation: In this report, the reporting tables were adjusted to the requirements. By 2024, an electronic reporting system (CRF) will be built and will replace the current system (CRTs). After the system is established, all the required tables will be filled in. At this stage, the main tables (of all emissions and of each source) will be filled out.
- Comment: Emissions and sinks from land changes are required to be reported separately in accordance with decision Annex 3A.2 – IPCC GPG LULUCF.
  - Explanation: During the technical analysis, Israel stated that soil emissions and absorption are a relatively negligible share of Israel's total GHG emissions, therefore they were not reported separately as required.
- Comment: It is required to report on sectoral report tables.
  - Explanation: Some of the information appears in the report. In addition, the main tables (of all emissions and of each emission source) were filled out, and the rest will be completed in the future after the CRTs are filled out.
- Comment: Emission history series are required to be reported.
  - Explanation: Some of the information appears in the report, and the rest will be completed in the future after filling out the CRTs.
- Comment: It is required to explain the calculation method.
  - Explanation: In this report, the calculation method, the assumptions made and the limitations of the data were explained.
- Comment: It is required to complete the calculation of the emissions of NMVOCs.
  - Explanation: The calculation of the emissions from burning fuels of NMVOCs has not yet been completed.
- Comment: It is required to calculate the GHG emissions from fuel combustion (in the energy sector) also according to the Reference Approach.
  - Explanation: In this report, the emissions were also calculated according to the Reference Approach.
- Comment: No uncertainty analysis was performed.
  - Explanation: At this stage, an uncertainty analysis has not yet been performed. It is planned to be carried out in the future.

1.3. Calculation methods and sources of information

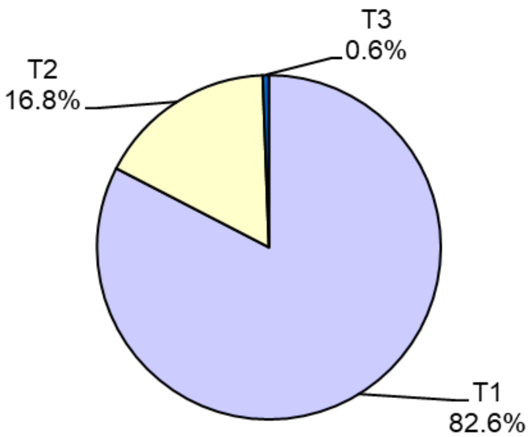
1.3.1. Calculation methods

The inventory was calculated according to the IPCC 1996 calculation guidelines and in some cases according to the 2006 guidelines. The guidelines present different levels of calculation depending on the information available in the country. The first level (T1) presents basic calculation methods based on average international emission factors. There are higher levels of calculation in the calculation – second level (T2) and third level (T3), where more detailed information about the activity is required as well as the use of emission factors unique to the country.

The emissions were calculated using the best available information existing in Israel. When there was detailed information about emissions in Israel, it was used, and when there was no information, default values of emission factors were used.

Most of the emission sources (82.6%) were calculated according to the first level calculation guidelines (T1) and based on the default emission factors in the IPCC 1996 guidelines, while adapting them to Israel as needed (for example, the different energy value of the fuels and their sulfur content). In some cases unique factors were calculated for Israel according to the second (T2) and third (T3) calculation levels using information unique for Israel.

DIAGRAM 1.1 GHG EMISSIONS, ACCORDING TO CALCULATION METHOD 2022



1.3.2. The sources of information

The inventory is calculated by combining administrative sources and information received from companies in the economy.

The administrative data were obtained from government ministries: the Ministry of Energy and Infrastructure, the Ministry of Environmental Protection, the Ministry of Agriculture and Rural Development and the Ministry of Economy and Industry.

In addition, information collected at the CBS in the Senior Sector of Agriculture, Environment and Energy and in the Business and Manufacturing Indices Sector was received, as well as information from dedicated surveys which collect information from manufacturing enterprises that emit greenhouse gases as part of their activities.

Table 1.1 Sources of Information for Calculating GHG Emissions Inventories, by Emission Source

Emission Source	Information Sources
1. Energy	Ministry of Energy and Infrastructure, Ministry of Environmental Protection. CBS surveys among electricity producers, refineries and manufacturing companies.
2. Industrial processes	Ministry of Economy and Industry. CBS surveys among manufacturing companies.
3. Agriculture	Ministry of Environmental Protection, Ministry of Agriculture and Rural Development. CBS survey – Waste and Recycling of the Local Authorities.
4. Land use change and forestry	JNF (Jewish National Fund), Nature and Parks Authority. Geography and GIS Sector at the CBS.
5. Waste and wastewater	Ministry of Environmental Protection. Manufacturing Indicators Sector at the CBS, CBS survey – Waste and Recycling of the Local Authorities.

1.4. Main emission sources

To estimate the relative share of emission sources, the IPCC provides methods to examine and quantify the main categories of emission sources on which to focus the emissions calculation.

The calculation process of the main categories of emission sources and results is detailed in Appendix B, Analysis of Key Category Sources.

According to the UNFCCC guidelines, some emissions are considered a "key source category", and are defined as follows: "A main emission source is an emission source that has a significant effect on the total emissions of greenhouse gases in the country or on the trend of emissions over time. The analysis of main emission sources makes it possible to identify where are the best opportunities for reducing emissions".

In accordance with these guidelines, two tests are conducted: One is to examine the relative contribution of the emission source to the total **absolute emissions** and the other is to examine its effect on the **trend of emissions** over the years.

The analysis of the relative contribution of the emission sources to the total **absolute emissions** shows that the main emission sources in 2022 were as follows: Electricity generation (41.5%), transportation (22.4%), disposal of waste as landfill (9.8%), fuel combustion in the manufacturing and construction industries (7.1%), substitutes for ozone-depleting substances - air conditioning and refrigeration system (HFCs) (5.3%), petroleum refining (3.2%), cement production (2.2%) and enteric fermentation in the digestive system of animals (1.4%).

Over the years, electricity generation has been the largest main source of emissions, but their share in total emissions has decreased over the years: In 2003 it was 52.4%, and in 2022 – 41.5%.

Over the years, the emissions from transportation and the manufacturing and construction industries were about 20% and about 7% of the total emissions, respectively. The share of emissions from the use of substitutes for ozone-depleting substances has considerably increased over the years: In 2008 it was 2.5%, and in 2022 it rose to 6.1% due to the reduction in the use of controlled gases as required by the Montreal Protocol.

Waste landfill was the third largest source of emissions and accounted for 9.8% of all emissions.

The relative contribution of the emission sources on the **trend of emissions** is analyzed relative to a base year. In order to isolate other influences on the trend analysis, the base year 2011 was chosen in Israel, since from this year the emissions are calculated using the same calculation methods. From this analysis it is possible to learn what are the main emission sources that influenced the trend of emissions in 2022.

Electricity generation (42.2%), transportation (18.2%) and substitutes for ozone-depleting substances - emissions of gases used for air conditioning and refrigeration (HFCs) (15.7%) were the main emission sources that influenced the trend of emissions. Electricity generation and transportation contributed to the trend due to their large share of emissions, and the use of substitutes for ozone-depleting substances affected the trend due to an increase in emissions from this source over the years.

These emission sources influenced the trend, but their influence was relatively small: disposal of waste as landfill (6.9%), petroleum refining (3.9%) and cement Production (2.9%).

1.5. Uncertainty

No inventory uncertainty estimate has been performed yet.

1.6. Completeness of the inventory

The emission inventory calculation includes the vast majority of the emission sources. In collecting the data and processing it, an effort is made to include in each topic the sources of information available for the areas of activity that were included in the calculation of the emissions inventory.

An important area of activity that is not included in the inventory calculation is fugitive emissions from oil and natural gas. The calculation method of this source is under development and was not included here, in order to choose the most appropriate calculation methods for Israel and to avoid, as much as possible, the appropriate use of inaccurate default factors.

Table 1.2 Completeness of GHG Emissions Inventory, by Emission Source

Emission source	Completeness of the inventory
1. Energy	The vast majority of fuel consumption was included in the emissions calculation. Fugitive emissions from oil and natural gas, whose calculation method is under development, were not included.
2. Industrial processes	The vast majority of emissions from industrial processes were calculated. Emissions from the use of non-energy fuel products (lubricants, paraffin/wax) and solvents were not included. Also, emissions of gases containing fluorine (HFCs, PFCs, SF6), originating from imported consumption products containing these gases, were not included (except for inhalers, for which the emission was estimated).
3. Agriculture	The vast majority of emissions from agricultural activity were calculated. Emissions from the incineration of agricultural residues in the fields were not included.
4. Land use change and forestry	Methane (CH_4) and nitrous oxide (N_2O) emissions were not included.
5. Waste and wastewater	Emissions from waste and wastewater treatment were fully included in the inventory calculation.

1.7. Geographic coverage

In the inventory, emissions generated in the territory of the State of Israel were calculated. In the Judea and Samaria Area, emissions created by Israeli residents were included (such as emissions from waste landfills, wastewater treatment and fuel consumption).

For the most part, in the Judea and Samaria Area and the Gaza Strip, emissions created by Palestinian residents were not included, but emissions created from the use of sources from Israel were included. For example, emissions from the consumption of fuels transferred to the Palestinian Authority were not included in the inventory, but emissions from the consumption of fuels originating in Israel and consumed by the Palestinian Authority were included. Additionally, emissions from waste originating from the Judea and Samaria Area and buried in landfill sites in Israel were included.

2. Chapter 2: Overview of Emissions and Trends

2.1. Total Emissions

In 2022, total GHG emissions stood at 81.1 million tons of CO_2eq – an increase of 5.4% compared with 2010, and an increase of 3.4% compared with 2021.

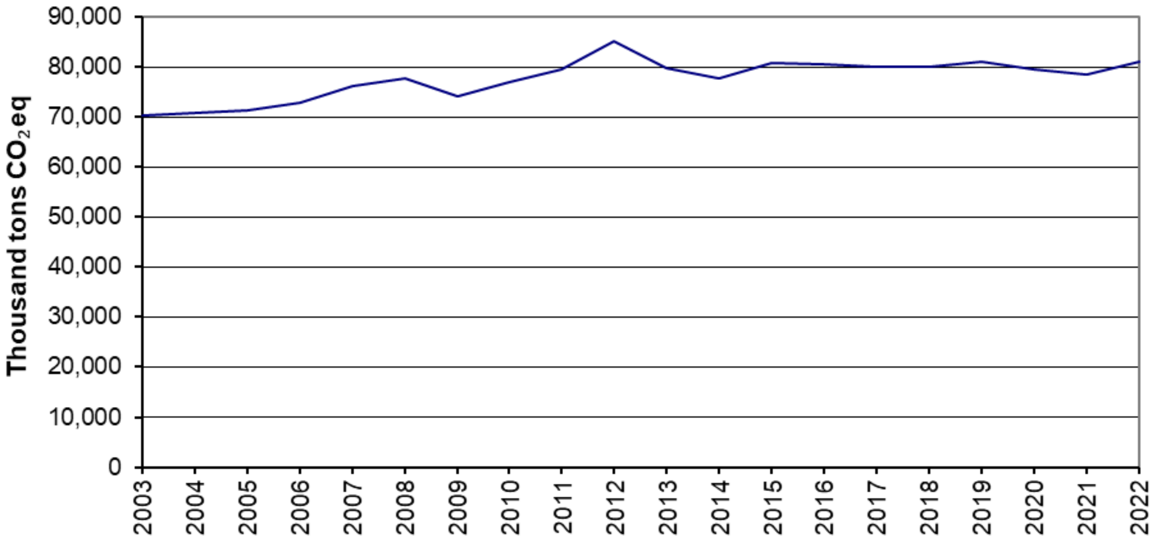
Table 2.1 GHG Emissions, by Source, Selected Years

Thousand tons of carbon dioxide equivalent

Year / **Source of Emission**	2000	2003	2005	2008	2010	2015	2020	2021	2022
Total	**67,925**	**70,397**	**71,364**	**77,738**	**76,883**	**80,713**	**79,481**	**78,369**	**81,063**
Energy	59,045	60,743	60,662	63,986	63,194	64,126	61,199	60,807	62,853
Industrial processes and product use	2,740	2,270	2,560	4,527	3,986	6,065	7,634	6,619	6,968
Agriculture	2,340	2,291	2,392	2,563	2,474	2,330	2,325	2,389	2,419
Land use change and forestry	-213	-286	-376	-347	-411	-141	-260	-294	-286
Waste and wastewater	4,013	5,379	6,125	7,007	7,640	8,333	8,584	8,849	9,108

Between 2003 and 2022, total emissions increased by 15.2%. (Until 2007, emissions from the use of substitutes for ozone-depleting substances were not included in the calculation, under the assumption that these emissions were not high). From 2003, there was a general upward trend in emissions, until 2012. From 2012 to 2014, emissions decreased, and in 2014 they stabilized.

DIAGRAM 2.1 TOTAL GHG EMISSIONS
2003–2022



2.2. Emissions, by Source

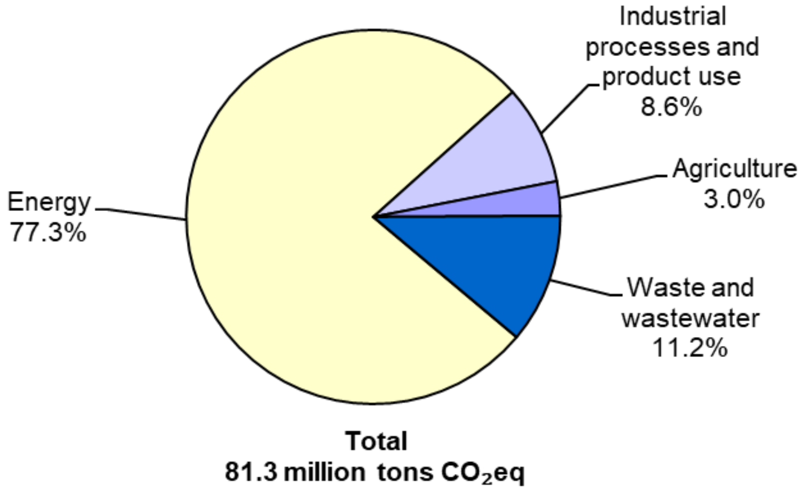
The largest source of emissions, as at the global level, was the energy sector, and in 2022 the emissions from this sector stood at 62.9 million tons of CO_2eq. The increase in emissions from the energy sector over the years is due to an increase in the population and an increase in the standard of living, and it is affected by the mix of fuels used to generate energy. In 2003, the energy sector's share of all emissions (not including emissions from land use change and forestry) was 85.9%. It has gradually decreased over the years (due to an increase in emissions from other sources), and in 2022 stood at 77.3%.

Other major sources of emissions were industrial processes and product use – 7.0 million tons of CO_2eq (8.6%) and waste and wastewater – 9.1 million tons of CO_2eq (11.2%).

Emissions resulting from industrial processes and product use increased primarily due to the increase in the use of substitutes for ozone-depleting substances. In 2008, the share of emissions from industrial processes and product use was 5.8% of all emissions, and it has increased over the years, reaching 8.6% in 2022. Emissions from waste increased, with an increase in the disposal of waste as landfill due to population growth and an increase in the standard of living. The share of emissions from waste and wastewater, out of all emissions, has increased over the years – in 2003, it was 7.6%, and in 2022, 11.2%.

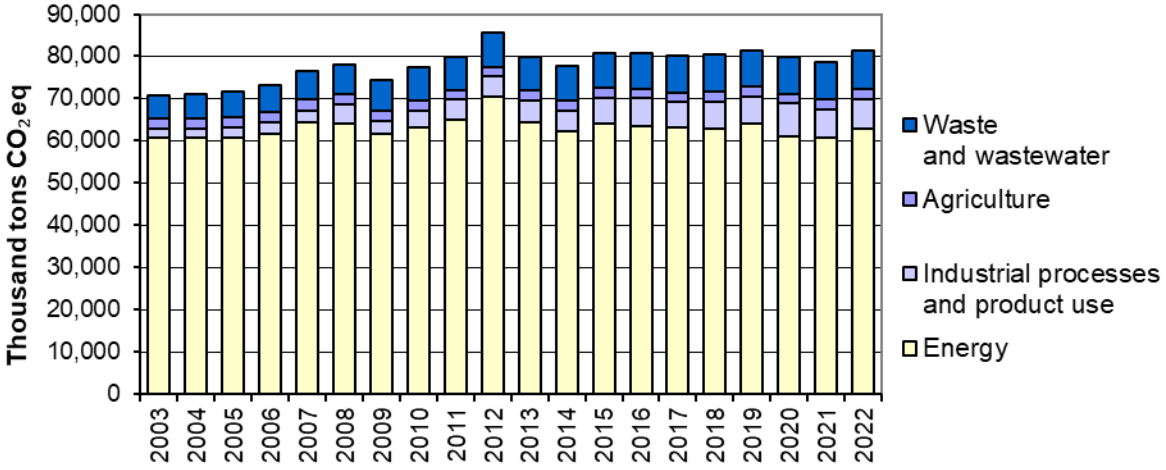
The share of emissions from agriculture did not change substantially over the years, and stood at about 3%.

DIAGRAM 2.2A. GHG EMISSIONS,(1) BY SOURCE
2022



(1) Not including emissions from land use change and forestry.

DIAGRAM 2.2B. GHG EMISSIONS,(1)(2) BY SOURCE
2003–2022



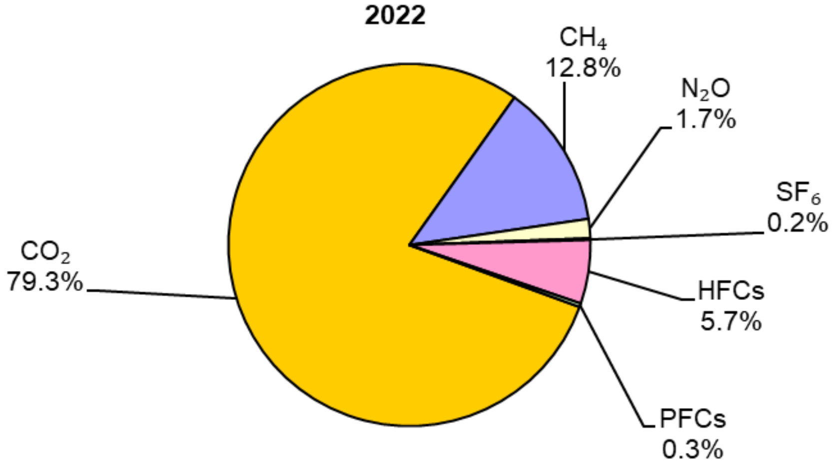
(1) Not including emissions from land use change and forestry.
(2) Calculation of emissions from the use of substitutes for ozone-depleting substances began in 2008.

2.3. Emissions, by Gas

In 2022, CO_2 emissions constituted 79.3% of all emissions (not including emissions from land use change and forestry), deriving predominantly from the energy sector. The share of CH_4 emissions, out of all emissions, stood at 12.8%, originating mainly from the waste and wastewater sector, in general, and the disposal of waste as landfill, in particular. The share of emissions of HFCs – gases used for air conditioning and refrigeration, which are included in the industrial processes and product use sector – out of total emissions increased from 1.0% in 2008 to 5.7% in 2022.

Emissions of N_2O, which were generated mainly in the agriculture sector, stood at about 2% over of the years.

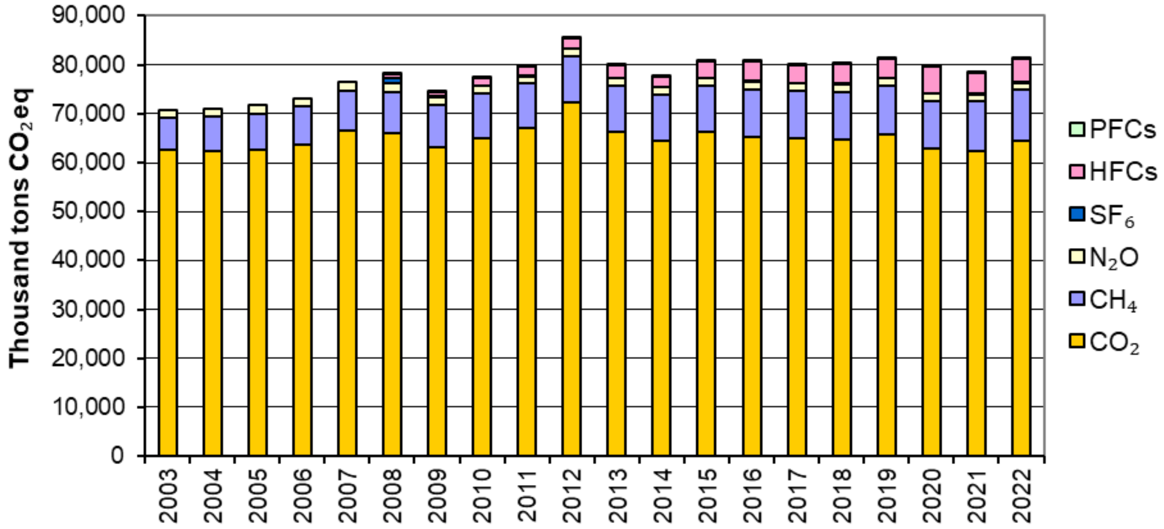
DIAGRAM 2.3A. GHG EMISSIONS,(1) BY GAS 2022



Total
81.3 million tons CO_2eq

(1) Not including emissions from land use change and forestry.

DIAGRAM 2.3B. GHG EMISSIONS,(1)(2) BY GAS 2003–2022



(1) Not including emissions from land use change and forestry.
(2) Calculation of emissions from the use of substitutes for ozone-depleting substances began in 2008.

2.4. Emissions per Capita

The rate of emissions per capita (including emissions from land use change and forestry) was 8.5 tons of CO_2eq in 2022, compared with 10.5 in 2003. In general, emissions per capita have decreased over the years, despite increases during a few of the years.

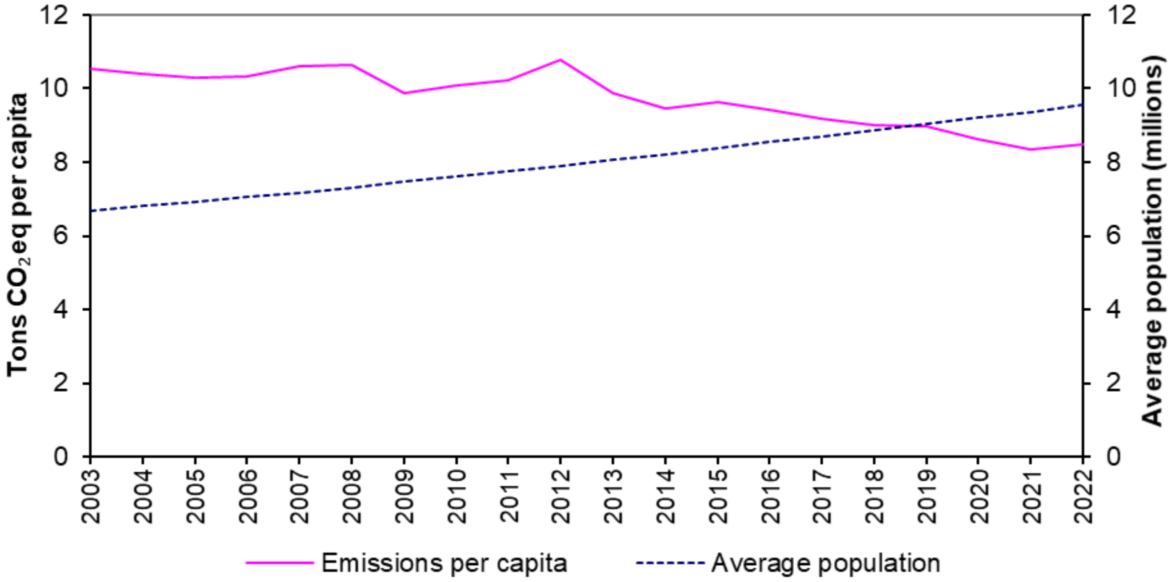


DIAGRAM 2.4 AVERAGE POPULATION AND EMISSIONS PER CAPITA 2003–2022

Israel is characterized by a large demographic growth rate, relative to developed countries (about 2% per year), due to high birth rates and positive net migration. Coinciding with the increase in population over the years, was a decrease in emissions, mainly in the energy sector. The combination of population increase and emissions decrease brought about a decrease in the rate of emissions per capita over the years.

As shown in Diagram 2.5, between 2003 and 2022 the population increased by 42.9%, however, emissions increased by only 12.2%. As a result, the rate of emissions per capita decreased by 19.4%.

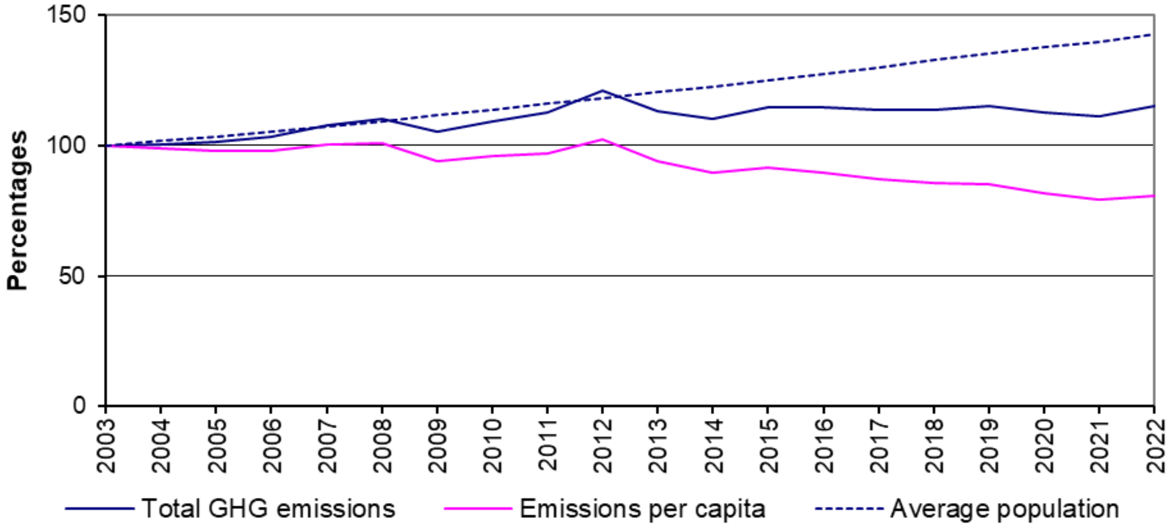
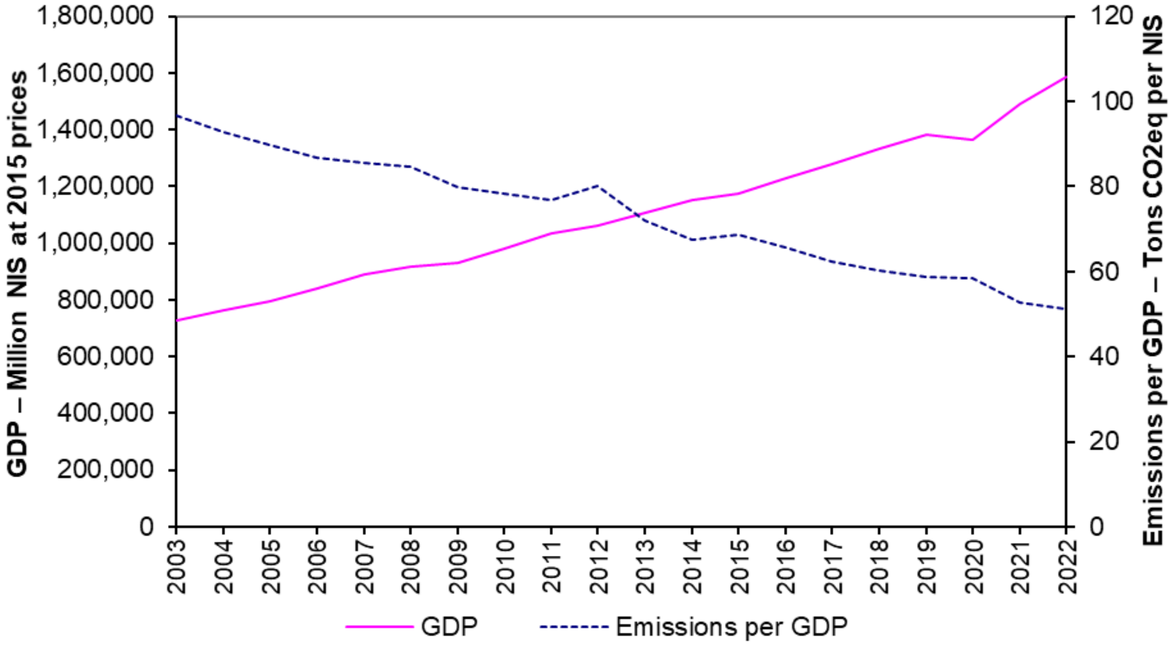


DIAGRAM 2.5 TOTAL GHG EMISSIONS, EMISSIONS PER CAPITA, AND AVERAGE POPULATION 2003–2022

2.5. GHG Emissions per Gross Domestic Product (GDP)

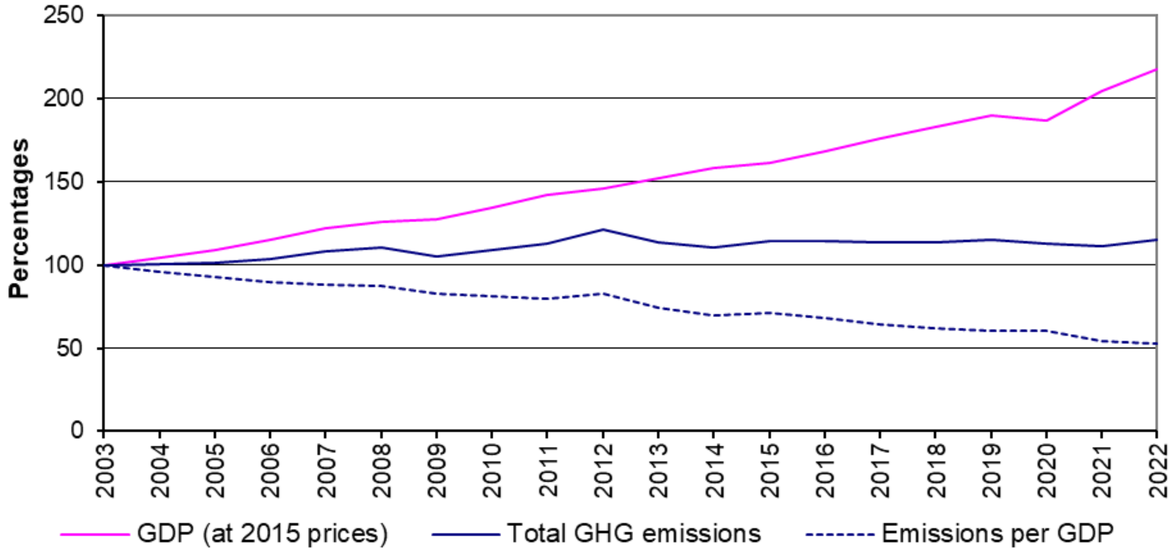
Israel's gross domestic product (GDP) increased from 728 billion NIS in 2003 to 1.587 trillion NIS in 2022 (at 2015 prices). During this same period, the rate of emissions per GDP decreased from 97 tons of CO_2eq per GDP NIS to 51 tons of CO_2eq per GDP NIS. This trend could indicate higher efficiency in the economy, since for each NIS of product, less GHGs were emitted, or it could indicate structural changes in the economy that led to a reduction in emissions, such as a shift to industry that consumes less energy.

**DIAGRAM 2.6 GDP AND EMISSIONS PER GDP
2003–2022**



Between 2003 and 2022, total emissions increased by 15.2%, while the GDP increased by 117.8%. Thus, the rate of emissions per GDP decreased by 47.1%.

DIAGRAM 2.7 GDP, TOTAL GHG EMISSIONS, AND EMISSIONS PER GDP 2003–2022



3. Chapter 3: Energy

3.1. Background on the Energy Sector

3.1.1. Introduction

The energy sector includes generation of energy by means of combustion of fossil fuels[1] (coal, natural gas, oil distillates, etc.). These fuels are used to refine petroleum, generate electricity, propel transport vehicles (road vehicles, trains, ships, and airplanes) and generate energy for production in the manufacturing, trade, and residential sectors.

Most of the emissions in the energy sector are those of CO_2, which is produced in the process of the fuels' combustion as a result of the carbon (C) in the fuels bonding with the oxygen (O_2) in the air. The amount of emissions depends on the fuel's property (its carbon content) and the combustion processes.

3.1.2. Overview of the Energy Industries Sector

The energy industries include petroleum refining, production and transmission of natural gas, and electricity generation by the Israel Electric Corporation and private companies (only companies whose main business activity is electricity generation were included in the calculation of emissions in this sector).

Petroleum refining - In 2007, the government petroleum refining company in Israel was privatized and two private companies were established. Today, there are two refineries in Israel: in Haifa (owned by Oil Refineries Ltd.), and in Ashdod (owned by Paz Ashdod Oil Refinery).

The privatization and establishment of the companies created a difficulty in publishing energy data in accordance with the Statistics Ordinance, under which the Central Bureau of Statistics (CBS) operates. In 2010, the Knesset (Israel's parliament) passed the law to amend the Statistics Ordinance (No. 3), 2010, which allows the publication of data despite the obligation to keep them confidential according to section 17 of the ordinance, regarding "the corporation operating in the industry listed in the second addendum, and the prime minister permitted in a notice in the records, with the approval of the Knesset's Economic Affairs Committee, their publication after finding that the publication is vital to the public interest, but publication according to this subparagraph of data that constitute information as

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[1] Fossil fuel is fuel created from the fossilization of organisms over millions of years. The fossil fuels that are formed are coal, oil, and natural gas.

defined in section 7 of the Protection of Privacy law, 1981, will not be permitted, nor will publication of information about a person's private affairs even though it is not within the scope of such information."

In July 2011, the prime minister's permission to publish the energy data was publicized in the official file containing administrative announcements of state institutions. However, in order to avoid harming competition, the publication of the data is permitted only after a minimum of one year has passed, from the end of the civil year in which the business activity took place.

With the consent of the Israel Competition Authority, the CBS contacted the refineries, with a request to shorten the publication delay. In 2021, the refineries agreed to allow publication of energy data after eight months from the end of the year of reference.

The vast majority of the crude oil processed by the refineries is imported. The output of the refineries – gasoline, diesel oil, etc. – is intended for consumption in Israel and for export.

Production and transmission of natural gas – Natural gas was first used in Israel in 2004, and it was initially imported. After several large natural gas reserves were discovered off the coast of Israel, domestic production of natural gas, brought ashore at several entry points, began. At each entry point there is a connection to a high-pressure transmission system operated by Israel Natural Gas Lines Ltd. (INGL), a government company responsible for Israel's gas transmission system.

By means of this system, the gas is delivered to private companies for electricity generation, to large manufacturing consumers, to distribution companies that convey gas at low pressure to end users and for compressed natural gas (CNG), which is used to propel transport vehicles and by natural gas consumers who are not connected to the distribution network.

As of the end of 2022, the import of Liquefied natural gas (LNG), which was imported through the "marine link", was stopped (the LNG buoy was constructed in early 2013 off the coast of Hadera). The imported NLG was used as a backup for the national gas system.

By the end of 2022, INGL had built a transmission pipeline that is approximately 900 km in length, and to which the following are connected: power plants of the Israel Electric Corporation, power plants of large private electricity generation companies, additional manufacturing enterprises that use natural gas for electricity generation, and large manufacturing consumers. In 2022, the length of the distribution pipeline was approximately 628 km, and 150 customers had access to natural gas by means of this method of distribution.

According to the Statistics Ordinance, the CBS is prohibited from publishing data that could reveal the commercial secrets of a company in the economy. Since only a limited number of companies are active in the gas industry, the data on the production, export, and import of natural gas are based on existing publications of the Natural Gas Authority.

Natural gas is a primary source of energy in the generation of electricity and in manufacturing. Its use has been increasing over the years, and it serves as an alternative source of energy to other fuels: coal, residual fuel oil, and diesel oil. In 2022, about 80% (10.1 BCM)[2] of the domestic demand for natural gas came from the electricity sector, and about 20% (2.56 BCM) of the gas was destined for consumers in the manufacturing sector.[3] In 2022, natural gas exports to Egypt and Jordan increased significantly and stood at 9.21 BCM, constituting 42% of total natural gas supply. During the course of the year 2022, about 0.05 BCM of natural gas was imported via the "marine link", which was 0.2% of the total supply of natural gas during this period.

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[2] Billion cubic meters.

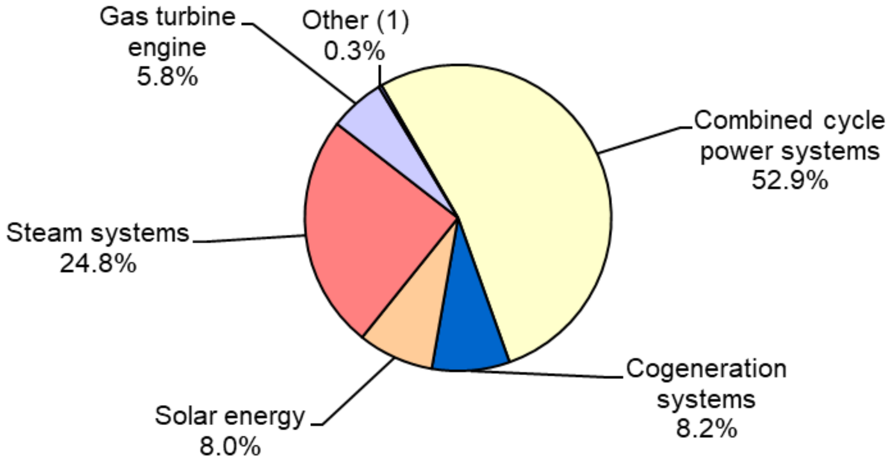
[3] Natural Gas Authority, Ministry of Energy and Infrastructure. Overview of Developments in the Natural Gas Sector: A Summary for 2022. (Hebrew only)

Electricity generation – Of all the sources of energy available to the economy, electricity is the primary one. An increase in electricity consumption is due to increases in the population, in manufacturing, in trade, and in services, and due to an increase in the standard of living.

Electricity is generated by means of a variety of technologies, and the following are used in Israel:

- **Cogeneration systems – combined heat and power (CHP) –** combined generation of electricity and heat which is used in production processes;
- **Gas turbine engine** - turbines that are powered directly by combustion gases;
- **Combined cycle power systems –** electricity generation and use of the residual heat for additional electricity generation;
- **Steam systems –** systems that produce steam which is used to generate electricity (in Israel, used mainly in coal combustion);
- **Renewable energy –** solar energy, wind energy, water (hydroelectric) energy, and biogas energy.

DIAGRAM 3.1 GENERATION OF ELECTRICITY, BY TECHNOLOGY
2022



(1) Other: wind energy, water (hydroelectric) energy and biogas

In the past, the electricity sector was dominated exclusively by the Israel Electric Corporation, however, in recent years, after private companies have entered the field of electricity generation, this monopoly has been reduced. The entry of additional companies was made possible due to the option of using natural gas as a cheap and readily available source of electricity generation and due to encouragement to use renewable energy for electricity generation.

In 2013, the Israel Electric Corporation's share of total electricity generation stood at 93.1%, and by 2022, it had decreased to 51.7%.

Table 3.1 Electricity Generation, by Provider, 2013–2022

Percentages

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Israel Electric Corp.	93.1	84.3	78.7	72.3	72.0	69.2	66.1	61.0	51.8	51.7
Private companies	6.9	15.7	21.3	27.7	28.0	30.8	33.9	39.0	48.2	48.3

Most of the electricity generation is based on combustion of fossil fuels (91.6% in 2022). Since 2013, the share of electricity generation from natural gas has increased, and the use of coal, residual fuel oil, and diesel oil has decreased. The share of electricity generation from renewable energy, mainly solar energy, increased from 0.9% in 2013 to 8.4% in 2022.

Table 3.2 Electricity Generation, by Type of Energy, 2013–2022

Million kWh, unless otherwise stated

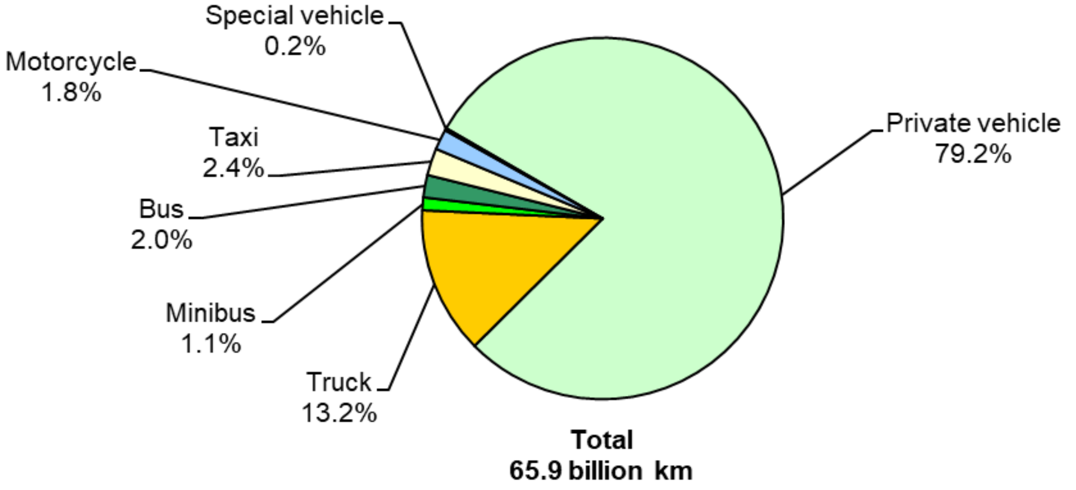
	2013	2014	2015	2018	2019	2020	2021	2022	2022 Percentages
Total	**61,359**	**61,330**	**64,331**	**69,280**	**72,377**	**72,760**	**73,788**	**75,964**	**100.0**
Non-renewable energy	**60,797**	**60,374**	**63,013**	**67,264**	**69,072**	**68,394**	**68,267**	**69,564**	**91.6**
Natural gas	26,462	29,945	33,149	46,061	46,095	48,921	50,956	52,402	69.0
Coal	32,101	30,105	29,161	20,599	21,892	18,963	16,946	16,723	22.0
Diesel oil	1,485	52	355	239	738	222	86	153	0.2
Residual fuel oil	466	10	65	57	56	26	21	61	0.1
Other	283	263	283	308	290	262	258	225	0.3
Renewable energy	**562**	**957**	**1,318**	**2,016**	**3,305**	**4,367**	**5,521**	**6,400**	**8.4**
Solar energy	485	876	1,216	1,828	3,115	4,163	5,351	6,084	8.0
Wind energy	6	6	7	..	..	..	..	..	..
Water (hydro-electric) energy	28	13	24	..	..	..	..	..	..
Other	43	62	70	..	..	..	..	..	..

3.1.3. Overview of the Transport Sector

The transport sector includes road transportation, railways, domestic aviation, and domestic water-borne navigation. Most of the energy is consumed for road transportation. The energy consumption for domestic aviation and domestic water-borne navigation in Israel is small in scope.

Road transportation – Road transportation is the main mode of transporting passengers and freight in Israel. In 2022, total vehicle kilometers travelled stood at 65.9 billion, 79.2% of which was by private vehicles. Between 2003 and 2022, the total number of kilometers travelled by all vehicles and private vehicles increased by 69.2% and 113.8%, respectively. The sources of energy for vehicles were primarily gasoline and diesel oil, while a small number of vehicles were propelled by liquefied petroleum gas (LPG) and electricity.

DIAGRAM 3.2A. VEHICLE KILOMETERS TRAVELLED, BY TYPE OF VEHICLE
2022



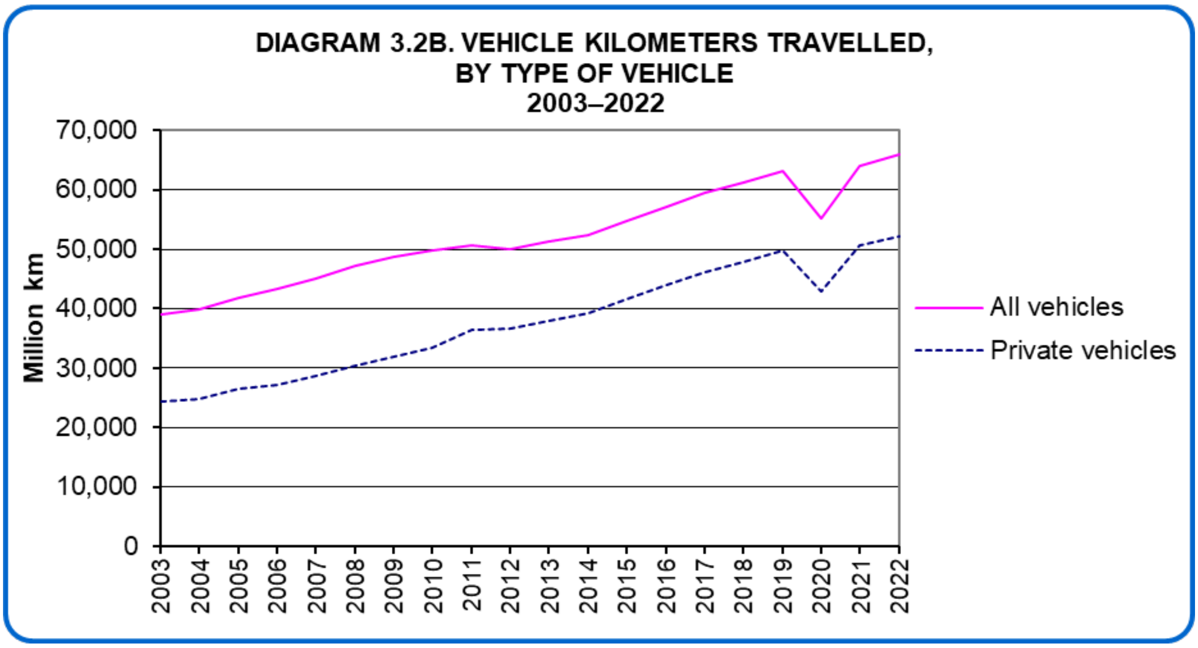


DIAGRAM 3.2B. VEHICLE KILOMETERS TRAVELLED, BY TYPE OF VEHICLE 2003–2022

The kilometers travelled by vehicles fueled with gasoline (including hybrid vehicles which constitute 11.4%) and diesel oil was 73.7% and 24.9%, respectively, of kilometers travelled by all vehicles in 2022. The kilometers travelled by vehicles propelled by LPG and vehicles propelled by electricity, together amounted to less than 1.4% of kilometers travelled by all vehicles.

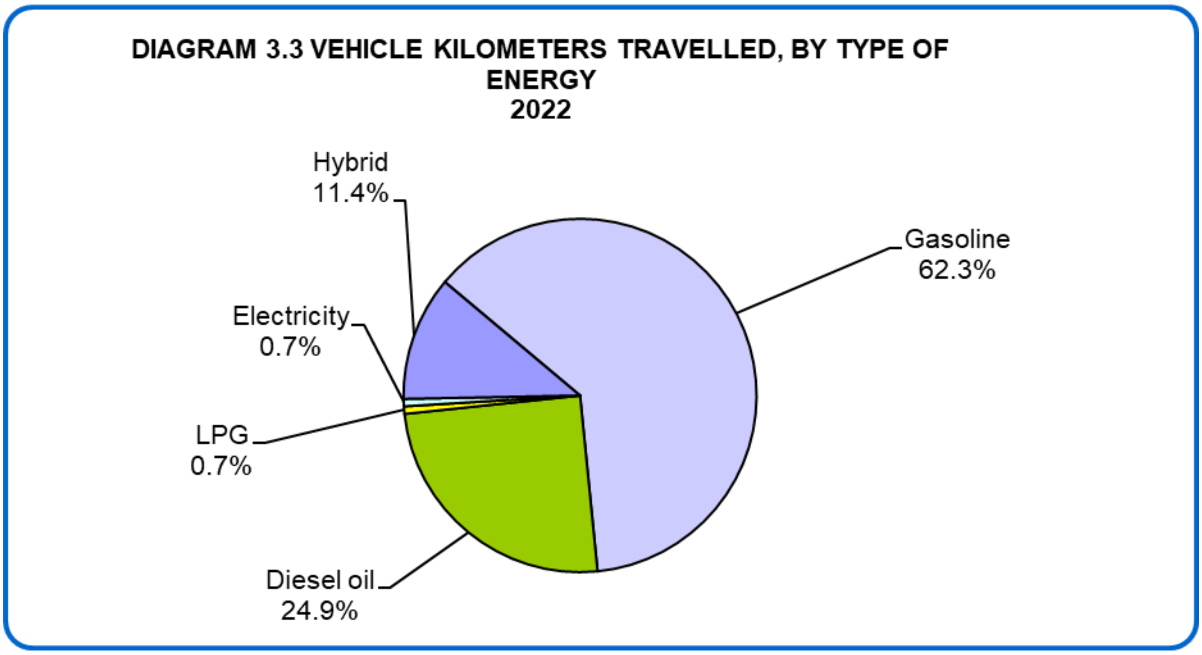


DIAGRAM 3.3 VEHICLE KILOMETERS TRAVELLED, BY TYPE OF ENERGY 2022

Railways – Trains are used to transport passengers and freight. During the past two decades, the option of using the train as a means of transportation for passengers has expanded. In 2003, the total length of railway tracks in Israel was 615 km. Since then, lines have been added, with the total track length reaching 1,511 km in 2022.

The number of train passengers in 2022 was 2.8 times the number in 2003, increasing from about 20 million to 55 million. (The year 2020 was an exception, due to the Coronavirus [COVID-19] epidemic, and there were only 24 million train passengers that year.) The trend in freight transport was mixed over the years. Between 2003 and 2016, the amount of freight increased, and from 2017 to 2022 the freight transport decreased by 30%.

With the increase in the use of trains, came an increase in energy consumption, and with this, an increase in emissions. For some of the railway lines the source of energy was switched to electricity.

DIAGRAM 3.4 PASSENGERS ON TRAINS 2003–2022

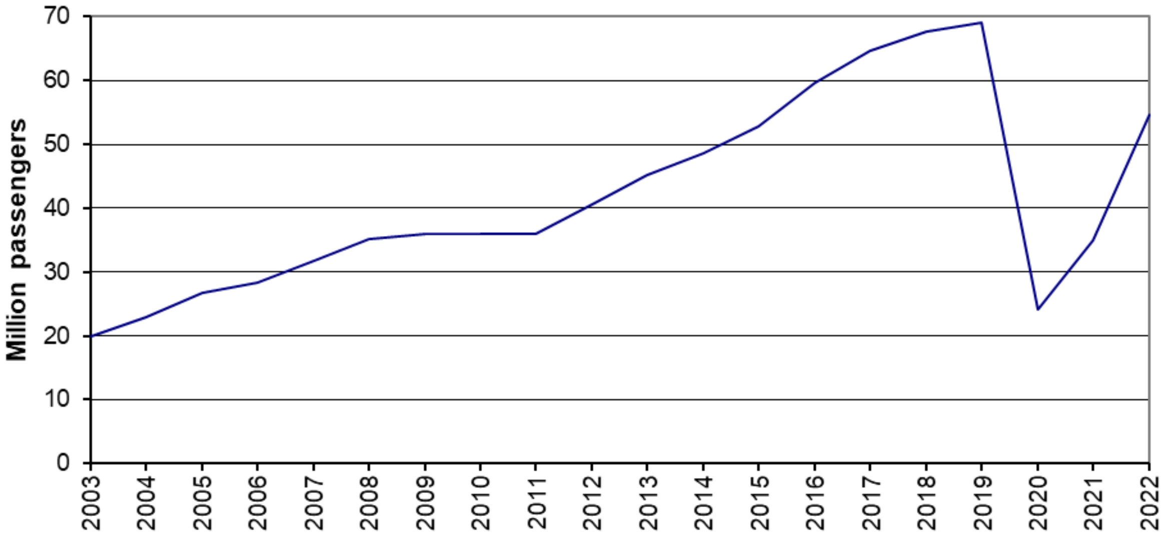
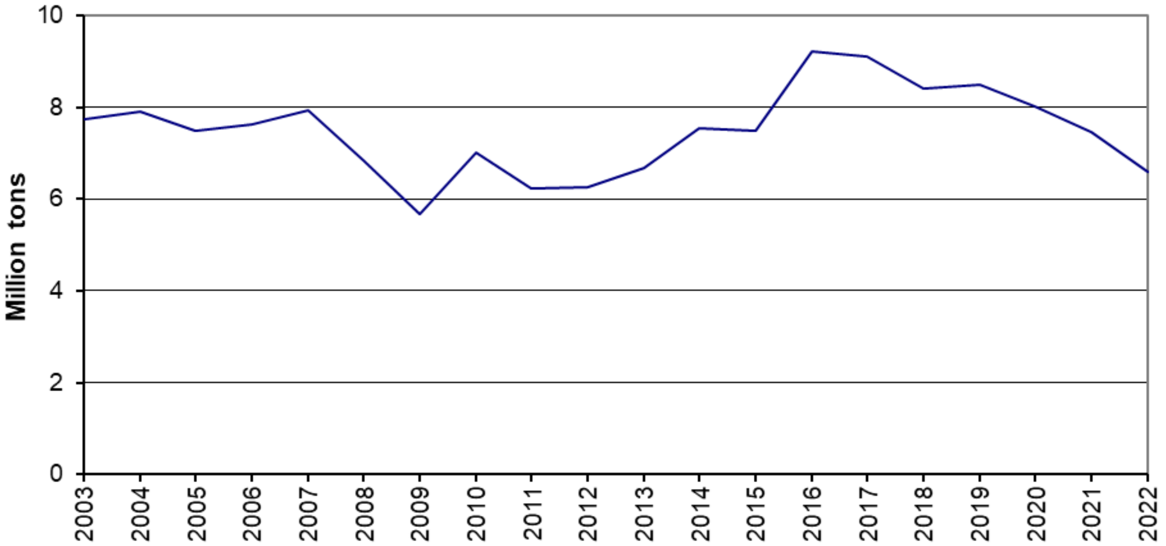


DIAGRAM 3.5 FREIGHT TRANSPORT ON TRAINS 2003–2022



3.1.4. Overview of the Residential Sector

The primary use of energy in residences in Israel consists of consumption of electricity and diesel oil for acclimatisation and LPG for cooking.

Energy consumption for acclimatisation mainly includes electricity consumption for cooling in the summer and heating in the winter by means of air conditioning systems. In some parts of the country, heating systems using diesel oil, LPG, and kerosene are used in the winter. There is also heating in fireplaces, by means of combustion of wood, but the use of this method has not been assessed, and it is assumed not to be widespread. LPG or electricity are used for cooking.

3.1.5. Trends in Energy Consumption in All Sectors

Between 2003 and 2022, energy consumption increased by 22.6% – from 18.7 million toe[4] to 23.0 million toe, whereas the per capita consumption during this period decreased by 14.2% – from 2.8 toe per capita to 2.4 toe per capita. Over the course of these years, the mix of fuels changed: The share of natural gas increased, and the share of oil distillates and solid fuels (mainly coal) decreased. In 2003, the mix of fuels consisted of 58.2% oil distillates and 41.8% solid fuels, and natural gas consumption was marginal. In contrast, in 2022, the share of oil distillates and solid fuels decreased to 38.6% and 17.0%, respectively, and natural gas consumption was 44.4% of the total consumption.

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[4] toe = ton of oil equivalent – The various energy sources (crude oil, gas, electricity, coal, etc.) have different units of measurement (cubic meter, kilowatt, etc.). A uniform unit of measurement that can be applied to all of the sources is required. In the majority of countries, the different units which apply to the various energy sources are converted to units of "ton of oil equivalent". This unit is defined as the amount whose combustion releases 10^7 kilocalories.

DIAGRAM 3.6A. FUEL CONSUMPTION IN ALL SECTORS BY TYPE 2022

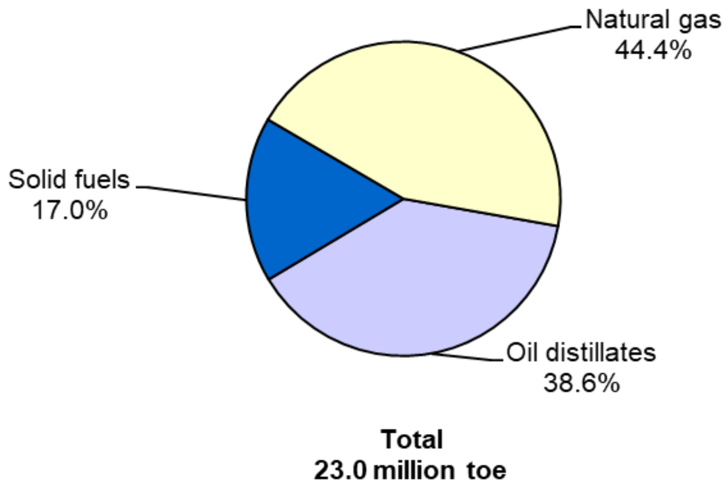


DIAGRAM 3.6B. FUEL CONSUMPTION IN ALL SECTORS BY TYPE 2003–2022

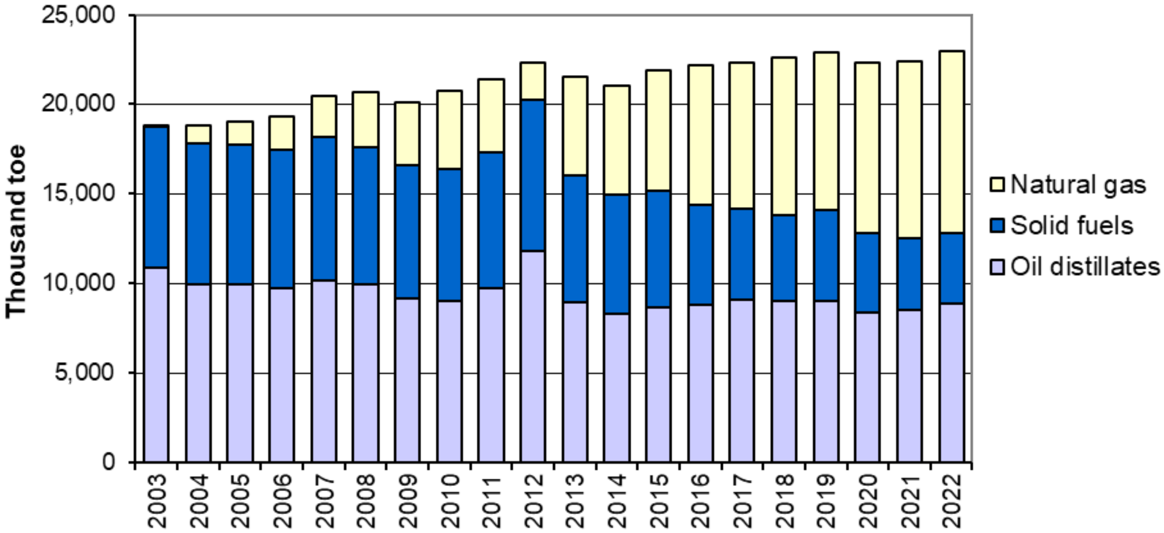
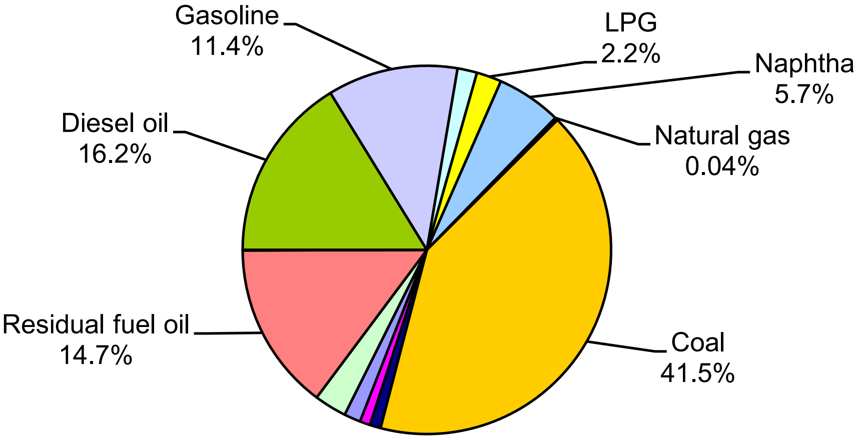


Diagram 3.7 shows the main fuels that were consumed over the years. In 2003 and 2022 the consumption of these fuels amounted to 84% and 89% of the total consumption, respectively. We see an increase in the consumption of natural gas, and on the other hand, a decrease in the consumption of residual fuel oil and coal, which the natural gas replaced. Although natural gas is also an alternative to diesel oil as an energy source (in manufacturing and electricity generation), the consumption of diesel oil has not decreased substantially over the years. This is because diesel oil also serves as a main source of energy for transport.

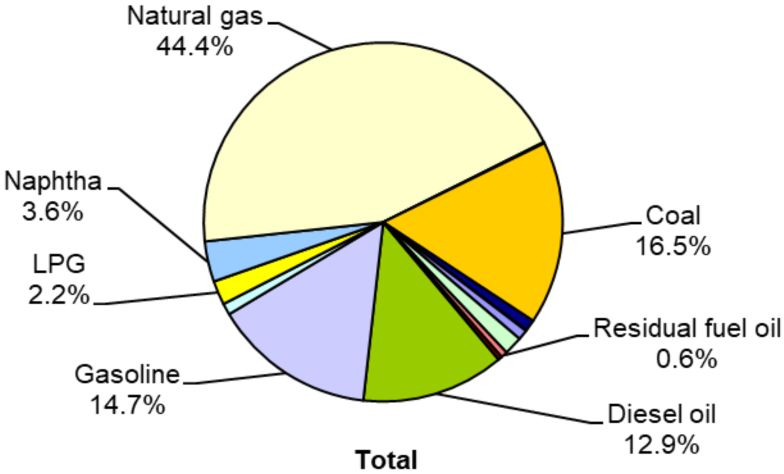
Between 2003 and 2022, the share of coal out of total consumption decreased from 41.5% to 16.5%, of residual fuel oil – from 14.7% to 0.6%, and of diesel oil – from 16.2% to 12.9%. In 2012, the consumption of natural gas decreased due to malfunctions in the supply of natural gas for electricity generation, and, coinciding with this, was an increase in the consumption of coal.

DIAGRAM 3.7A. CONSUMPTION OF SELECTED FUELS
2003



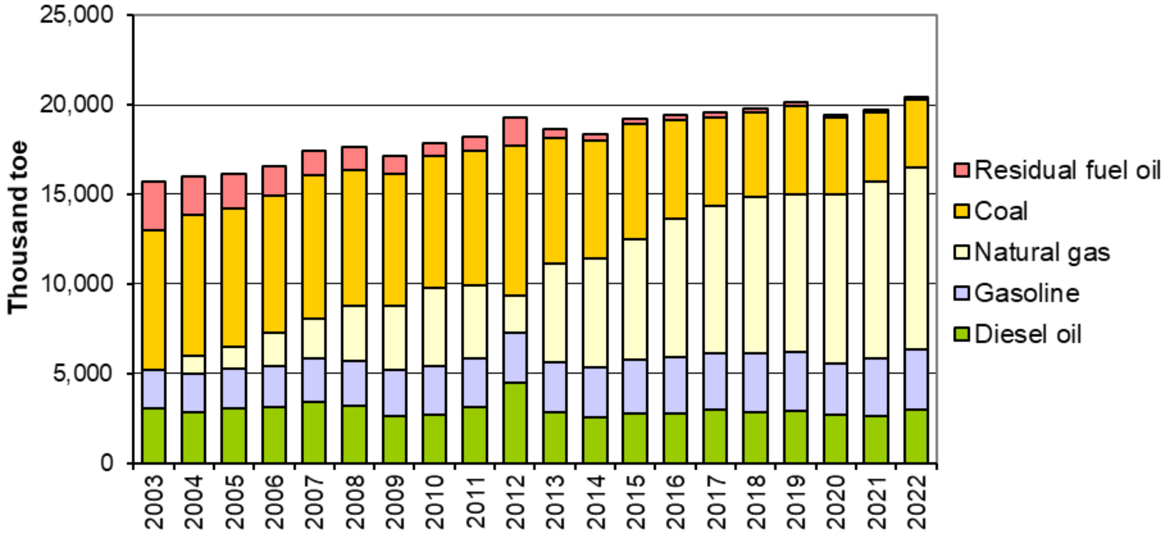
Total
18.7 million toe

DIAGRAM 3.7B. CONSUMPTION OF SELECTED FUELS
2022



Total
23.0 million toe

DIAGRAM 3.7C. CONSUMPTION OF SELECTED FUELS 2003–2022



3.2. Overview of Emissions

3.2.1. Total Emissions

In 2022, total GHG emissions in the energy sector stood at 62.9 million tons of CO_2eq, which was 77.5% of all GHG emissions.

Table 3.3 GHG Emissions in the Energy Sector, by Source and Gas, 2022

Thousand tons of CO_2eq

Gas / Source of Emission	Total	N_2O	CH_4	CO_2
1. Total	**62,853.3**	**131.3**	**129.6**	**62,592.4**
A. Fuel combustion activities (sectoral approach)	62,853.3	131.3	129.6	62,592.4
1. Energy industries	36,616.0	71.7	16.4	36,527.9
a. Electricity and heat production	34,008.7	68.3	14.2	33,926.2
b. Petroleum refining	2,607.3	3.4	2.2	2,601.7
c. Manufacture of solid fuels	NO	NO	NO	NO
2. Manufacturing industries and construction	5,859.5	10.2	12.6	5,836.7
3. Transport	19,287.3	46.8	95.8	19,144.7
a. Domestic aviation	715.9	5.3	0.1	710.5
b. Road transportation	18,383.7	41.0	95.3	18,247.3
c. Railways	183.8	0.4	0.3	183.1
d. Domestic water-borne navigation	3.8	0.0	0.0	3.8
e. Other transportation	NO	NO	NO	NO
4. Other sectors	1,090.5	2.7	4.8	1,083.1
5. Other transportation (military)	IE	IE	IE	IE
B. Fugitive emissions from fuels	NE	NE	NE	NE
1. Solid fuels	NE	NE	NE	NE
2. Oil and natural gas	NE	NE	NE	NE
C. CO2 transport and storage	NO	NA	NA	NO

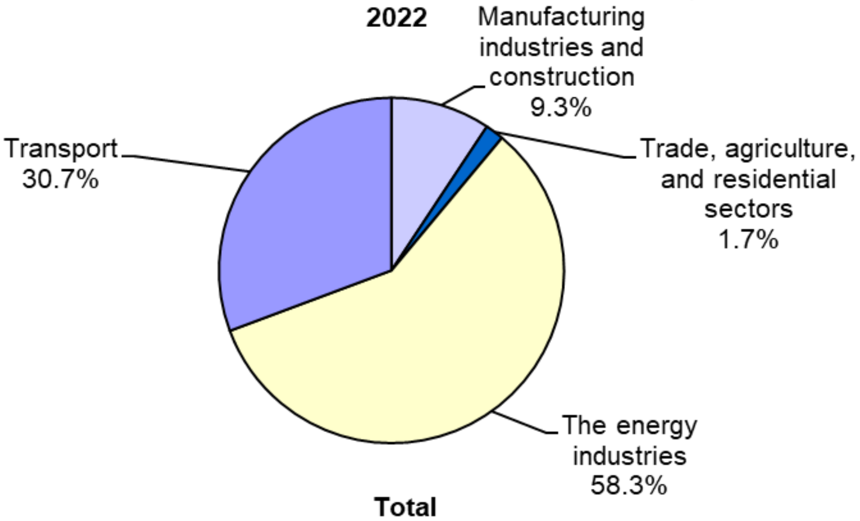
NE = not estimated, NO = not occurring, IE = included elsewhere, NA= not applicable

3.2.2. Trends

Emissions, by Source

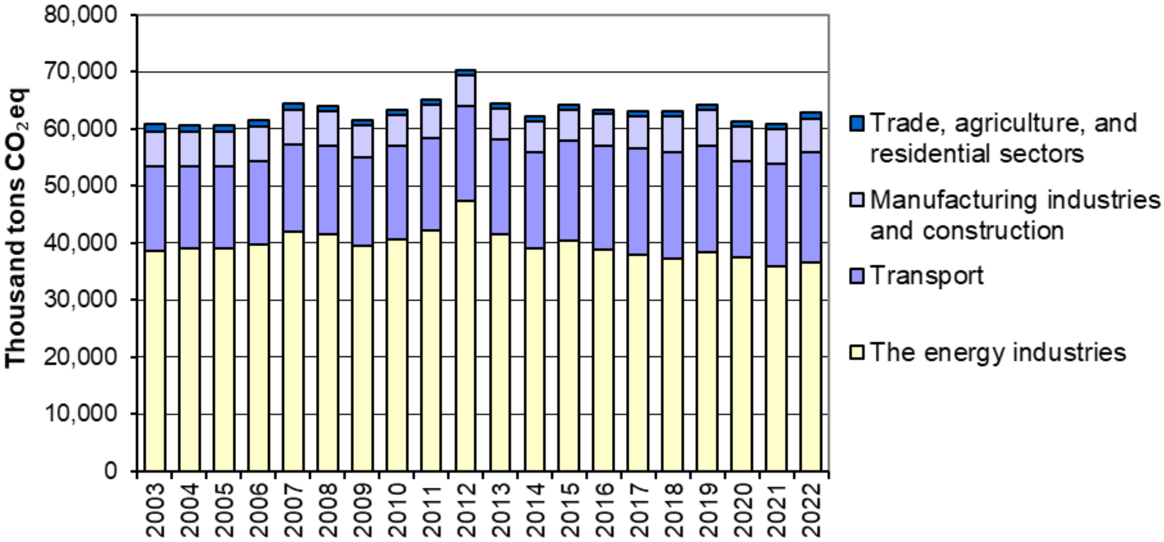
Between 2003 and 2022, total emissions in the energy sector fluctuated, ultimately increasing by 3.5% during this period. Between 2021 and 2022, the emissions increased by 3.4%. The largest source of emissions was electricity generation (which is a part of the energy industries), which accounted for 54.1% of all emissions in the energy sector. The second largest source of emissions was road transportation – 29.2% of all emissions in the energy sector. Between 2003 and 2022, emissions from the energy industries decreased by 5.3%, and emissions from transport increased by 31.0%.

DIAGRAM 3.8A. GHG EMISSIONS IN THE ENERGY SECTOR, BY SOURCE 2022



Total 62.9 million tons CO_2eq

DIAGRAM 3.8B. GHG EMISSIONS IN THE ENERGY SECTOR, BY SOURCE 2003–2022

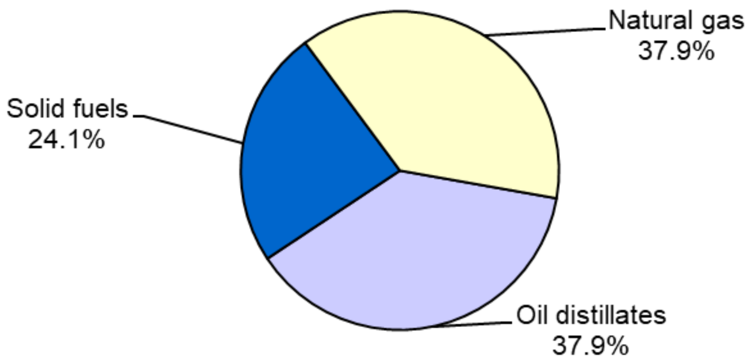


Emissions, by Fuel

The primary fuels used in Israel until 2004 were solid fuels (mainly coal) and oil distillates. In 2004, Israel began producing natural gas from offshore gas fields located within its territory. Since then, the use of natural gas has increased considerably and the mix of fuels has changed. Between 2009 and 2012 there was an increase in emissions, however, from 2013, due to the shift to the use of natural gas, there was a mixed trend of an overall decrease in emissions together with a slight increase in some of the years.

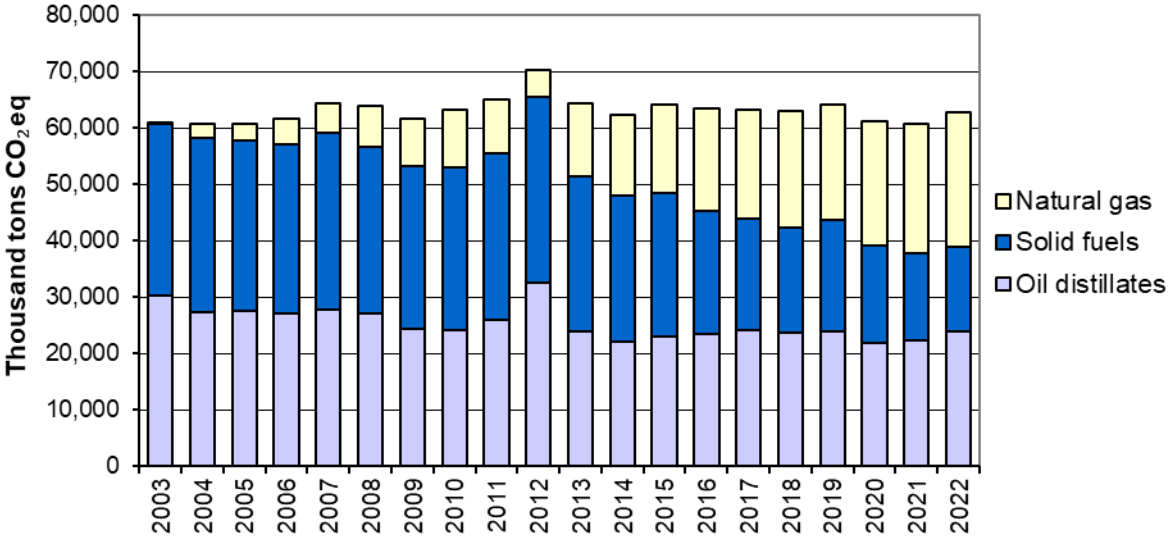
In 2003, emissions were quite evenly divided between solid fuels (mainly coal) and oil distillates (natural gas consumption being marginal). In contrast, in 2022, the share of solid fuels (24.1%) and oil distillates (37.9%) decreased, while natural gas accounted for 37.9% of emissions.

DIAGRAM 3.9A. GHG EMISSIONS IN THE ENERGY SECTOR, BY FUEL
2022



Total
62.9 million tons CO_2eq

DIAGRAM 3.9B. GHG EMISSIONS IN THE ENERGY SECTOR, BY FUEL
2003–2022

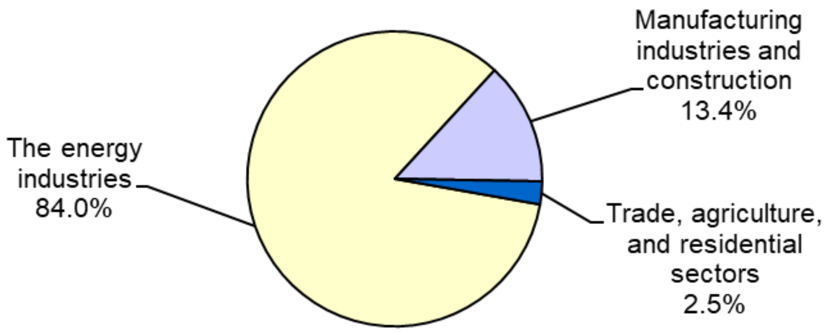


3.2.3. Emissions From Stationary Sources

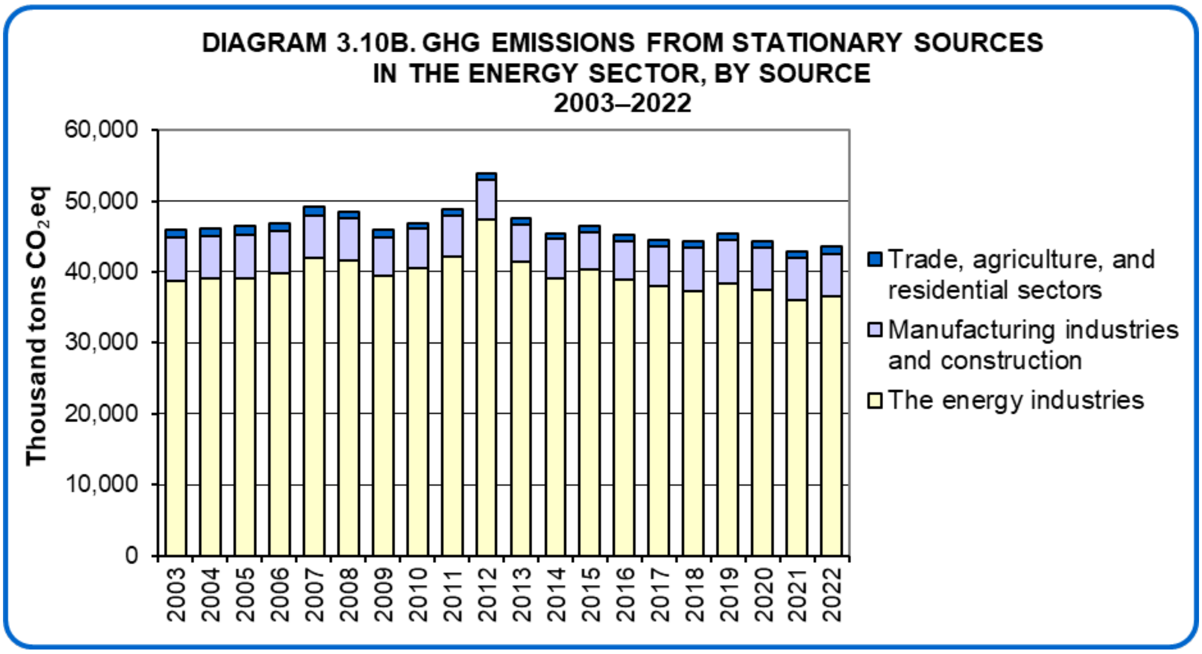
GHG emissions in the energy sector from stationary sources include emissions from combustion of fuels in the energy industries, in the manufacturing industries and construction, in trade, in agriculture, and in the residential sector. In 2022, total emissions from combustion of fuels from stationary sources stood at 43.6 million tons of CO_2eq, which was 69.3% of all emissions in the energy sector.

The energy industries are the primary source of emissions from stationary sources. In 2022, emissions from the energy industries stood at 36.6 million tons of CO_2eq, which was 58.3% of all emissions in the energy sector and 84.0% of the emissions from stationary sources in this sector.

DIAGRAM 3.10A. GHG EMISSIONS FROM STATIONARY SOURCES
IN THE ENERGY SECTOR, BY SOURCE
2022



Total
43.6 million tons CO_2eq



In 2022, the primary fuels used for combustion in stationary sources were natural gas and solid fuels (mainly coal), and emissions from these sources stood at 23.8 and 14.8 million tons of CO_2eq, respectively.

3.2.4. Emissions From Mobile Sources

Combustion of fuels from mobile sources in the energy sector includes combustion of fossil fuels to propel transport vehicles: road vehicles (in road transportation), trains, airplanes (in domestic aviation) and ships (in domestic water-borne navigation). In 2022, total emissions from mobile sources in the energy sector stood at 19.3 million tons of CO_2eq, which was 30.7% of all emissions in this sector.

The main source of emissions from mobile sources was road transportation, and in 2022 emissions from this source stood at 18.4 million tons of CO_2eq, which was 29.2% of all emissions in the energy sector and 95.3% of the emissions from mobile sources within this sector.

DIAGRAM 3.11A. GHG EMISSIONS FROM MOBILE SOURCES IN THE ENERGY SECTOR, BY SOURCE 2022

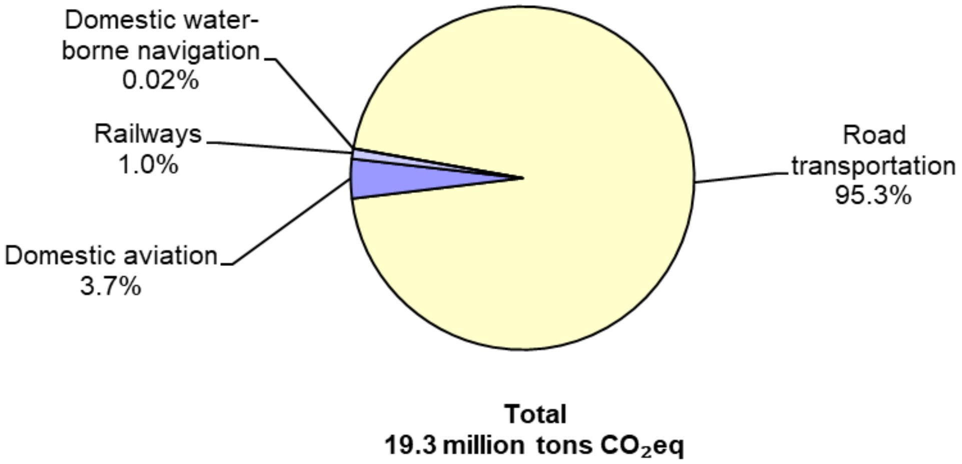
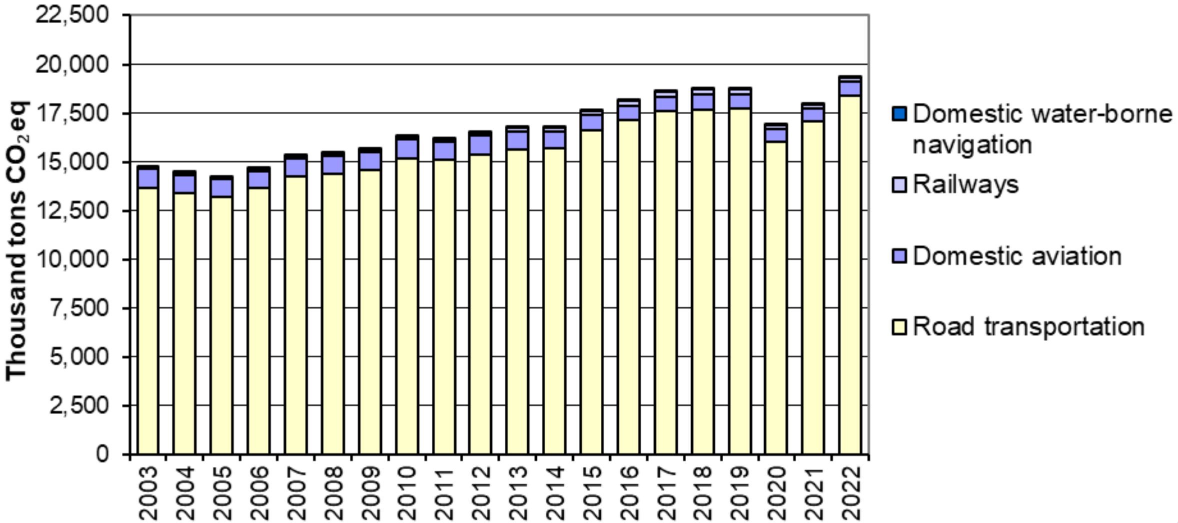


DIAGRAM 3.11B. GHG EMISSIONS FROM MOBILE SOURCES IN THE ENERGY SECTOR, BY SOURCE 2003–2022



In 2022, the primary fuels used for combustion in mobile sources were gasoline and diesel oil, and emissions from these fuels stood at 9.8 and 8.7 million tons of CO_2eq, respectively.

3.2.5. Fugitive Emissions

At this stage, the calculation of fugitive emissions is not included in the inventory. With the increase in the use of natural gas, and the emissions from the process of its production, transmission, and distribution, there is a high potential for fugitive emissions of CH_4.

The method of calculation is in the development process, and for this purpose several interdisciplinary working groups convened, with the participation of the CBS, government ministries, outside consultants, and companies operating in the field. These groups examined the calculation methods existing internationally, and compared them to the calculations which have been made in Israel, in order to select the calculation methods most appropriate for Israel.

3.3. Emission Sources and Calculation Methods

3.3.1. GHGs Included in the Calculation

The GHGs included in the energy sector are CO_2, CH_4, and N_2O.

Additional gases involved in the generation of GHGs were also included: CO and NO_X. SO_2 emissions were also calculated.

Calculation of emissions of NMVOCs was discontinued in 2011, in the absence of updated emission factors for emissions from transport.

3.3.2. Calculation Methods

As mentioned earlier, emissions in the energy sector come from combustion of fuels. The emissions were calculated according to the availability of data and information. Where there was no specific information, the default factors were used, according to the IPCC 1996 guidelines, by adapting them to Israel and multiplying them by the values of the level of activity in the field (amount of production or amount of use). Some of the emissions were calculated based on specific measurements or calculations received from the companies active in the field.

The emissions in the energy sector were calculated according to the first level (tier 1), and when the data made the use of an advanced approach possible, the emissions were calculated at higher levels of calculation (tier 2, tier 3).

According to the UNFCCC guidelines, emissions must be calculated using two methods: The sectoral approach and the reference approach.

In the calculation of the inventory, the emissions from combustion of fuels were calculated according to both methods. With the sectoral approach, each emission is calculated according to the sector or emission source in which the fuel is consumed. With the reference approach, CO_2 emissions from combustion of fuels are calculated according to the "top-down" calculation principle, which uses the country's energy supply data. The reference approach does not differentiate between different sectors and emission sources in the energy sector, and it only estimates the total CO_2 emissions from combustion of fuels.

3.3.2.1. CO_2 Emissions – Calculation Method and Emission Factors

3.3.2.1.1. Calculation Formula

The calculation of emissions from combustion of fuels was based on the amount of fuel consumed in the various emission sources and its multiplication by the emission factors.

Emissions of CO_2 for each fuel, k, in each emission source, h, were calculated as follows:

$$E_{hk} = (F_{hk} \times CV_{hk} \times FO_{hk} \times E_{cf}/1000) \times (1 - S_{hk}) \times 44/12$$

E_{hk} – total CO_2 emissions from combustion of fuels of type k in source h (thousands of tons)

F_{hk} – total consumption of fuels of type k in source h (thousands of tons)

CV_{hk} – net calorific value of fuel of type k in source h (terajoules per thousand tons)

FO_{hk} –fraction of oxidized carbon of fuel of type k in source h

E_{cf} – carbon content factor (ton of carbon per terajoule)

S_{hk} – fraction of the carbon stored in fuels

44/12 – multiplication by the mole ratio between the C and CO_2

With some fuels there is a portion that does not evaporate or combust, but instead remains in the products. This portion is not included in the emission calculation. The S_{hk} factor indicates the portion of the substance which is stored in the products.

The parameters and emission factors for each fuel can be found in Appendix C.

3.3.2.1.2. Emissions, by Fuel

To make a comparison between the fuels possible, after calculation of the emissions (based on the formula presented above), the ratio of CO_2 emissions to energy consumption in toe was calculated. From this ratio, implied emission factors were obtained that facilitate a comparison between the fuels and estimation of their effect on the emissions.

Table 3.4 CO_2 Implied Emission Factors, by Fuel, 2022

Tons per toe

Fuel	CO_2 Emission Factors
Diesel oil	3.07
Gasoline	2.87
Jet kerosene	2.96
LPG	2.61
Naphtha	0.61
Natural gas	2.34
Oil shale	4.42
Coal	3.88
Other gas (petrochemistry)	0.52
Kerosene	2.98
Petroleum coke	4.18
Refinery gas	2.39
Residual fuel oil	3.21
Waste (Refuse-derived fuel [RDF] and hazardous waste)	3.14

The energy sector is the primary source of GHGs (about 80%, over the years). The transition to combustion of natural gas, and the reduction in the use of coal, residual fuel oil, and diesel oil, contributed to the decrease in emissions in this sector. As for the CO_2 implied emission factors per toe by fuel, the emission per unit of energy from natural gas is considerably lower than the emission from coal, residual fuel oil, and diesel oil.

Table 3.5 CO_2 Implied Emission Factors in the Energy Sector, by Fuel, 2022

Fuel	CO_2 Emission Factors (tons per toe)	Compared to Natural Gas (percentages)
Coal	3.88	166%
Natural gas	2.34	100%
Residual fuel oil	3.21	137%
Diesel oil	3.07	131%

3.3.2.2. Non-CO2 Emissions – Calculation Method and Emission Factors

3.3.2.2.1. Calculation Formula

Other emissions from combustion of fuels, aside from CO_2, that should be calculated are CO, NO_X, N_2O, CH_4, and NMVOC. The calculation of emissions was based on the amount of fuel consumed in the various sectors and emission factors, in accordance with the IPCC 1996 guidelines. In some cases, other models were used, based on vehicle kilometers travelled and measurements of emission concentrations.

With some fuels there is a portion that does not evaporate or combust, but instead remains in the fuel. This portion is not included in the calculation of emissions.

Following, is a general description of the various methods for calculating emissions:

Emissions of N_2O and CH_4 were calculated using emission factors that are the default in the IPCC 1996 guidelines.

Emissions of NO_X and CO were also calculated using emission factors that are the default in the IPCC 1996 guidelines, or by using estimates relying on reports to the PRTR[5] (which are based on monitoring or models for calculation of emissions). Emissions from vehicles were calculated based on kilometers travelled. SO_2 emissions were calculated based on the sulfur content of the fuels. The sulfur content was obtained from sulfur content standards or from measurements of sulfur content. There may be several sulfur content standards for the same fuel. Emission reduction measures were also taken into account, and in some cases emission monitoring data was used. Calculation of NMVOC emissions was discontinued, due to the fact that the emissions from vehicles that were calculated were implausible. The calculation of emission factors that are unique to Israel is under development.

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[5] The PRTR (Pollutant Release and Transfer Register) is a mechanism for reporting environmental emissions that provides information on waste, wastewater, and other pollutants that are emitted to the land, air, sea, and streams. The information is based on the annual reports submitted to the Ministry of Environmental Protection by factories, landfills, transit stations, wastewater treatment facilities, etc.

3.3.3. Sources of Information on Fuel Consumption

3.3.3.1. Included Fuels

The fuels used to generate energy in Israel include oil distillates (residual fuel oil, diesel oil, gasoline, etc.), solid fuels (coal, oil shale, refuse-derived fuel[6] [RDF] and hazardous waste), and natural gas. The sources of the fuels are imports (such as crude oil and oil distillates) or domestic production (such as natural gas).

Oil Distillates – The source of oil distillates is importation of the distillates or the domestic refining of crude oil (the vast majority of the crude oil in Israel is imported, and only a very limited amount is domestically produced).

Oil distillates include gasoline, diesel oil, residual fuel oil (light and heavy), kerosene, LPG, naphtha, other gases (propylene, etc.), petroleum coke, and refinery gases.

Solid Fuels – Coal (bituminous) constitutes the major portion of the solid fuels consumed and it is all imported. Other solid fuels are oil shale, refuse-derived fuel, and hazardous waste, which are all produced in Israel.

Natural Gas – The source of the natural gas is mainly production from reserves along the coast of Israel and small quantities of imports.

The emissions from the following fuels were not calculated:

- Biogas that is used to generate electricity and as a fuel in manufacturing and is combusted by means of a flare in landfills;
- Combustion of biomass of blocks of coal and wood for heating.

The assumption is that the extent of emissions from these sources is negligible.

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[6] Refuse-derived fuel (RDF) is fuel produced from the various types of waste, such as solid municipal waste and solid industrial waste. It consists mainly of the various types of plastic, wood, and textiles, and is used as combustion material in the cement industry.

3.3.3.2. Sources of information

As far as the sources of information are concerned, the total consumption of fuel products in the economy is covered nearly completely, the information coming from the Fuel and LPG Department of the Ministry of Energy and Infrastructure and supplementary sources. Consumption by sector was obtained at a different level of detail, according to the availability of information.

Oil Distillates

The data on the consumption of all of the oil distillates (gasoline, diesel oil, residual fuel oil, kerosene, LPG, naphtha, and other gases) were obtained from the Ministry of Energy and Infrastructure, which makes annual estimates of fuel consumption by the main sectors.

The main sectors are manufacturing; electricity generation (by the Israel Electric Corporation and by private companies); the manufacturing industries and construction; transport (road transportation, railways, domestic aviation, and domestic water-borne navigation); trade; and residential.

Over the years, the Ministry of Energy and Infrastructure periodically updated the method of estimating fuel consumption by sector.

Data on oil distillate consumption for electricity generation were obtained from the Israel Electric Corporation and private companies.

The consumption of refinery gases was calculated according to the difference between the inputs and the outputs of the refinery.

Solid Fuels

Data on the consumption of coal for electricity generation were obtained from the Israel Electric Corporation. Data on coal consumption in manufacturing are based on the extent of imports, obtained from the customs data of companies that use coal for energy generation.

The consumption data for petroleum coke, oil shale, refuse-derived fuel, and hazardous waste were obtained from the companies that consume these fuels.

Natural Gas

Data on total natural gas consumption were obtained from the reports of the Natural Gas Authority of the Ministry of Energy and Infrastructure.

The natural gas consumption for electricity generation data were obtained from the Israel Electric Corporation, private electricity generation companies, and companies in the economy.

3.3.4. Calculation of Emissions According to the Reference Approach

3.3.4.1. Calculation Method

The reference approach[7] is a simple method of calculation, and can be applied based on relatively easily available energy supply statistics. Furthermore, it enables a comparison in the calculation of emissions according to the sectoral approach and the detection of gaps that may indicate flaws in the activity data, the energy values, the carbon content, and additional data.

With the reference approach, it is presumed that the carbon is preserved throughout its transfer. For example, the carbon content of crude oil is equal to the total carbon content of all the products produced from it. The reference approach does not differentiate between different emission sources in the energy sector, but only evaluates the total CO_2 emissions from combustion of fuels. The emissions result both from the combustion of fuels in the energy sector, where the fuel is used as an energy source for petroleum refining or for generating secondary energy (such as electricity), and from the final consumption of the fuel in the manufacturing, trade, transport, and residential sectors, and in additional sectors.

The calculation of emissions according to the reference approach is based on the observed energy consumption in the country and the calculation of the carbon content in the energy sources. In the calculation, it is necessary to separate primary fuels (such as crude oil, coal, and natural gas) from secondary fuels (such as gasoline, diesel oil, and residual fuel oil). In order to avoid duplicate listings, the calculation did not include the carbon in the secondary fuels produced, since they are derivatives of the primary fuels. (For example, the carbon contained in gasoline and diesel oil, which are refined products, is already included in the crude oil that was used as an input in the refining process).

In the first stage, the amount of carbon in all fuels was calculated. Then, the amount of carbon that does not combust (but instead remains in the products or is used as a raw material) was subtracted from this amount. The resulting amount was multiplied by the combustion correction factor and the mole ratio between carbon and CO_2.

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[7] See section 3.3.2.

Additional details on the calculation of emissions with the reference approach can be found in Appendix D.

3.3.4.2. Sources of Information

Activity data: The calculation of emissions according to the reference approach relied in most cases on the energy balance data, except for certain cases, such as waste combustion (where more detail is required than is found in the balance).

Energy values: The conversion of fuels to energy values was based on Israel's energy balance, presented in units of toe. The energy values of the fuels were taken according to the availability of data (see section 3.3.2).

Estimate of carbon content: The estimates of carbon content in the fuels were taken from the IPCC 1996 guidelines, as with the values in calculating emissions according to the sectoral approach.

Carbon that is not included: Some of the carbon does not combust, but instead remains stored in the products or is used as a raw material. The estimate of the carbon stored in the products was based on the estimates of the sectoral approach calculation method (according to the factors of the fraction of the carbon stored in the product, from the IPCC 1996 guidelines). Carbon that does not combust and is stored in the products is found in naphtha and gases in the petrochemical industry, and carbon that does not combust and is used as a raw material is found in the use of tar and natural gas.

The oxidation factor: The oxidation factors were taken from the IPCC 1996 guidelines (see Appendix C).

3.3.4.3. Comparison Between the Calculation Methods

In 2022, the results of calculating the fuel combustion emissions according to the sectoral approach and according to the reference approach were 62.9 and 61.2 million tons of CO_2eq, respectively. The difference between the methods stood at 1.8%.

Table 3.6 CO_2 Emissions From Fuel Combustion, by Calculation Method, 2022
Thousand tons of CO_2eq, unless otherwise stated

Sectoral approach	62,853
Reference approach	61,741
Difference (percent)	1.77

As mentioned earlier, the reference approach provides estimates of CO_2 emissions for the purpose of comparing them with the emission estimates of the sectoral approach. The results obtained from calculating the emissions by the sectoral approach and the reference approach differ because with the sectoral approach the estimation process is done "from the bottom up", using detailed information on fuel consumption in each sector, whereas with the reference approach the process is done "from the top down", using all of the country's energy supply data, without a breakdown into the specific uses.

3.4. Limitations of the Data

In the manufacturing industries and construction, domestic aviation, domestic water-borne navigation, trade, agriculture, and residential sectors, fuel consumption is based on estimates. The methods of estimation have been updated over the years and this, too, caused changes in the emissions estimates.

The emission factors selected from the IPCC 1996 guidelines are general factors, and do not necessarily represent the technologies in Israel.

3.5. 1.A.1 The Energy Industries

3.5.1. Description of the Sector

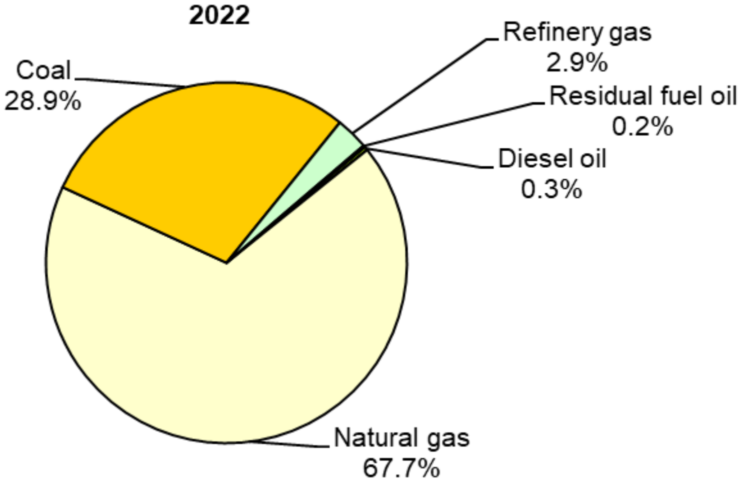
The energy industries include petroleum refining and electricity generation by the Israel Electric Corporation and by private companies (only emissions from companies whose main business activity is electricity generation are included). Emissions from the production and transmission of natural gas should be included in this sector, but they were not. It is necessary to include them in the future.

3.5.2. Fuel Consumption

In the energy industries there have been major changes in the mix of fuels, particularly in the generation of electricity. The use of natural gas has expanded, with the discovery of natural gas within Israel's borders, the development of the natural gas transmission system, and the entry of private companies that have established new production facilities based on the consumption of natural gas. This has brought about a reduction in the combustion of coal and oil distillates for electricity generation. Furthermore, the increase in generation of electricity from renewable sources (primarily solar energy) has moderated the need to burn fuels for this purpose.

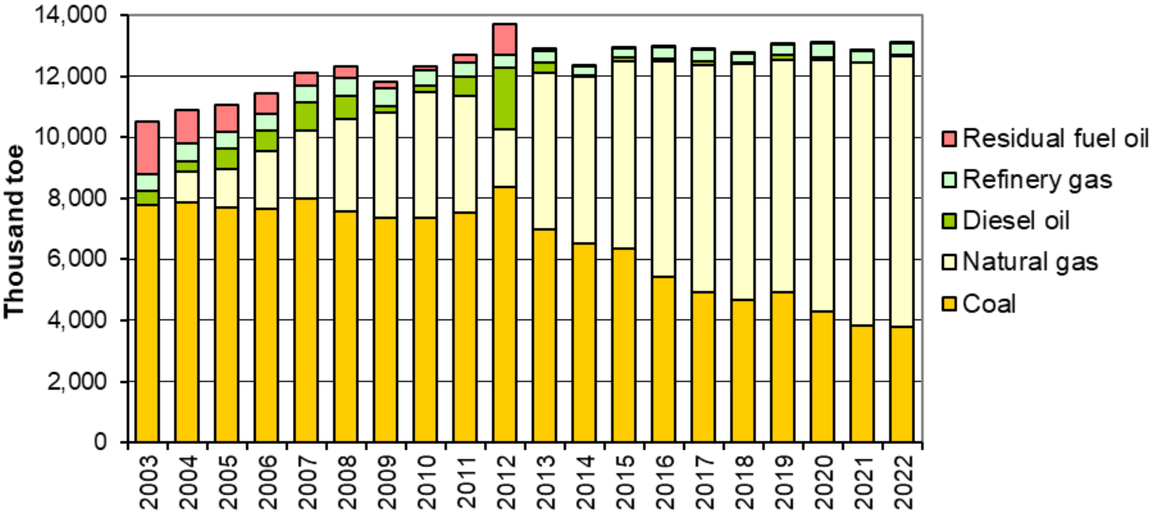
Between 2003 and 2022, energy consumption in the energy industries increased by 24.4% – from 10.5 million toe to 13.1 million toe. During this period, the mix of fuels changed substantially. The share of natural gas increased, while the share of solid fuels (mainly coal) and oil distillates decreased. Whereas in 2003 the fuel mix consisted of 73.9% coal and 26.1% oil distillates, in 2022, their share decreased to 28.9% and 3.4%, respectively, and the share of natural gas increased to 67.7% of the total consumption.

DIAGRAM 3.12A. FUEL CONSUMPTION IN THE ENERGY INDUSTRIES, BY FUEL 2022



Total
13.1 million toe

DIAGRAM 3.12B. FUEL CONSUMPTION IN THE ENERGY INDUSTRIES, BY FUEL 2003–2022



Parallel to the transition to the use of natural gas, the new generation facilities have employed generation systems with advanced technologies of cogeneration and combined cycle power, which enable better utilization of energy and the generation of electricity and heat with lower energy consumption. The ratio between the energy produced (electricity) and the energy consumed (fuel combustion) shows the electricity transformation efficiency. The higher this ratio, the more efficient the transformation, and the higher the capability to produce more electricity with less energy. High conversion efficiency impacts the total emissions of air pollutants and GHGs from electricity generation.

Due to a change in the fuel mix and an increase in the use of natural gas for electricity generation, the conversion efficiency increased from 42.2% in 2013 to 45.0% in 2022. The efficiency increased due to more widespread generation of electricity by means of efficient technology of combined cycle power generation systems (52.9% of total electricity generation).

3.5.3. Calculation Method

The emissions were calculated using the best available information found in Israel. When there was no available information, default values of emission factors were used. The emissions calculation was based on the emission factors from the IPCC 1996 guidelines, and the different energy values of the products (coal, natural gas, refinery gases) and the characteristics of the fuels (their sulfur content) were taken into account.

Following, are emission calculation methods adapted for use in Israel:

The calculation of NO_X emissions from coal combustion was based in 2003–2011 on the emission factors recommended in the IPCC 1996 guidelines, taking into account the emission reduction systems that exist in some facilities in Israel. Since 2012, the emissions have been obtained from the reports to the PRTR, which are based on continuous monitoring of emissions or on models for calculation of emissions used at each site.

The calculation of SO_2 emissions from coal combustion was based in 2003–2011 on an emissions model, taking into account the emission reduction systems that exist in some facilities in Israel. Since 2012, the emissions have been obtained from the reports to the PRTR, which are based on continuous monitoring of emissions or on models for calculation of emissions used at each site.

The calculation of CO and NO_X emissions from natural gas combustion was based on reports to the PRTR, which are based on continuous monitoring of emissions or on models for calculation of emissions used at each site. For companies that did not have information on emissions, an imputation was made based on data from other companies.

Table 3.7 Methods of Calculating GHG Emissions in the Energy Industries, by Fuel and Gas, 2022

Fuel/Gas	SO_2	CO	NO_X	N_2O	CH_4	CO_2
Coal	T2,3 – CS, PS	T1– D	T2,3 – CS, PS	T1 – D	T1 – D	T1 – D
Natural gas	T2 – CS	T2,3 – CS,PS	T2,3 – CS, PS	T1 – D	T1 – D	T1 – D
Residual fuel oil	T2 – CS	T1– D	T1– D	T1– D	T1 – D	T1– D
Diesel oil	T2 – CS	T1– D	T1 – D	T1 – D	T1 – D	T1 – D
Refinery gas	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D

T1 = tier 1, T2 = tier 2, T3 = tier 3, CS= Country-specific, PS = Plant-specific, D= IPCC default

Following, are the implied emission factors of the various gases (emissions per thousand toe). From these factors, it is possible to make a comparison between the fuels and learn about their impact on emissions.

We see that the implied emission factors of tons of CO_2 per toe of coal (3.88), residual fuel oil (3.21), and diesel oil (3.07) are greater than the emission factor of natural gas (2.34). This means that for each unit of available energy, less CO_2 is emitted from natural gas combustion than the amount which is emitted from combustion of coal, residual fuel oil, and diesel oil.

Table 3.8 Implied Emission Factors of Direct GHGs in the Energy Industries, by Fuel and Gas, 2022

Fuel/Gas	Tons of N_2O CO_2eq per thousand toe of fuel	Tons of CH_4 CO_2eq per thousand toe of fuel	Tons of CO_2 per toe of fuel
Coal	15.54	1.17	3.88
Natural gas	1.11	1.17	2.34
Residual fuel oil	6.66	3.52	3.21
Diesel oil	6.66	3.52	3.07
Refinery gas	6.66	3.52	2.39

Table 3.9 Implied Emission Factors of Indirect GHGs in the Energy Industries, by Fuel and Gas, 2022

Tons per thousand toe of fuel

Fuel/Gas	SO_2	CO	NO_X
Coal	5.28	0.84	4.07
Natural gas	1.19	0.79	0.00
Residual fuel oil	8.38	0.63	10.42
Diesel oil	8.38	0.63	1.93
Refinery gas	0.50	0.63	0.96

3.5.4. GHG Emissions, by Fuel

In 2022, total GHG emissions in the energy industries (electricity generation and petroleum refining) stood at 36.6 million tons of CO_2eq, which was 58.3% of all emissions in the energy sector.

Table 3.10 GHG Emissions in the Energy Industries, by Fuel and Gas, 2022

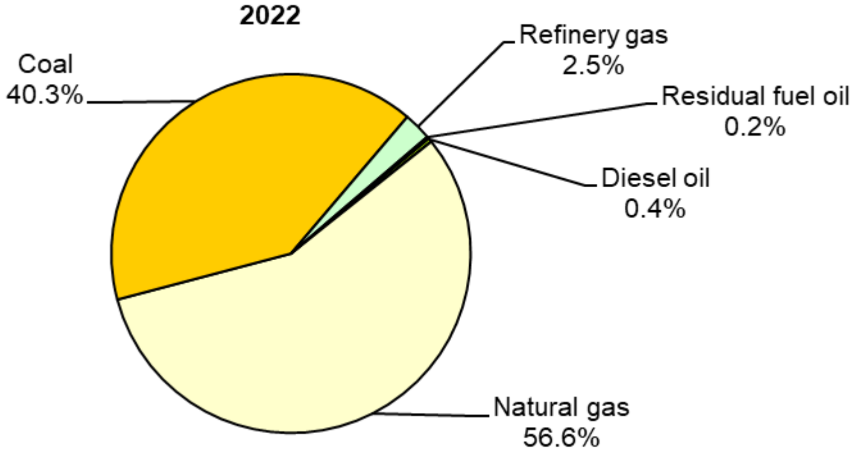
Thousand tons of CO_2eq

Fuel/Gas	Total	N_2O	CH_4	CO_2
Total	**36,616**	**72**	**16**	**36,528**
Coal	14,766	59	4	14,703
Natural gas	20,730	10	10	20,709
Residual fuel oil	65	0	0	65
Diesel oil	138	0	0	137
Refinery gas	918	3	1	914

GHG emissions in the energy industries decreased between 2003 and 2022 by 5.3%, and increased between 2021 and 2022 by 1.7%. The decrease in emissions over the years was brought about primarily as a result of the change in the fuel mix and the 51.3% reduction in coal combustion between 2003 and 2022.

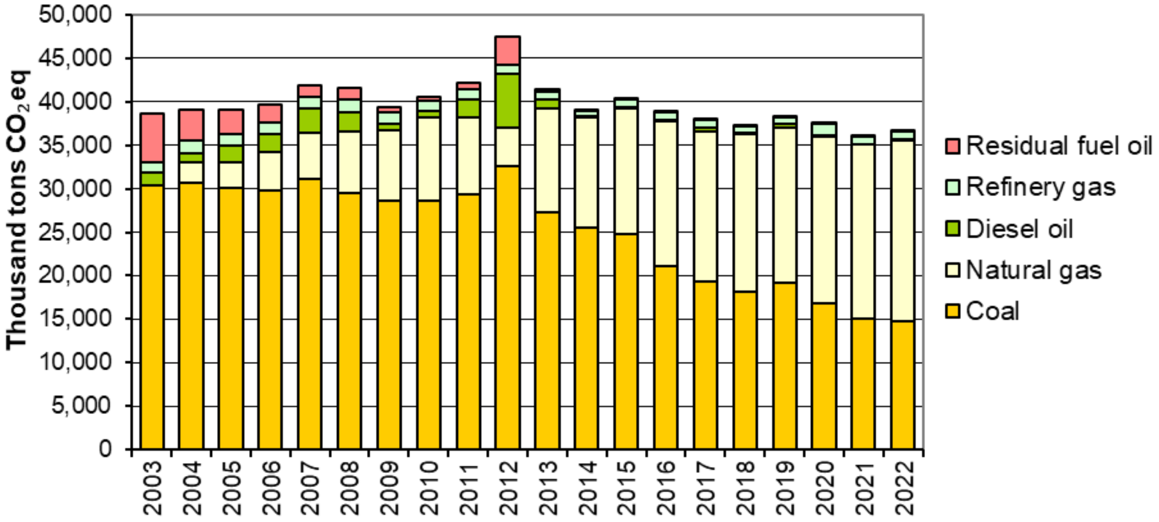
In 2003, the emissions in the energy industries came from combustion of coal (78.5%) and oil distillates (21.5%), and since then, the share of coal has decreased, coming to 40.3% in 2022. Coinciding with the reduction in the share of coal in GHG emissions, the share of natural gas increased, reaching 56.6% in 2022. The decrease in the use of residual fuel oil and diesel oil in the energy industries resulted in the fact that in 2022, less than 0.6% of emissions in the energy sector originated from these two fuels.

DIAGRAM 3.13A. GHG EMISSIONS IN THE ENERGY INDUSTRIES, BY FUEL 2022



Total
36.6 million tons CO_2eq

DIAGRAM 3.13B. GHG EMISSIONS IN THE ENERGY INDUSTRIES, BY FUEL 2003–2022



3.5.5. Non-GHG Emissions

In 2022, approximately 31,300 tons of NO_X, 10,400 tons of CO, and 16,100 tons of SO_2 were emitted in the energy industries. Most of the emissions of NO_X (63.9%) and SO_2 (95.9%) came from coal combustion. Natural gas was the second largest source of NO_X emissions (33.7%), despite the fact that it was the largest source of energy supply. CO and SO_2 emissions from natural gas combustion are relatively lower than emissions from other fuels due to a better combustion process and very low sulfur content.

Table 3.11 Non-GHG Emissions in the Energy Industries, by Fuel and Gas, 2022

Thousand tons

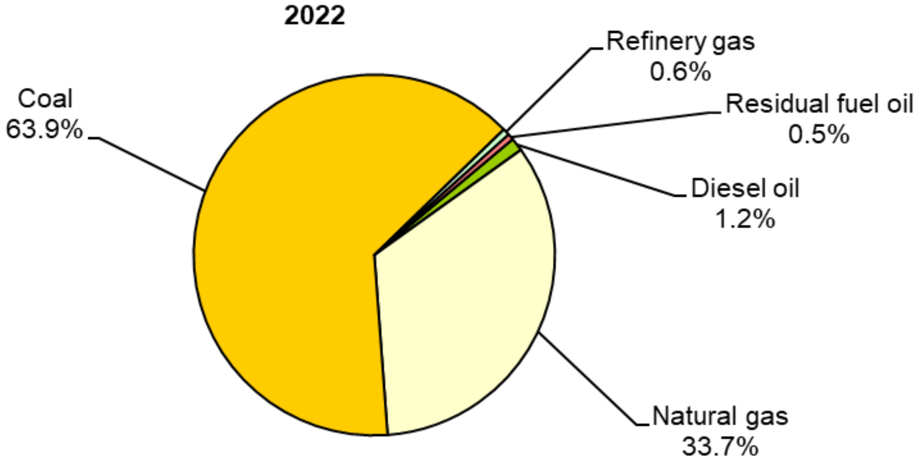
Fuel/Gas	SO_2	CO	NO_X
Total	**16.1**	**10.4**	**31.3**
Coal	15.4	3.2	20.0
Natural gas	0.0	7.0	10.5
Residual fuel oil	0.2	0.0	0.2
Diesel oil	0.1	0.0	0.4
Refinery gas	0.4	0.2	0.2

NOx Emissions

NOx emissions in the energy industries decreased from approximately 111,800 tons in 2003 to approximately 31,300 tons in 2022, a decrease of 72.0%. This was due to the reduction in the use of coal and oil distillates and the increase in the use of natural gas.

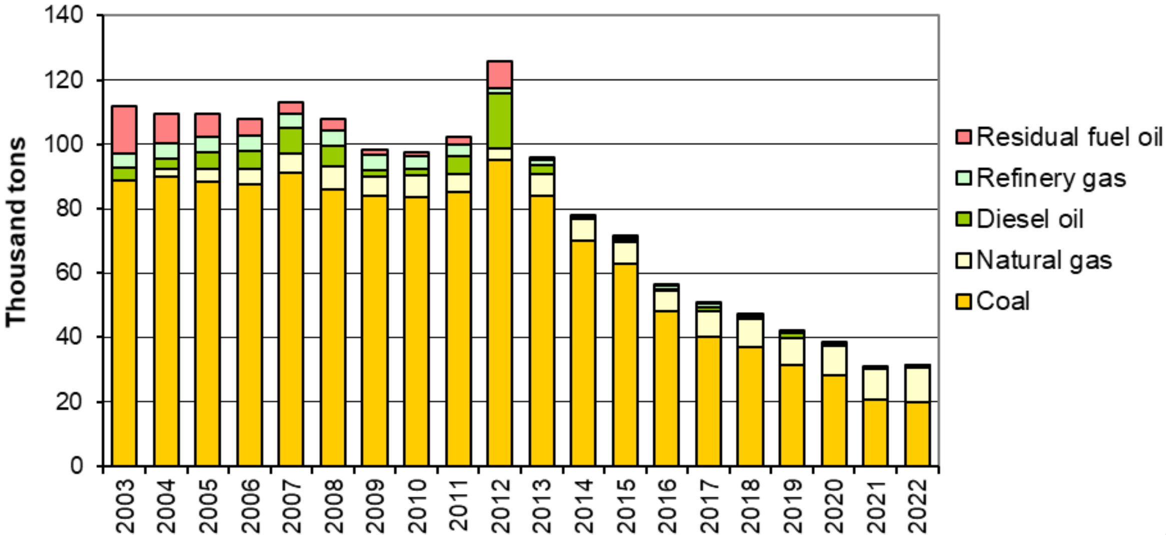
Most of the NOx emissions, throughout the years, came from coal combustion. In 2003, the share of coal in the emissions was 79.5%, and in 2022, it was 63.9%. Coinciding with the reduction in the share of coal in total NOx emissions, the share of natural gas increased, reaching 33.7% in 2022.

DIAGRAM 3.14A. NO_x EMISSIONS IN THE ENERGY INDUSTRIES, BY FUEL
2022



Total
31.3 thousand tons

DIAGRAM 3.14B. NO_x EMISSIONS IN THE ENERGY INDUSTRIES, BY FUEL
2003–2022



SO_2 Emissions

SO_2 emissions in the energy industries decreased from approximately 179,700 tons in 2003 to approximately 16,100 tons in 2022, a decrease of 91.1%. This was due to the reduction in the use of coal and oil distillates, the installation of emission reduction systems in the coal-fired power plants, and the increase in the use of natural gas, which has a very low sulfur content. Coal combustion was the main source of SO_2 emissions over the years, and between 2003 and 2022, emissions from this source decreased by 87.1%.

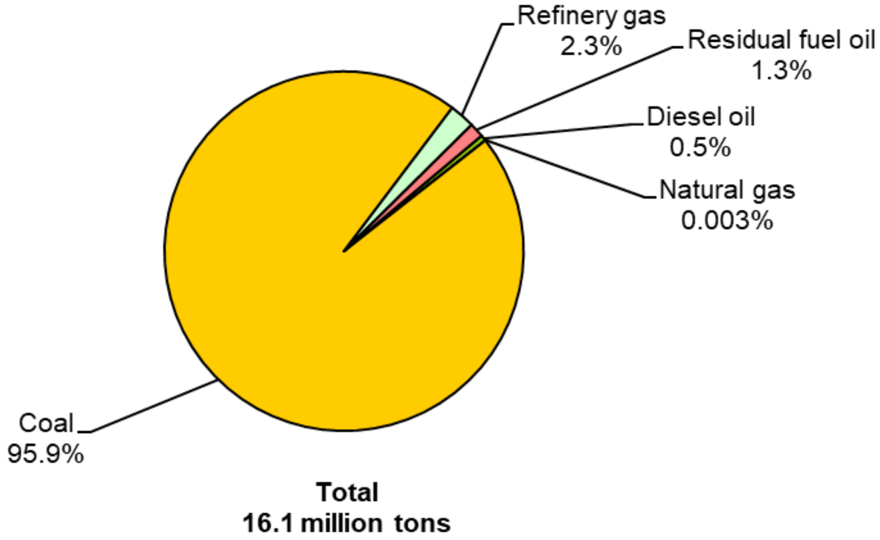


DIAGRAM 3.15A. SO_2 EMISSIONS IN THE ENERGY INDUSTRIES, BY FUEL 2022

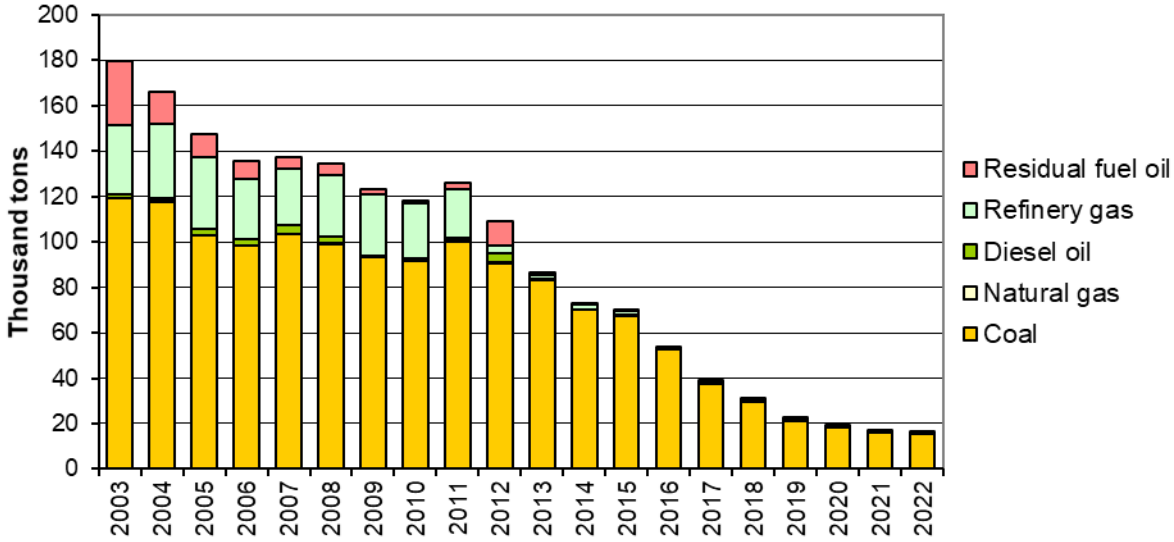


DIAGRAM 3.15B. SO_2 EMISSIONS IN THE ENERGY INDUSTRIES, BY FUEL 2003–2022

3.6. 1.A.2 The Manufacturing Industries and Construction

3.6.1. Description of the Sector

This sector includes the manufacturing and mining and quarrying industries.

3.6.2. Fuel Consumption

In the manufacturing industries and construction (as in the economy as a whole) there have been major changes in the mix of fuels. The use of natural gas began with the discovery of the gas and expanded with the expansion of the infrastructure for transmission of gas to industrial zones and large consumers of energy in manufacturing.

Between 2003 and 2022, energy consumption in the manufacturing industries and construction increased by 4.5% – from 2.9 million toe to 3.0 million toe. During this period, there was a change in the fuel mix: The share of natural gas in consumption increased, and the share of oil distillates decreased. Whereas in 2003 fuel consumption was almost entirely from oil distillates, in 2022 their share in consumption decreased to 51.9%, and natural gas constituted 44.2% of total consumption.

DIAGRAM 3.16A. FUEL CONSUMPTION IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL 2022

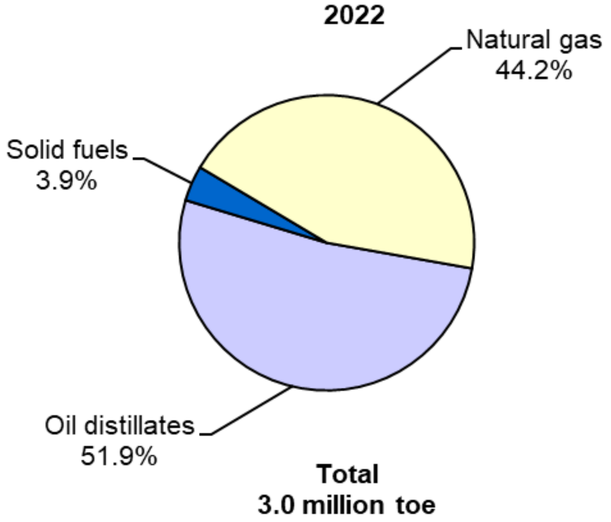
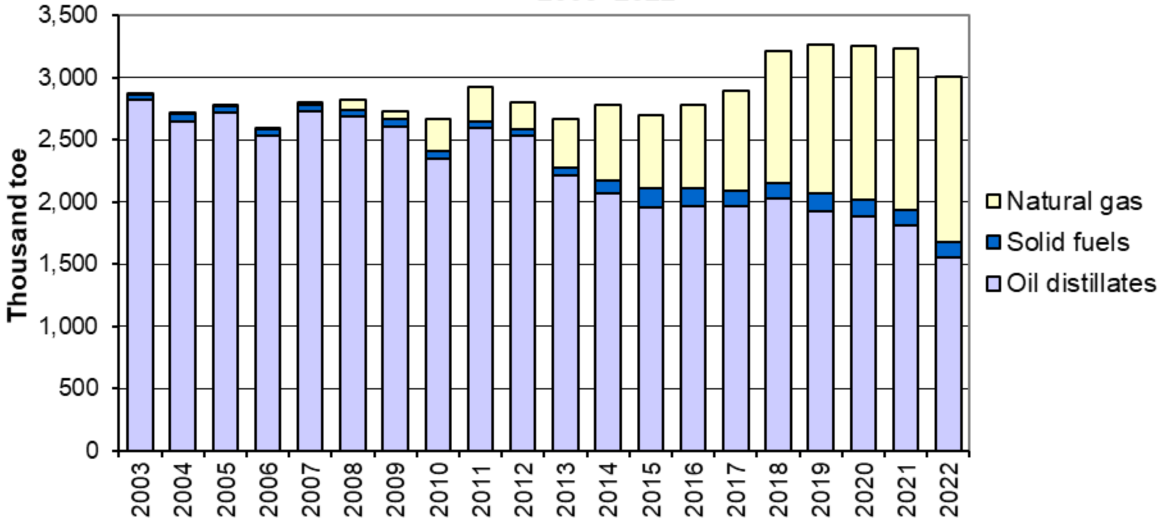


DIAGRAM 3.16B. FUEL CONSUMPTION IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL 2003–2022



3.6.3. Calculation Method

The emissions were calculated using the best available information found in Israel. When there was no available information, default values of emission factors were used. The emissions calculation was based on the emission factors from the IPCC 1996 guidelines, and the different energy values of the products (coal, natural gas, oil shale) and the characteristics of the fuels (their sulfur content) were taken into account.

Following, are emission calculation methods adapted for use in Israel:

The calculation of CO and NO_X emissions from natural gas combustion was based on reports to the PRTR, which are based on continuous monitoring of emissions or on models for calculation of emissions used at each site. For companies that did not have information on emissions, an imputation was made based on data from other companies.

Table 3.12 Methods of Calculating GHG Emissions in the Manufacturing Industries and Construction, by Fuel and Gas, 2022

Fuel/Gas	SO_2	CO	NO_X	N_2O	CH_4	CO_2
Coal	T2 – CS	T1 – D	T1 – D	T1 – D	T1– D	T1 – D
Natural gas	T2 – CS	T2, T3 – CS, PS	T2, T3 – CS, PS	T1 – D	T1 – D	T1 – D
Residual fuel oil	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Diesel oil	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Petroleum coke	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Naphtha	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
LPG	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Kerosene	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Refuse-derived fuel (RDF) and hazardous waste	NE	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Other gas (petrochemistry)	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Oil shale	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D

T1 = tier 1, T2 = tier 2, T3 = tier 3, CS= Country-specific, PS = Plant-specific, D= IPCC default, NE = not estimated

Following, are the implied emission factors of the various gases (emissions per thousand toe). From these factors, it is possible to make a comparison between the fuels and learn about their impact on emissions.

Table 3.13 Implied Emission Factors of Direct GHGs in the Manufacturing Industries and Construction, by Fuel and Gas, 2022

Tons of CO_2eq per thousand toe of fuel, unless otherwise stated

Fuel/Gas	N_2O	CH_4	Tons of CO_2 per toe of fuel
Coal	15.54	11.73	3.88
Natural gas	1.11	5.86	2.34
Residual fuel oil	6.66	2.35	3.21
Diesel oil	6.66	2.35	3.07
Petroleum coke	6.66	2.35	4.18
Naphtha	1.33	0.47	0.61
LPG	6.66	2.35	2.61
Kerosene	6.66	2.35	2.98
Refuse-derived fuel (RDF) and hazardous waste	44.39	35.18	3.14
Other gas (petrochemistry)	1.33	0.47	0.52
Oil shale	6.66	3.52	4.42

Table 3.14 Implied Emission Factors of Indirect GHGs in the Manufacturing Industries and Construction, by Fuel and Gas, 2022

Fuel/Gas	Tons of SO_2 per thousand toe of fuel	Tons of CO per thousand toe of fuel	Tons of NO_X per thousand toe of fuel
Coal	18.51	6.28	12.56
Natural gas	0.00	1.46	1.27
Residual fuel oil	17.51	0.42	8.38
Diesel oil	1.93	0.42	8.38
Petroleum coke	3.21	0.42	8.38
Naphtha	0.74	0.08	1.68
LPG	0.27	0.42	8.38
Kerosene	1.12	0.42	8.38
Refuse-derived fuel (RDF) and hazardous waste	-	41.88	4.19
Other gas (petrochemistry)	0.05	0.08	1.68
Oil shale	89.37	6.26	24.16

3.6.4. GHG Emissions, by Fuel

In 2022, total GHG emissions in the manufacturing industries and construction stood at 5.9 million tons of CO_2eq, which was 9.3% of all emissions in the energy sector.

Table 3.15 GHG Emissions in the Manufacturing Industries and Construction, by Fuel and Gas, 2022

Thousand tons of CO_2eq

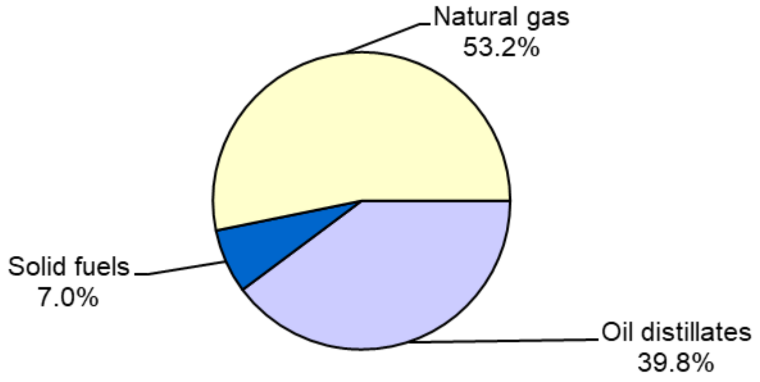
Fuel/Gas	Total	N_2O	CH_4	CO_2
Total	**5,859**	**10**	**13**	**5,837**
Coal	34	0.13	0.10	34
Natural gas	3,117	1.48	7.80	3,108
Residual fuel oil	300	0.62	0.22	299
Diesel oil	216	0.47	0.16	215
Petroleum coke	877	1.39	0.49	875
Naphtha	511	1.12	0.39	510
LPG	286	0.73	0.26	285
Kerosene	20	0.04	0.02	20
Refuse-derived fuel (RDF) and hazardous waste	270	3.72	2.95	263
Other gas (petrochemistry)	123	0.31	0.11	122
Oil shale	107	0.16	0.08	107

Emissions in the manufacturing industries and construction decreased between 2003 and 2022 by 5.0%. From 2003 to 2008 the level of emissions remained relatively stable. From 2008 to 2015, emissions decreased, in a fluctuating manner, by 10.1%, from 2015 to 2019, they increased by 17.1% and from 2019 to 2022, they decreased by 6.2%.

Emissions from natural gas increased over the years, while, in contrast, there was a decrease in emissions from oil distillates, primarily emissions from residual fuel oil combustion, which decreased by 90.6% between 2003 and 2022.

Nearly all of the emissions in the manufacturing industries and construction in 2003 came from combustion of oil distillates (96.4%), primarily residual fuel oil (51.4%). Due to the decrease in the use of oil distillates since 2003 and the transition to natural gas, in 2022, the share of natural gas out of total emissions stood at 53.2%, and the share of emissions from oil distillates decreased to 39.8%.

DIAGRAM 3.17A. GHG EMISSIONS IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL 2022



Total
5.9 million tons CO_2eq

DIAGRAM 3.17B. GHG EMISSIONS IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL 2003–2022

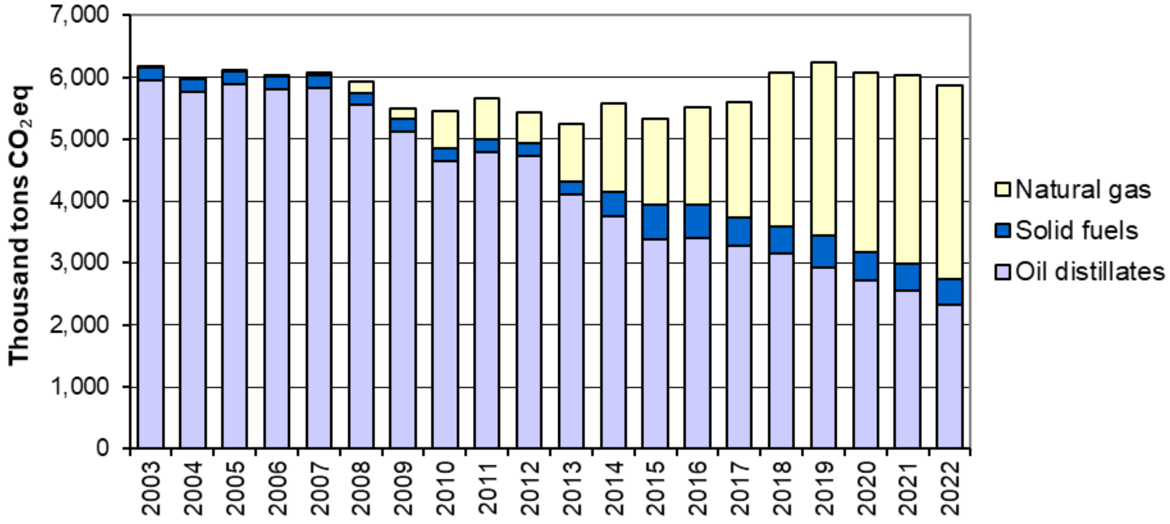
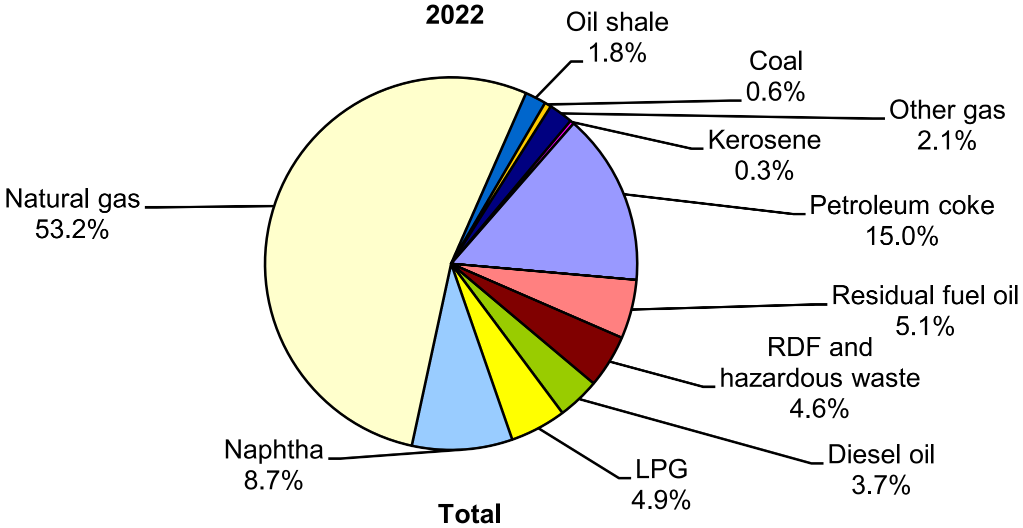


DIAGRAM 3.18 GHG EMISSIONS IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL

2022



Total
5.9 million tons CO_2eq

3.6.5. Non-GHG Emissions

In 2022, approximately 8,600 tons of NO_X, 5,900 tons of CO, and 5,400 tons of SO_2 were emitted in the manufacturing industries and construction.

The primary sources of NO_X emissions were petroleum coke (20.3%), natural gas (19.6%), naphtha (16.3%), LPG (10.6%), and residual fuel oil (9.1%).

Most of the CO emissions came from combustion of refuse-derived fuel and fuel deriving from hazardous waste (59.0%), and from natural gas (32.6%).

Emissions of SO_2 came primarily from oil shale (39.7%) and residual fuel oil (30.1%). (Emissions of SO_2 from waste combustion were not calculated.)

Table 3.16 Non-GHG Emissions in the Manufacturing Industries and Construction, by Fuel and Gas, 2022

Thousand tons

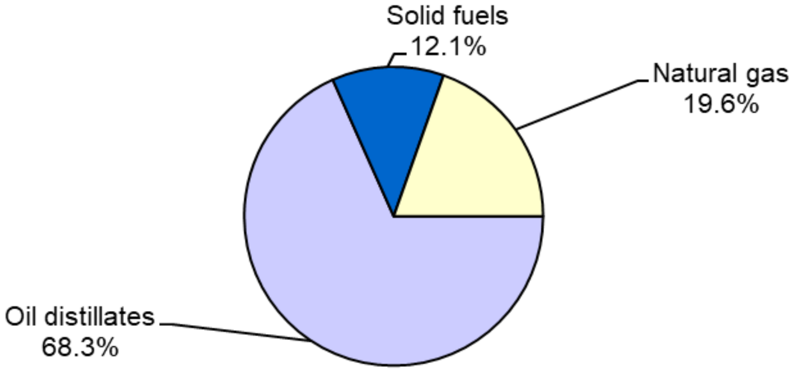
Fuel/Gas	SO_2	CO	NO_X
Total	**5.4**	**5.9**	**8.6**
Coal	0.2	0.1	0.1
Natural gas	0.0	1.9	1.7
Residual fuel oil	1.6	0.0	0.8
Diesel oil	0.1	0.0	0.6
Petroleum coke	0.7	0.1	1.8
Naphtha	0.6	0.1	1.4
LPG	0.0	0.0	0.9
Kerosene	0.0	0.0	0.1
Refuse-derived fuel (RDF) and hazardous waste	–	3.5	0.4
Other gas (petrochemistry)	0.0	0.0	0.4
Oil shale	2.2	0.2	0.6

NO$_X$ Emissions

NO$_X$ emissions in the manufacturing industries and construction decreased from approximately 16,000 tons in 2003 to approximately 8,600 tons in 2022, a decrease of 46.0%. This decrease was influenced by the decrease in the use of oil distillates and the increase in the use of natural gas.

The primary source of NO$_X$ emissions, throughout the years, was the combustion of residual fuel oil, however, its share in total emissions decreased from 51.8% in 2003 to 9.1% in 2022. As the share of residual fuel oil in total emissions decreased, the share of natural gas increased, and in 2022, it stood at 19.6%.

DIAGRAM 3.19A. NO$_x$ EMISSIONS
IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL
2022



Total
8.6 thousand tons

DIAGRAM 3.19B. NO$_x$ EMISSIONS
IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL
2003–2022

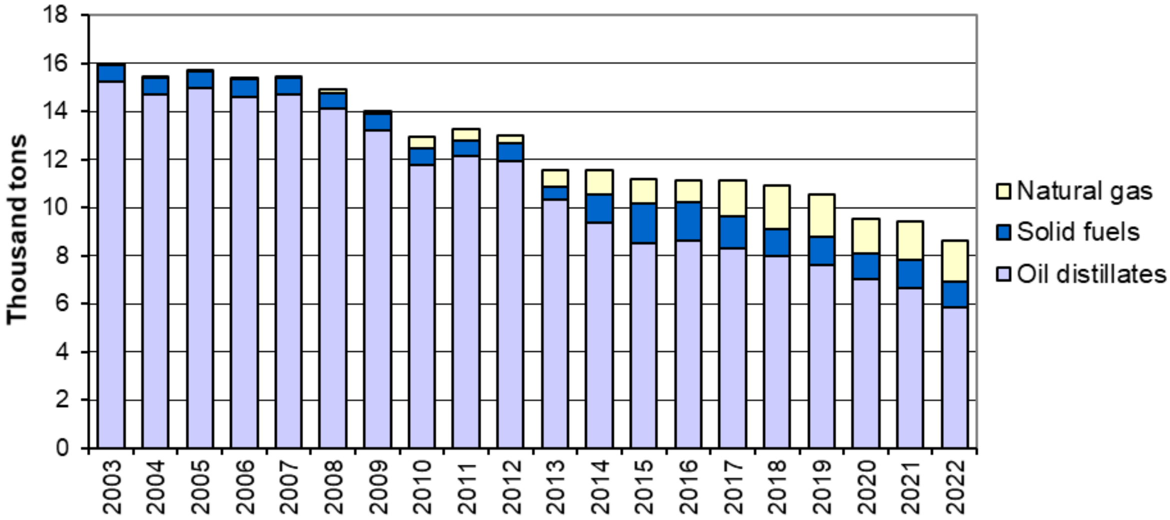
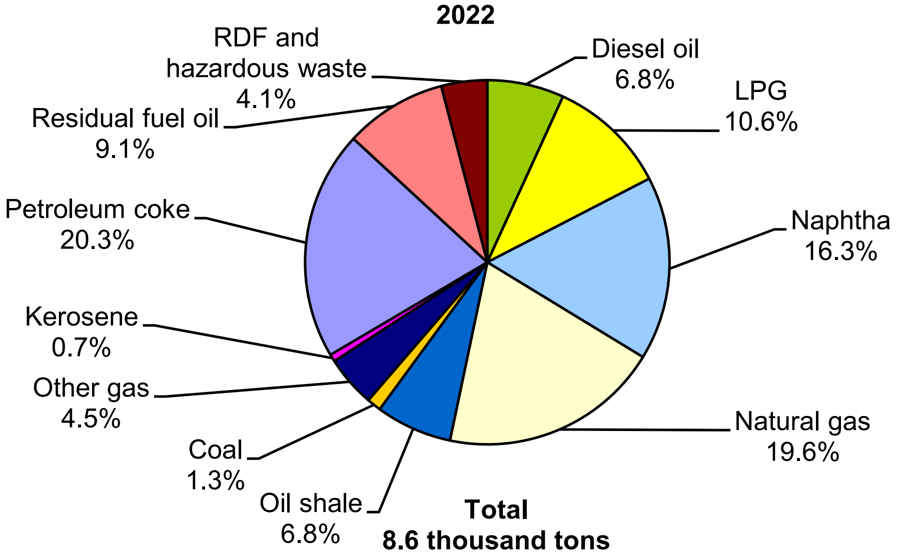


DIAGRAM 3.20 NO_x EMISSIONS
IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL
2022



SO$_2$ Emissions

SO$_2$ emissions in the manufacturing industries and construction decreased from approximately 45,800 tons in 2003 to approximately 5,400 tons in 2022, a decrease of 88.1%. This decrease was influenced by the decrease in the use of oil distillates and the increase in the use of natural gas, which has a very low sulfur content. In 2003, most of the SO$_2$ emissions came from combustion of residual fuel oil (84.6%), and, with the decrease in the use of residual fuel oil, its share in emissions decreased, standing at 30.1% in 2022. In that year, SO$_2$ emissions came primarily from combustion of various oil distillates (57.3%) and oil shale (39.7%).

DIAGRAM 3.21A. SO$_2$ EMISSIONS
IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL
2022

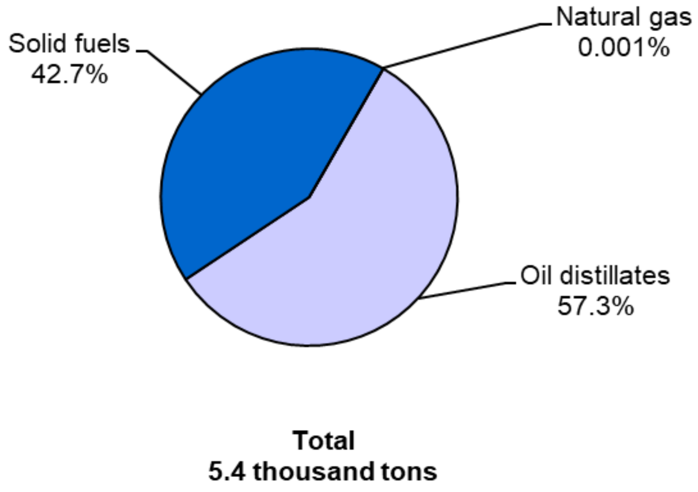


DIAGRAM 3.21B. SO$_2$ EMISSIONS
IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL
2003–2022

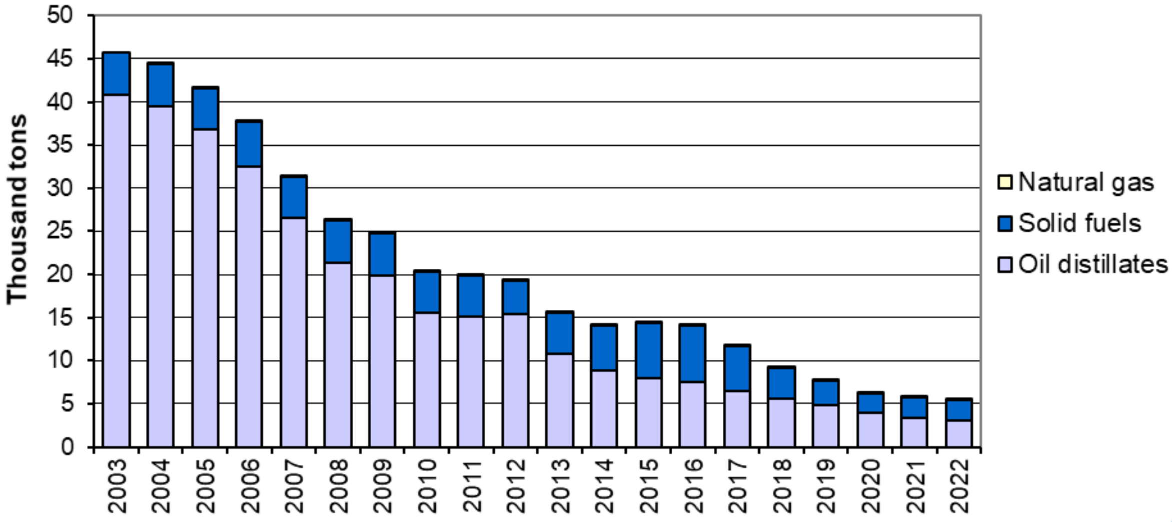
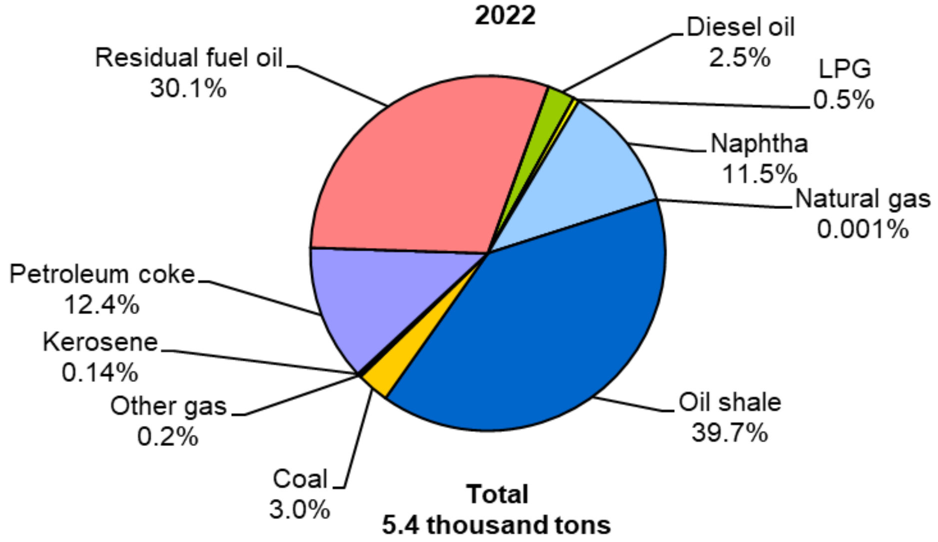


DIAGRAM 3.22 SO_2 EMISSIONS IN THE MANUFACTURING INDUSTRIES AND CONSTRUCTION, BY FUEL 2022



3.7. 1.A.3 Transport

3.7.1. Description of the Sector

The transport sector includes road transportation, railways, domestic aviation, and domestic water-borne navigation.

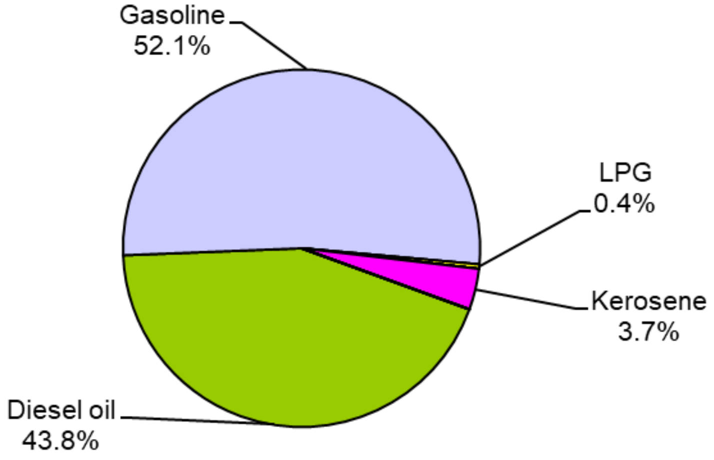
3.7.2. Fuel Consumption

Fuel consumption for transport consists primarily of consumption of gasoline and diesel oil for road transportation. Additional fuels are diesel oil for trains, kerosene (jet kerosene) for domestic aviation, and diesel oil for domestic water-borne navigation.

Between 2003 and 2022, energy consumption in transport increased by 31.6% – from 4.9 million toe to 6.5 million toe. This increase was mainly due to a 57.0% increase in the consumption of gasoline used to propel private vehicles.

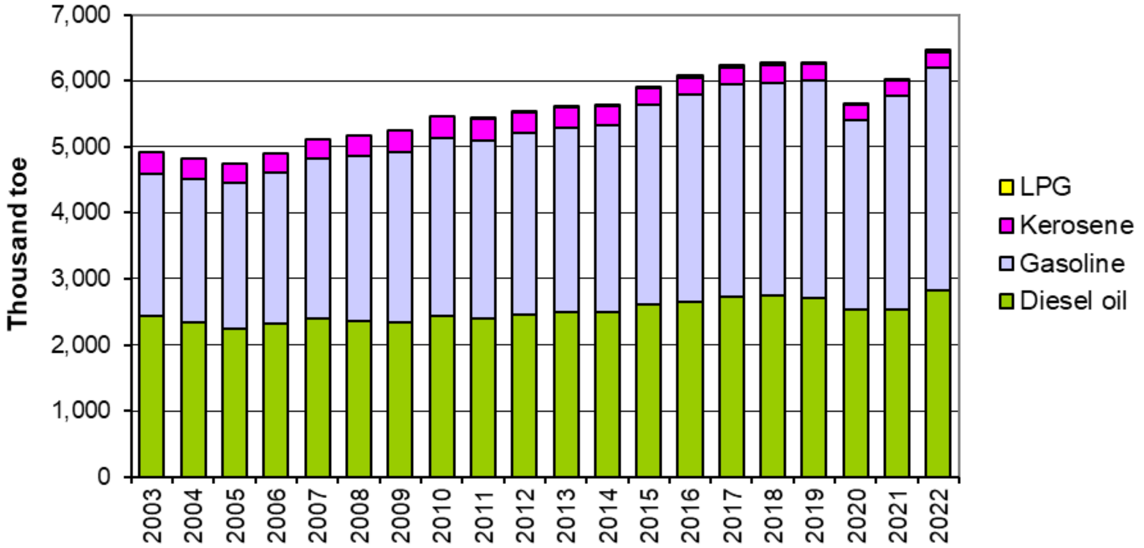
In 2022, fuel consumption consisted primarily of consumption of gasoline (52.1%) and diesel oil (43.8%).

DIAGRAM 3.23A. FUEL CONSUMPTION IN TRANSPORT, BY FUEL 2022



Total
6.5 million toe

DIAGRAM 3.23B. FUEL CONSUMPTION IN TRANSPORT, BY FUEL 2003–2022



3.7.3. Calculation Method

The emissions were calculated using the best available information found in Israel. When there was no available information, default values of emission factors were used. The emissions calculation was based on the emission factors from the IPCC 1996 guidelines, and the characteristics of the fuels (their sulfur content) were taken into account.

Following, are emission calculation methods adapted for use in Israel:

Two methods were used to calculate the emissions: a calculation based on fuel consumption and a calculation based on kilometers travelled.

Emissions of GHGs – CO_2, CH_4, and N_2O – were calculated based on fuel consumption and default factors from the IPCC 1996 guidelines.

Emissions of CO and NO_X from road transportation were calculated based on vehicle kilometers travelled and emission factors (grams per km). The emission factors were adjusted to conditions in Israel and are specified according to vehicle type, fuel, and vehicle age. Emissions of CO and NO_X from the other sources were calculated based on fuel consumption and default factors from the IPCC 1996 guidelines.

Furthermore, the emissions calculation based on the kilometers travelled was updated and improved by means of updated and detailed emission factors and by means of specific information about the vehicles and their kilometers travelled.

Table 3.17 Methods of Calculating GHG Emissions in Transport, by Source, Fuel, and Gas, 2022

Source	Fuel/Gas	SO_2	CO	NO_X	N_2O	CH_4	CO_2
Road transportation	Gasoline	T2 – CS	T3 – CS	T3 – CS	T1 –D	T1 – D	T1 – D
Road transportation	Diesel oil	T2 – CS	T3 – CS	T3 – CS	T1 – D	T1 – D	T1 – D
Road transportation	LPG	T2 – CS	T3 – CS	T3 – CS	T1 – D	T1 – D	T1 – D
Railways	Diesel oil	T2 – CS	T1–D	T1 – D	T1 – D	T1 – D	T1 – D
Domestic aviation	Jet kerosene	T2 – CS	T1–D	T1 – D	T1 – D	T1 – D	T1 – D
Domestic water-borne navigation	Diesel oil	T2 – CS	T1–D	T1 – D	T1 – D	T1 – D	T1 – D

T1 = tier 1, T2 = tier 2, T3 = tier 3, CS= Country-specific, D= IPCC default, NE = not estimated

Following, are the implied emission factors of the various gases. From these factors, it is possible to make a comparison between the fuels and learn about their impact on emissions.

Table 3.18 Implied Emission Factors of Direct GHGs in Transport, by Fuel and Gas, 2022

Tons of CO_2eq per thousand toe of fuel, unless otherwise stated

Fuel/Gas	N_2O	CH_4	Tons of CO_2 per toe of fuel
Gasoline	6.66	23.45	2.87
Diesel oil	6.66	5.86	3.07
LPG	6.66	5.86	2.61
Jet kerosene	22.19	0.59	2.96

Table 3.19 Implied Emission Factors of Indirect GHGs in Transport, by Fuel and Gas, 2022

Tons per thousand toe of fuel

Fuel/Gas	SO_2	CO	NO_X
Gasoline	0.02	31.68	0.91
Diesel oil	0.02	3.21	8.74
LPG	0.05	7.33	1.05
Jet kerosene	5.63	4.19	12.56

3.7.4. GHG Emissions, by Fuel and Source

In 2022, total GHG emissions in transport stood at 19.3 million tons of CO_2eq, which was 30.7% of all emissions in the energy sector.

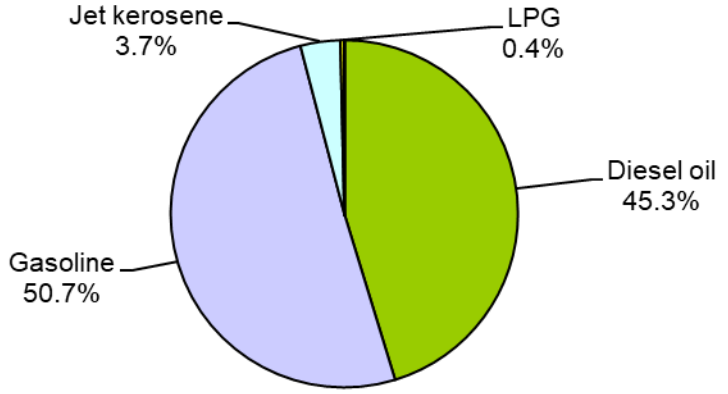
Table 3.20 GHG Emissions in Transport, by Fuel and Gas, 2022

Thousand tons of CO2eq

Fuel/Gas	Total	N_2O	CH_4	CO_2
Total	**19,287**	**47**	**96**	**19,145**
Gasoline	9,771	22	79	9,669
Diesel oil	8,731	19	17	8,696
LPG	69	0.2	0.2	69
Jet kerosene	716	5	0.1	710

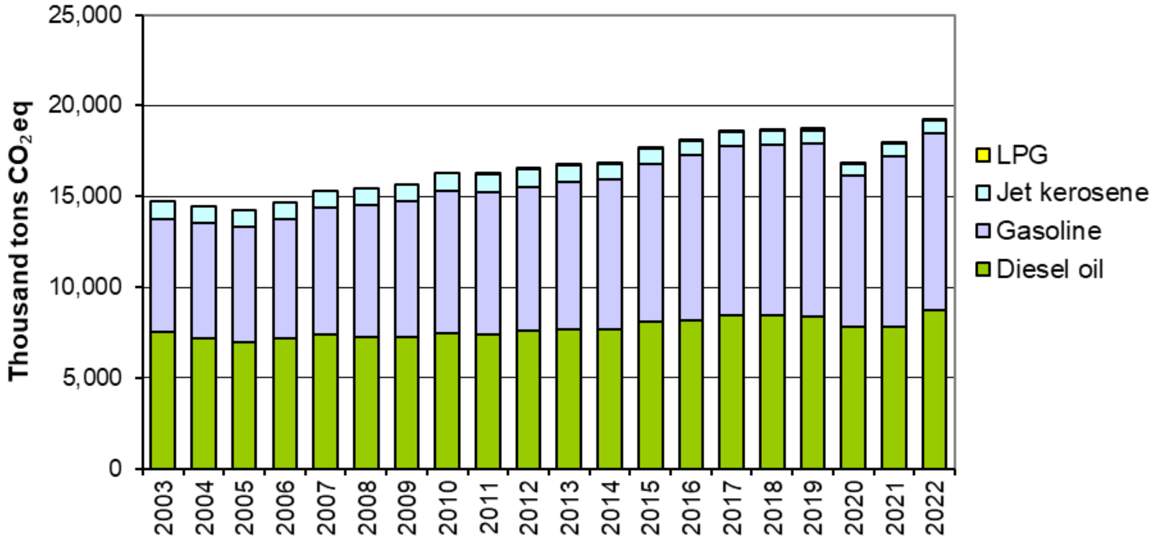
Emissions in transport came primarily from gasoline and diesel oil. From 2003 to 2022, emissions increased by 31.0% and between 2021 and 2022 they increased by 7.4%.

DIAGRAM 3.24A. GHG EMISSIONS IN TRANSPORT, BY FUEL 2022



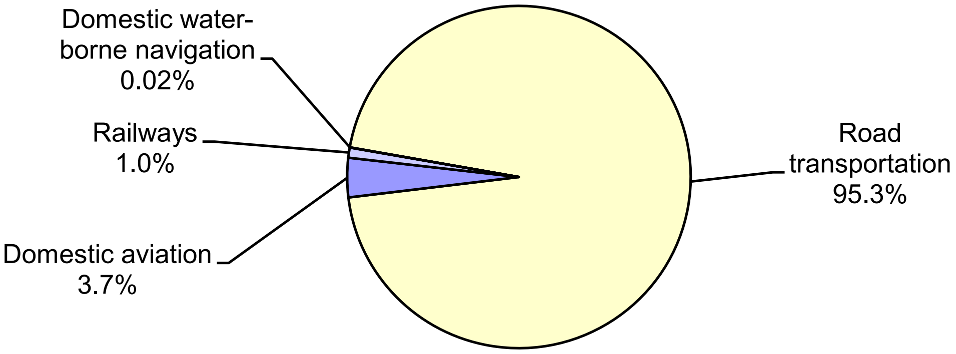
Total
19.3 million tons CO_2eq

DIAGRAM 3.24B. GHG EMISSIONS IN TRANSPORT, BY FUEL 2003–2022



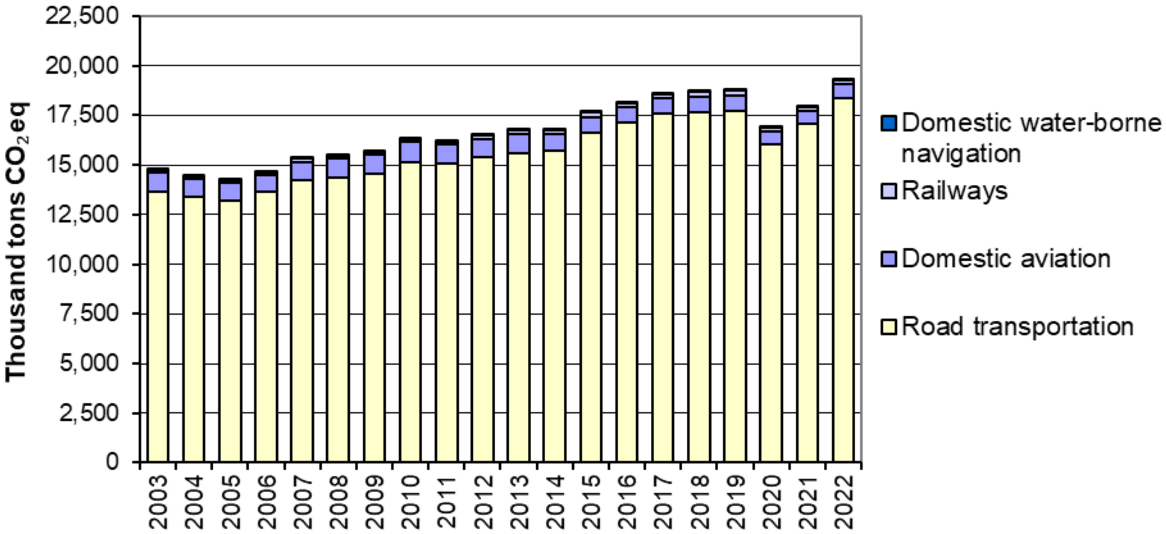
The vast majority of emissions came from road transportation: private vehicles, trucks, buses, etc. In 2022, the share of road transportation emissions out of total transport emissions was 95.3%.

DIAGRAM 3.25A. GHG EMISSIONS IN TRANSPORT, BY SOURCE
2022



Total
19.3 million tons CO_2eq

DIAGRAM 3.25B. GHG EMISSIONS IN TRANSPORT, BY SOURCE
2003–2022



3.7.5. Non-GHG Emissions

In 2022, approximately 30,900 tons of NO_X, 116,900 tons of CO, and 1,500 tons of SO_2 were emitted in transport. Most of the emissions of NO_X (80.3%) and CO (97.0%) came from land transport.

Table 3.21 Non-GHG Emissions in Transport, by Fuel and Gas, 2022

Thousand tons

Fuel/Gas	SO_2	CO	NO_X
Total	**1.5**	**116.9**	**30.9**
Gasoline	0.1	106.6	3.1
Diesel oil	0.1	9.1	24.8
LPG	0.0	0.2	0.03
Jet kerosene	1.4	1.0	3.0

NO_X Emissions

NO_X emissions in transport decreased from approximately 76,100 tons in 2003 to approximately 30,900 tons in 2022, a decrease of 59.4%. This decrease was primarily due to improvements in combustion engines and emission reduction systems in vehicles. Between 2003 and 2022, emissions from gasoline and diesel oil decreased by 86.3% and 50.2%, respectively.

Throughout the years, most of the NO_X emissions came from combustion of diesel oil, and the share of diesel oil in these emissions increased from 65.3% in 2003 to 80.2% in 2022.

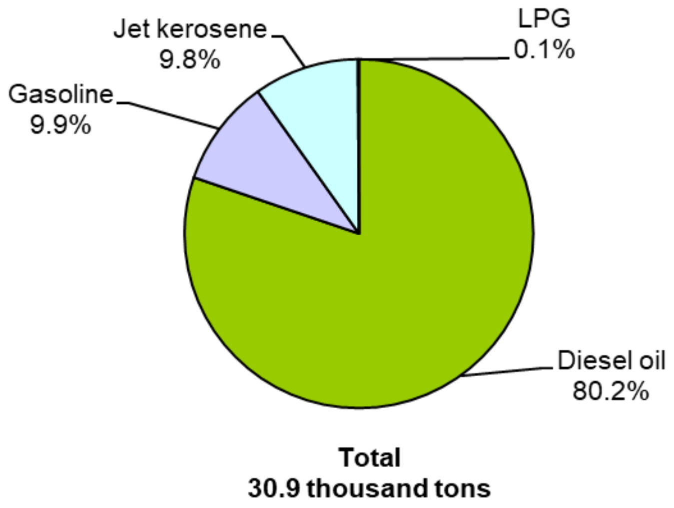


DIAGRAM 3.26A. NO_x EMISSIONS IN TRANSPORT, BY FUEL 2022

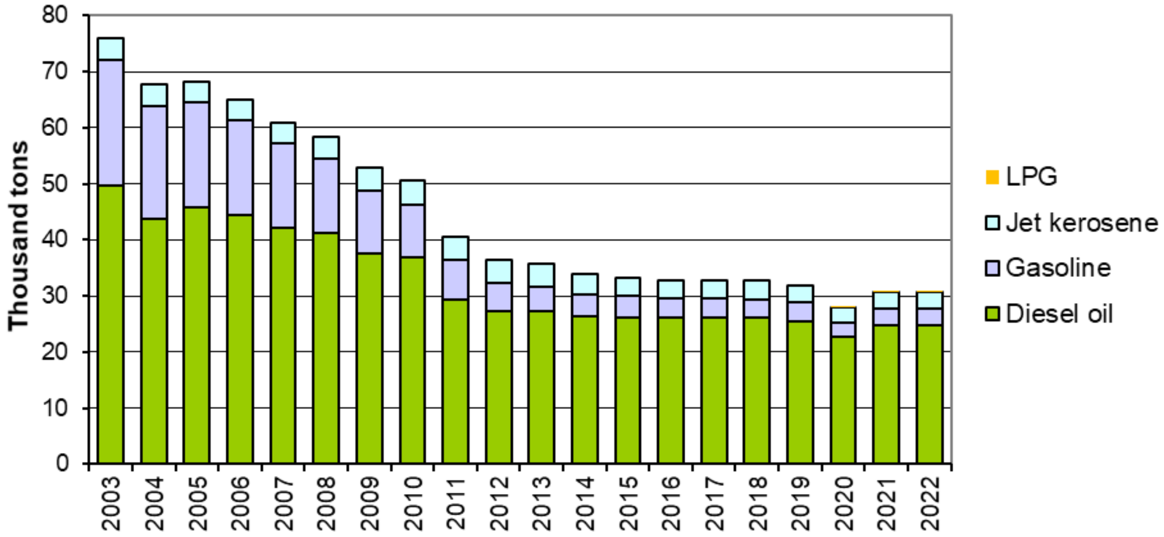
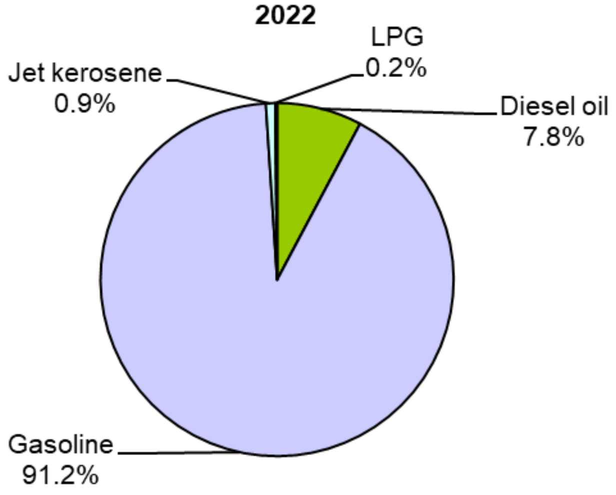


DIAGRAM 3.26B. NO_x EMISSIONS IN TRANSPORT, BY FUEL 2003–2022

CO Emissions

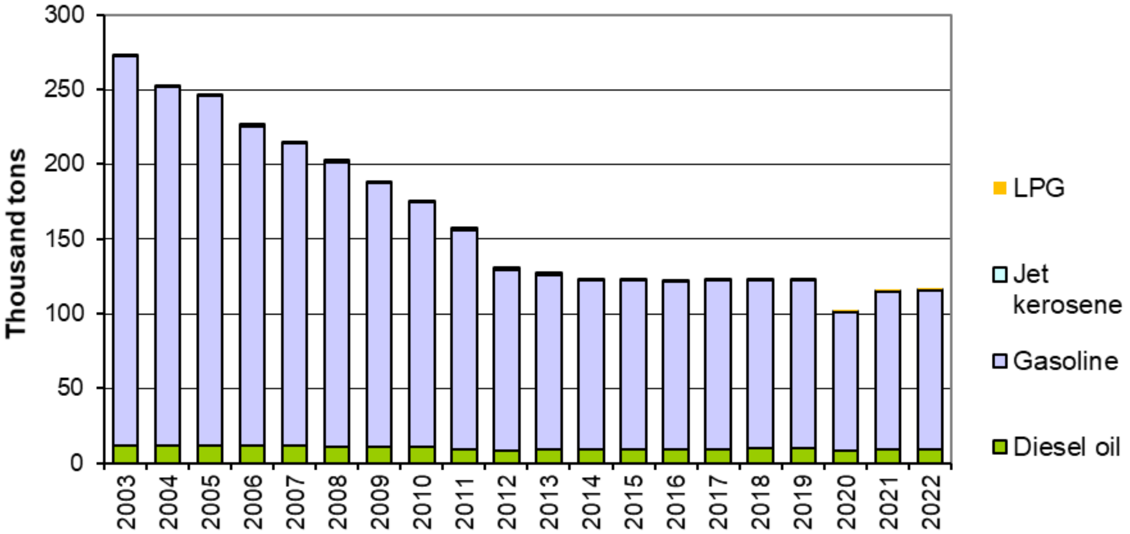
CO emissions in transport decreased from approximately 273,600 tons in 2003 to approximately 116,900 tons in 2022, a decrease of 57.3%. This decrease was primarily due to improvements in combustion engines and emission reduction systems in vehicles. Emissions from gasoline and diesel oil decreased between 2003 and 2022 by 59.1% and 22.6%, respectively. In 2022, the vast majority of emissions (91.2%) came from gasoline combustion.

DIAGRAM 3.27A. CO EMISSIONS IN TRANSPORT, BY FUEL
2022



Total
116.9 thousand tons

DIAGRAM 3.27B. CO EMISSIONS IN TRANSPORT, BY FUEL
2003–2022



3.8. 1.A.4 Other Sectors

3.8.1. Description of the Sectors

The other sectors include trade, agriculture, the residential sector, and sectors not elsewhere classified (n.e.c.).

3.8.2. Fuel Consumption

Fuel consumption in trade, agriculture, the residential sector, and n.e.c. was included. In these sectors, the highest consumption is that of LPG, followed by residual fuel oil, diesel oil, and kerosene. (There is minimal consumption of natural gas.)

For each sector, estimates of fuel consumption were obtained, and emissions were calculated based on the assessments of fuel consumption in each sector. The consumption assessments are not precise, and over the years, an inexplicable fluctuation in the amounts of fuel consumed has been observed.

Between 2003 and 2022, energy consumption in trade, agriculture, and the residential sector almost unchanged and decreased from approximately 420,000 toe to approximately 410,000 toe, a decrease of 2.9%. During this period there was a decrease in the consumption of residual fuel oil (56.8%) and diesel oil (76.2%), that can be attributed to the transition to consumption of electricity in place of energy produced from combustion of residual fuel oil and diesel oil and changes in the consumption requirements in the economy. In 2022, there is a significant increase in liquefied petroleum gas consumption, following an update of consumption estimates through a survey conducted by the Ministry of Energy.

The fuel consumption data in these sectors are fluctuating following improvements and updates in the fuel consumption estimates.

In 2022, the fuel consumption consisted mainly of LPG (89.3%), with low rates of residual fuel oil (5.1%), kerosene (2.5%), and diesel oil (3.1%).

DIAGRAM 3.28A. FUEL CONSUMPTION IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL
2022

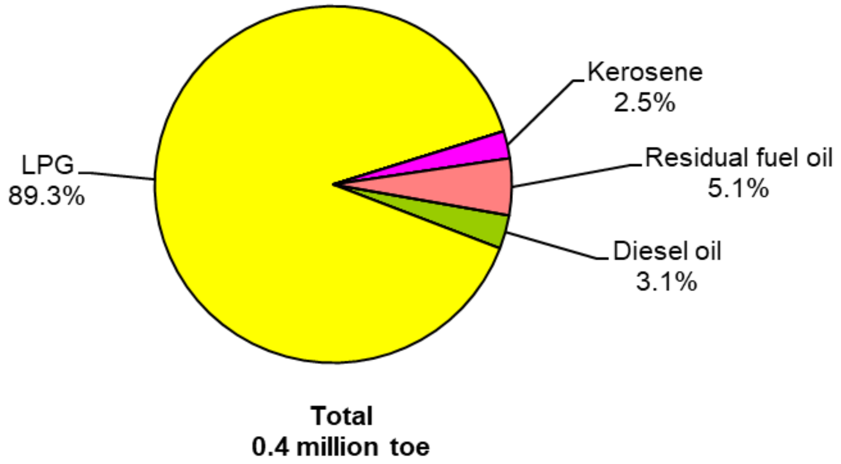
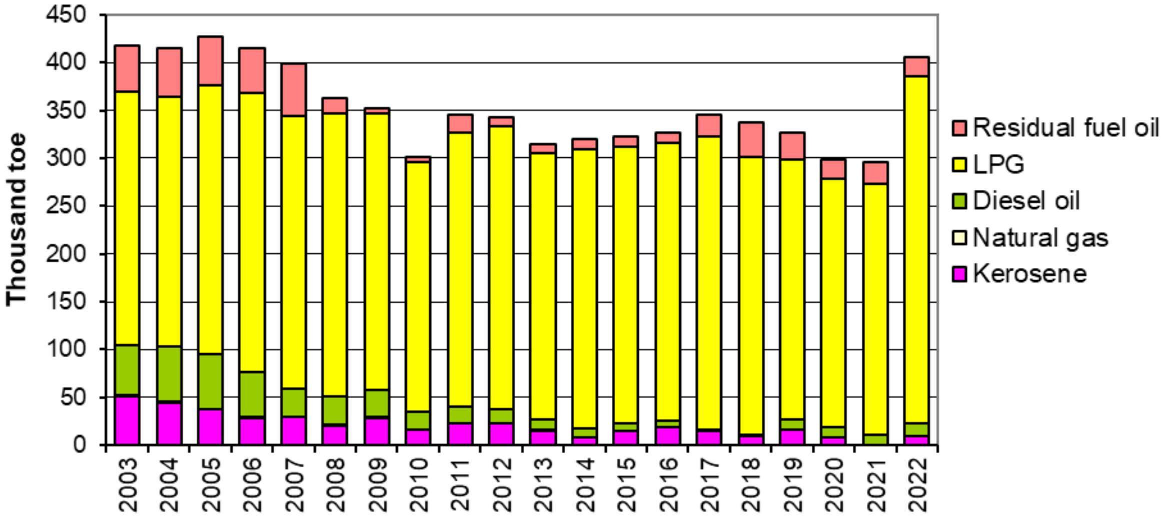


DIAGRAM 3.28B. FUEL CONSUMPTION IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL
2003–2022



3.8.3. Calculation Method

The emissions were calculated based on default values of the emission factors from the IPCC 1996 guidelines, and the characteristics of the fuels (their sulfur content) were taken into account. In the IPCC 1996 guidelines there are emission factors for each of the sectors (trade, agriculture, and the residential sector), and the emissions were calculated based on assessments of fuel consumption in each sector.

Emissions of SO_2 were calculated based on the quantities of the fuels and their sulfur content.

Table 3.22 Methods of Calculating GHG Emissions in Trade, Agriculture, and the Residential Sector, by Fuel and Gas, 2022

Fuel/Gas	SO_2	CO	NO_X	N_2O	CH_4	CO_2
LPG	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Residual fuel oil	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Diesel oil	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Kerosene	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D
Natural gas	T2 – CS	T1 – D	T1 – D	T1 – D	T1 – D	T1 – D

T1 = tier 1, T2 = tier 2, CS = Country-specific, D = IPCC default

3.8.4. GHG Emissions, by Fuel

In 2022, total GHG emissions in trade, agriculture, and the residential sector stood at 1.1 million tons of CO_2eq, which was 1.7% of all emissions in the energy sector.

Table 3.23 GHG Emissions in Trade, Agriculture, and the Residential Sector, by Fuel and Gas, 2022

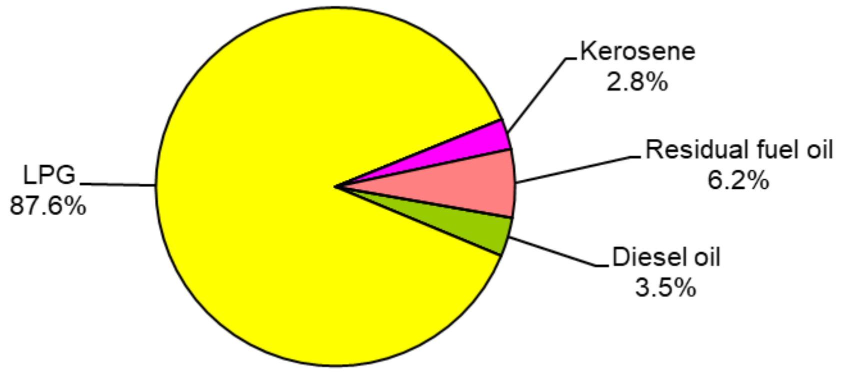
Thousand tons of CO_2eq

Fuel/Gas	Total	N_2O	CH_4	CO_2
Total	**1,090.5**	**2.7**	**4.8**	**1,083.1**
LPG	954.9	2.4	4.3	948.2
Residual fuel oil	67.1	0.1	0.2	66.8
Diesel oil	38.4	0.1	0.1	38.1
Kerosene	30.1	0.1	0.1	29.9
Natural gas	0.0	0.0	0.0	0.0

In 2022, emissions in trade, agriculture, and the residential sector came primarily from LPG (87.6%).

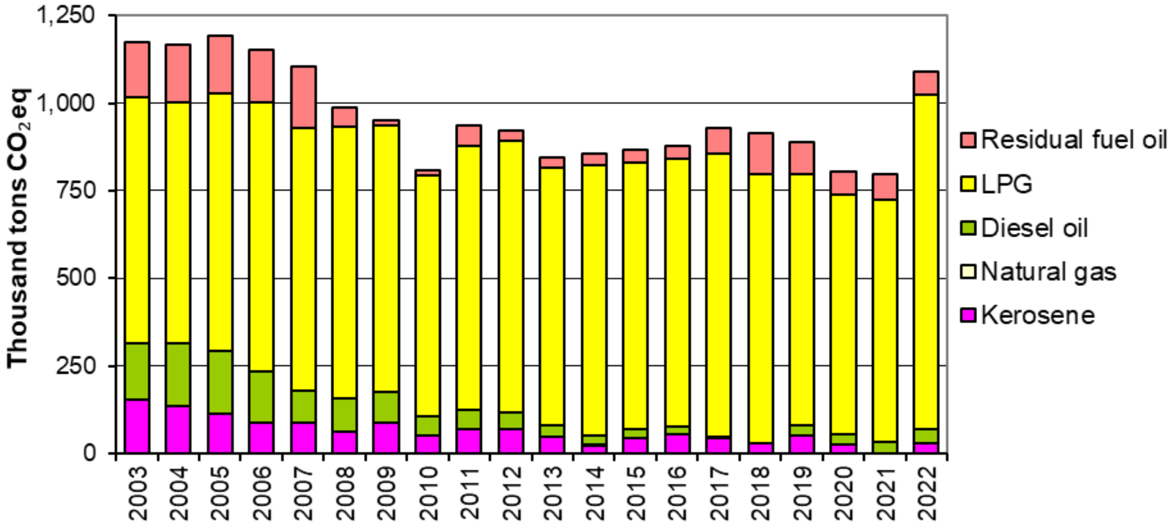
Between 2003 and 2022, emissions decreased by 7.0%. The share of residual fuel oil, kerosene, and diesel oil in emissions has decreased over the years. Whereas in 2003 it stood at 40.1%, in 2022, it decreased to 12.4%.

DIAGRAM 3.29A. GHG EMISSIONS IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL 2022



Total
1.1 million tons CO_2eq

DIAGRAM 3.29B. GHG EMISSIONS IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL 2003–2022



3.8.5. Non-GHG Emissions

In 2022, approximately 1,700 tons of NO_X, 300 tons of CO, and 500 tons of SO_2 were emitted in trade, agriculture, and the residential sector.

NO_X and CO emissions came primarily from LPG (about 89%), and SO_2 emissions came primarily from residual fuel oil (73.5%).

Table 3.24 Non-GHG Emissions in Trade, Agriculture, and the Residential Sector, by Fuel and Gas, 2022

Thousand tons

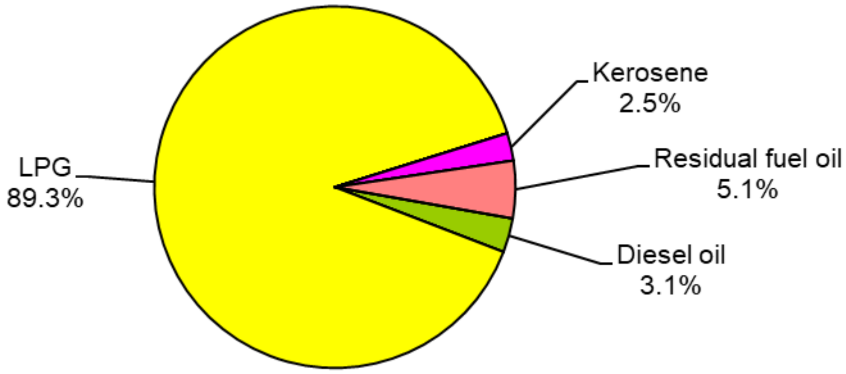
Fuel/Gas	SO_2	CO	NO_X
Total	**0.5**	**0.3**	**1.7**
LPG	0.1	0.3	1.5
Residual fuel oil	0.4	0.02	0.1
Diesel oil	0.02	0.01	0.1
Kerosene	0.01	0.01	0.04

NO$_X$ Emissions

NO$_X$ emissions in trade, agriculture, and the residential sector slightly decreased from approximately 1,800 tons in 2003 to approximately 1,700 tons in 2022, a decrease of 2.9%, due to a decrease in the consumption of residual fuel oil and diesel oil.

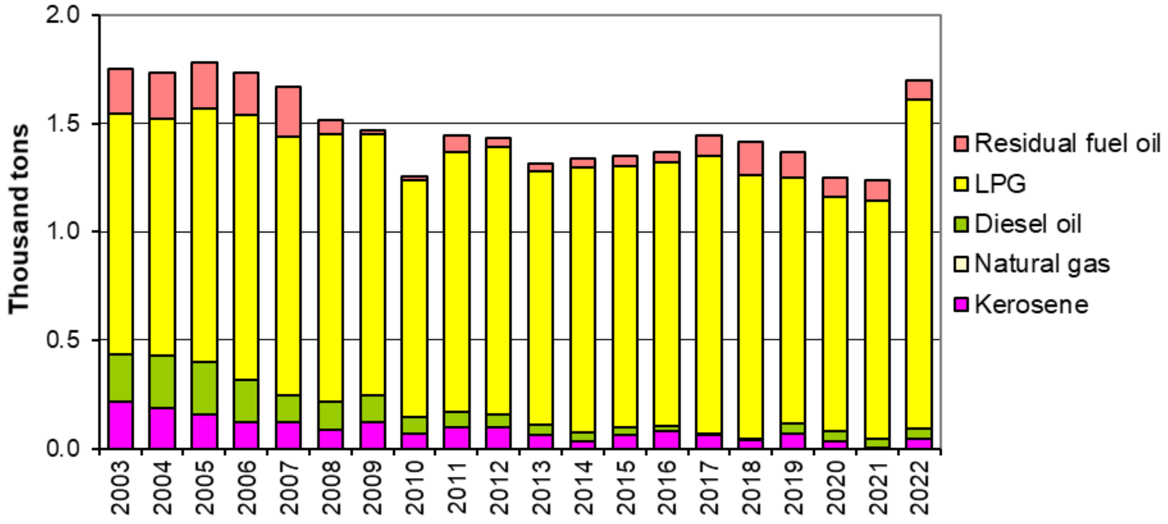
The primary source of NO$_X$ emissions, throughout the years, was the combustion of LPG, which is also the primary source of energy. In 2003, 36.3% of the emissions came from the combustion of residual fuel oil, kerosene, and diesel oil, compared to 10.7% in 2022.

DIAGRAM 3.30A. NO$_x$ EMISSIONS IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL 2022



Total
1.7 thousand tons

DIAGRAM 3.30B. NO$_x$ EMISSIONS IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL 2003–2022



SO_2 Emissions

SO_2 emissions in trade, agriculture, and the residential sector decreased from approximately 2,300 tons in 2003 to approximately 500 tons in 2022, a decrease of 78.7%, primarily due to a decrease in the consumption of residual fuel oil, whose sulfur content is relatively high, and a decrease in the standards of the sulfur content of residual fuel oil and diesel oil. The primary source of SO_2 emissions, over the years, was the combustion of residual fuel oil, and in 2022 it accounted for 73.5% of these emissions.

DIAGRAM 3.31A. SO_2 EMISSIONS IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL 2022

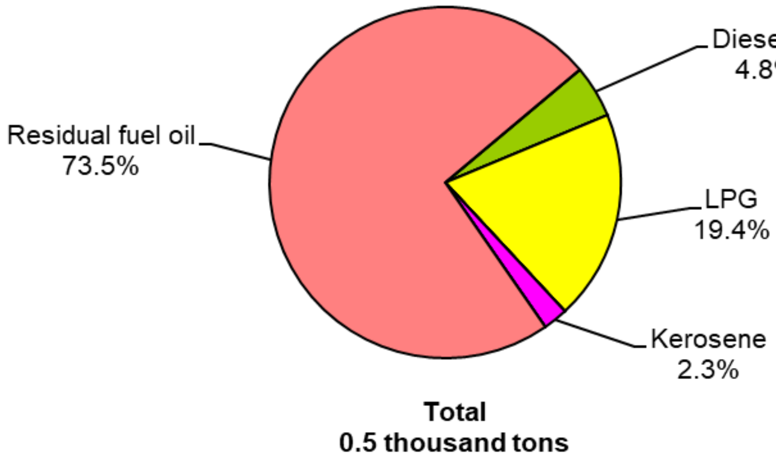
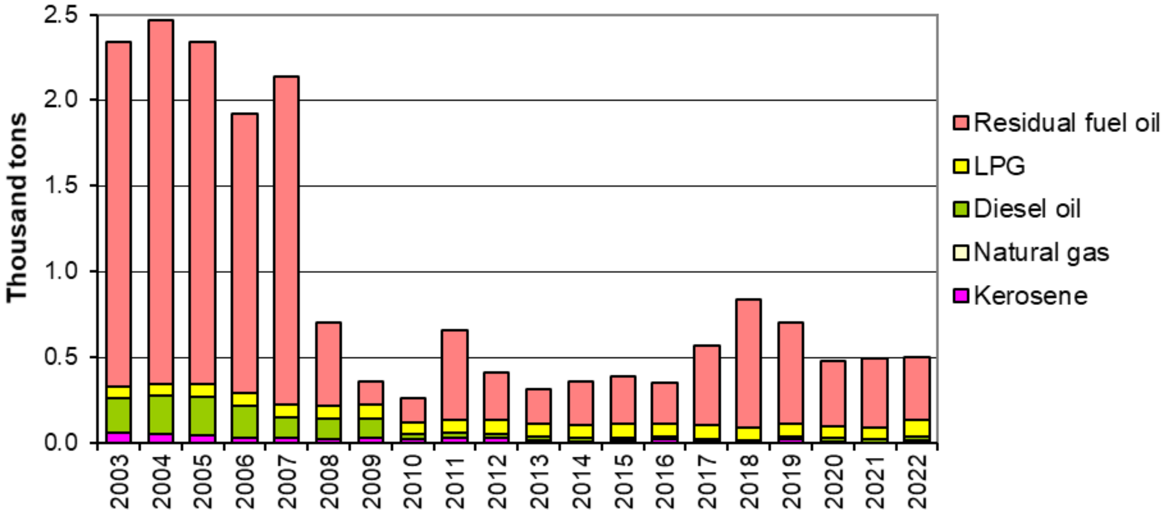


DIAGRAM 3.31B. SO_2 EMISSIONS IN TRADE, AGRICULTURE, AND THE RESIDENTIAL SECTOR, BY FUEL 2003–2022



3.9. 1.B Fugitive emissions from fuels

the calculation of fugitive emissions is not included in the inventory. The method of calculation is in the development process and a review of the calculation methods used worldwide is being conducted to select the calculation methods that are appropriate for Israel.

3.10. 1.C CO_2 transport and storage

There is no CO_2 transportation and storage activity in Israel.

3.11. Future Improvements

Fuel Consumption

The information on the total amount of fuel consumed in Israel is known to the authorities. Furthermore, in the sectors where fuel consumption is highest – energy and transport – there is reliable information on fuel consumption. However, in the manufacturing industries and construction, in domestic aviation, in domestic water-borne navigation, and in trade, agriculture, and the residential sector, the data on fuel consumption are based on assessments, which have undergone modifications over the years. There is a need to improve the data pertaining to these sectors.

The CBS's Agriculture, Environment, and Energy Sector plans to calculate estimates of energy consumption, by industry. These will be based on administrative sources (the reports to the PRTR), on data from surveys (the Environmental Quality in Industry Survey), and on input-output tables.

The emissions from the following fuels were not calculated and should be in the future:

- Biogas that is used to generate electricity and as a fuel in manufacturing and is combusted by means of a flare in landfills;
- Combustion of biomass of blocks of coal and wood for heating.

The assumption is that the extent of emissions from these sources is negligible.

Fugitive Emissions

Calculations of fugitive emissions are not included in the inventory, and, as mentioned earlier, the method of their calculation is in the development process. An examination of the calculation methods existing internationally is being carried out in order to select the calculation methods appropriate for Israel.

NMVOC Emissions

Calculation of emissions of NMVOCs was discontinued in 2011, in the absence of updated emission factors for emissions from transport. A request for estimates of these emissions was sent to the Ministry of Environmental Protection.

4. Chapter 4: Industrial Processes and Product Use

4.1. Background

Greenhouse gas emissions in Israel from industrial processes and product use originate from the mineral industry (cement production, lime production, and use of sodium carbonate), the chemical industry (production of various products, such as nitric acid), and the use of substitute products to prevent depletion of the ozone layer (fluorine-containing gases used for air conditioning and refrigeration [HFCs], fire protection systems, etc.).

4.2. Overview of the Emissions

4.2.1 Total Emissions

In 2022, total GHG emissions from industrial processes and product use amounted to 7.0 million metric tons of CO_2eq, which accounted for 8.6% of total GHG emissions.

Emissions from industrial processes and product use originate from two main sources: (a) product uses as substitutes for ozone-depleting substances (71.8%), of which gases for air conditioning and refrigeration systems (HFCs) account for the main part (66.3%); and (b) the mineral industry (27.5%), of which cement production accounts for the major part.

Table 4.1 GHG Emissions From Industrial Processes and Product Use, by Source, 2022

Thousands of Tons of CO_2eq

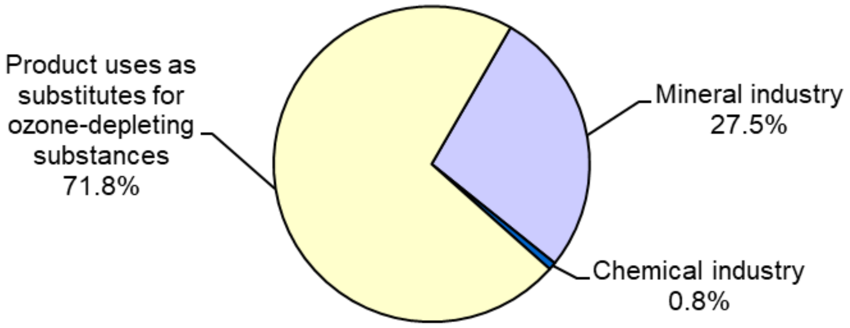
Emission Sources	Total	HFCs PFCs SF_6	N_2O	CH_4	CO_2
2. Industrial Processes and Product Use	**6,968.4**	**5,000.6**	**50.1**	**4.5**	**1,913.2**
A. Mineral Industry	1,913.2	NA	NA	NA	1,913.2
B. Chemical Industry	54.6	NO, NA	50.1	4.5	NO, NA
C. Metal Industry	NO	IE	NA	NA/NO	NO
D. Non-Energy Products from Fuels and Solvent Use	NE	NA	NE	NE	NE
E. Electronics Industry	IE, NO	IE, NO	NA	NA, NO	NA
F. Product Uses as Substitutes for Ozone-Depleting Substances	5,000.6	5,000.6	NA	NA	NA
G. Other product manufacture and use	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO

NE = not estimated, NA = not applicable, NO = not occurring, IE = included elsewhere

4.2.2. Trends

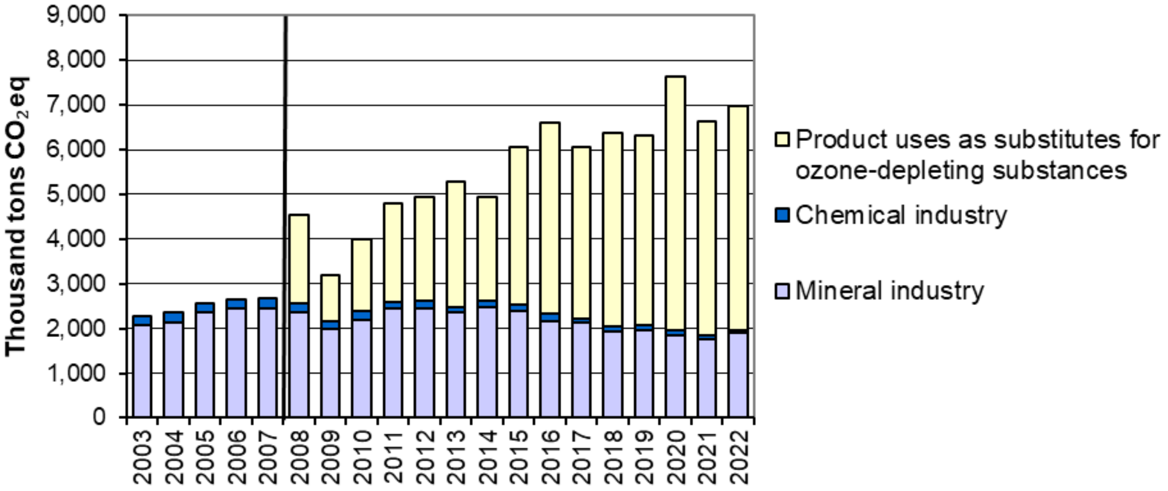
Emissions from industrial processes and product use increased by 53.9% between 2008 (the start of calculating emissions from product uses as substitutes for ozone-depleting substances) and 2022. Between 2021 and 2022, these emissions increased by 5.3%. The primary source of the emissions increase in 2022 was the use of HFCs: 66.3% of all emissions in this sector.

DIAGRAM 4.1A. GHG EMISSIONS FROM INDUSTRIAL PROCESSES AND PRODUCT USE, BY SOURCE 2022



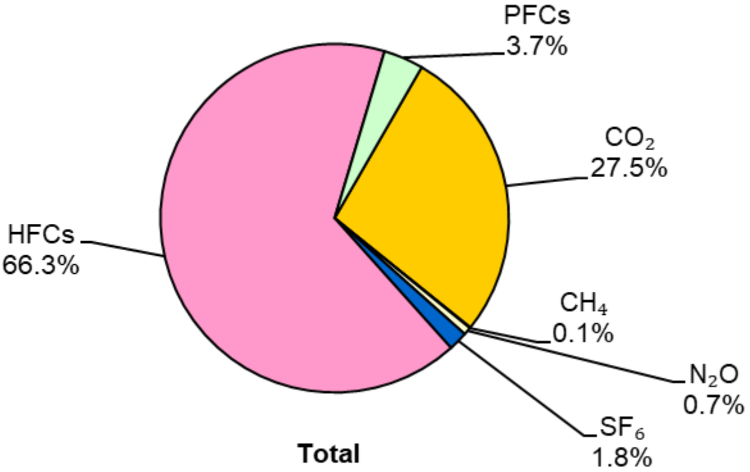
Total
7.0 million tons CO_2eq

DIAGRAM 4.1B. GHG EMISSIONS FROM INDUSTRIAL PROCESSES AND PRODUCT USE,(1) BY SOURCE 2003–2022



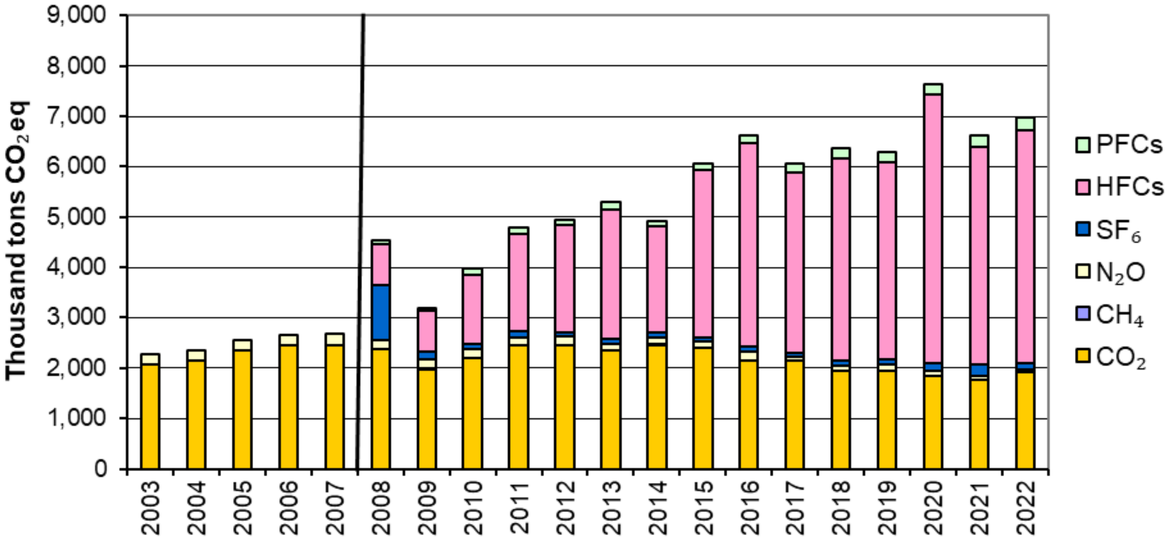
(1) Calculation of emissions from the use of substitutes for ozone-depleting substances began in 2008.

DIAGRAM 4.2A. GHG EMISSIONS FROM INDUSTRIAL PROCESSES AND PRODUCT USE, BY GAS 2022



Total
7.0 million tons CO$_2$eq

DIAGRAM 4.2B. GHG EMISSIONS FROM INDUSTRIAL PROCESSES AND PRODUCT USE,(1) BY GAS 2003–2022



(1) Calculation of emissions from the use of substitutes for ozone-depleting substances began in 2008.

4.2.3 Description of the Emission Sources

Mineral Industry

CO_2 is emitted from the mineral industry in the production of cement, lime, and glass. The emission rates depend on their production quantities. Over the years, the level of emissions has fluctuated according to the production quantities of these substances.

In 2022, emissions from the mineral industry totaled approximately 1.9 million tons of CO_2eq, which accounted for 27.5% of all emissions from industrial processes and product use. The vast majority of emissions from the mineral industry originated from cement production (1.8 million tons of CO_2eq).

Chemical Industry

N_2O is emitted from the chemical industry in the production of nitric acid (HNO_3). Over the years, the level of emissions has fluctuated according to the production and consumption quantities of this substance.

In 2017, there was a sharp decrease in the emissions due to a reduction in HNO_3 production. In 2022, emissions were 50,080 tons of CO_2eq (about third of the emissions in 2003), accounting for 0.7% of all emissions from industrial processes and product use. CH_4, which is emitted in small quantities from chemical production, accounted for less than 0.1% of total emissions from industrial processes and product use.

Product Uses as Substitutes for Ozone-Depleting Substances

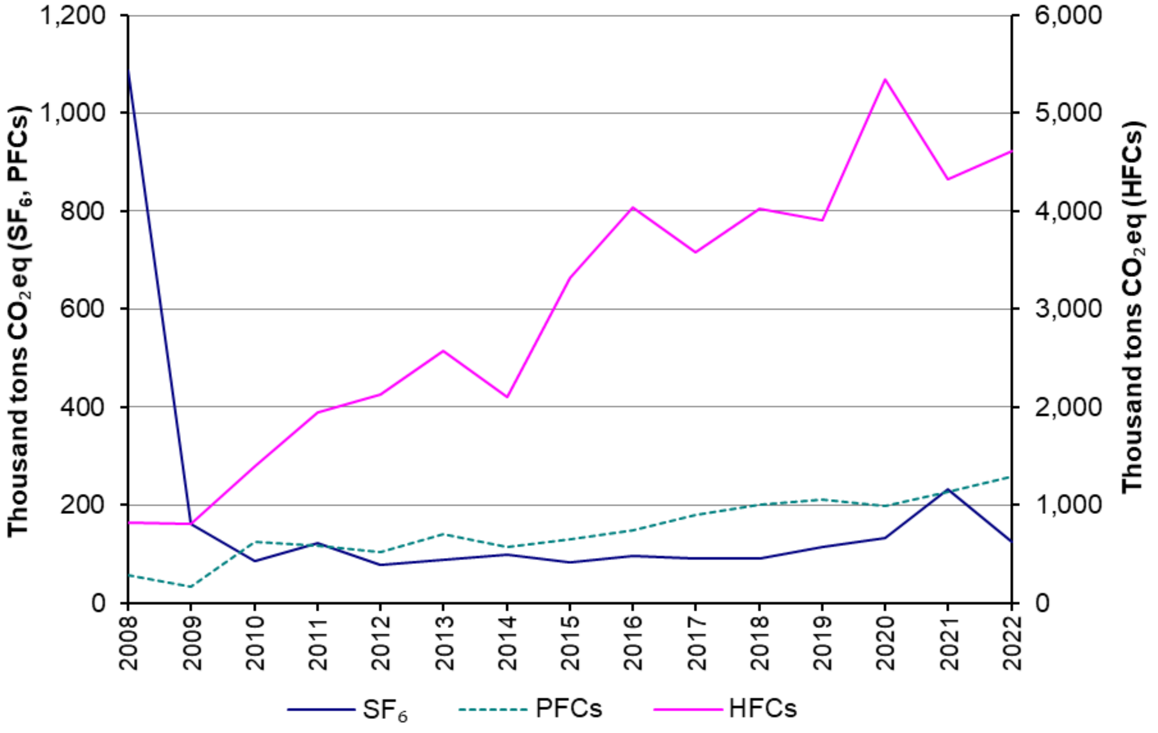
Emissions from product uses as substitutes for ozone-depleting substances have been calculated since 2008. Emissions from the use of these products have steadily increased over the years due to the discontinuation of CFC refrigerants and an increase in demand for refrigerants.

The main gases in emissions from this source were HFCs, mainly in air conditioning and refrigeration systems. In 2022, they accounted for approximately 66.3% (4.6 million tons of CO_2eq) of all emissions from industrial processes and product use. From 2008 to 2022, HFC emissions increased by approximately 6 times. In 2022, there was a 6.8% increase in these gas emissions. Changes in emissions were mainly influenced by changes in the import quantities of these gases over the years. Import quantities were influenced by regulatory decisions and limitations on imports, and by importers’ economic and operational considerations.

Emissions from the use of PFCs in 2022 were approximately 3.7% (0.26 million tons of CO_2eq) of all emissions from industrial processes and product use, 4.5 times more than in 2008.

In 2008, emissions from SF_6 use were approximately 1.1 million tons of CO_2eq. Due to the transition to substitute gases, emissions decreased substantially, to 0.12 million tons of CO_2eq in 2022, accounting for 1.8% of all emissions from industrial processes and product use.

DIAGRAM 4.3 GHG EMISSIONS FROM PRODUCT USES AS SUBSTITUTES FOR OZONE-DEPLETING SUBSTANCES 2008–2022



4.3. Calculation Method and Data Sources

Emissions from industrial processes and product usage originate from a wide range of processes and uses and include various gases. Emissions were calculated based on the availability of data and information. Where specific data were not available, default factors were used according to IPCC guidelines and multiplied by activity data (production quantity or usage quantity). In some sources, emissions were calculated based on measurements or specific calculations provided by active companies in the field. The use of substitute products to prevent depletion of the ozone layer required the calculation of emissions using models tailored to Israel.

Table 4.2 Methods of Calculating GHG Emissions From Industrial Processes and Product Use, by Source and Gas, 2022

Source/Emission Gas	SF_6	PFCs	HFCs	N_2O	CH_4	CO_2
2. Industrial Processes and Product Use						
A. Mineral Industry	NA	NA	NA	NA	NA	T1, T2, D
1. Cement Production	NA	NA	NA	NA	NA	T1, D
2. Lime Production	NA	NA	NA	NA	NA	T1, D
3. Glass Production	NA	NA	NA	NA	NA	T2, D
4. Other Process Use of Carbonates	NA	NA	NA	NA	NA	T1, D
B. Chemical Industry	NO, NA	NO, NA	NO, NA	T3, D	T1, D	NO, NA
1. Ammonia Production	NA	NA	NA	NO	NO	NO
2. Nitric Acid Production	NA	NA	NA	T3	NA	NA
3. Adipic Acid Production	NA	NA	NA	NO	NA	NO
4. Caprolactam, Glyoxal, and Glyoxylic Acid Production	NA	NA	NA	NO	NA	NO
5. Carbide Production	NA	NA	NA	NA	NO	NO
6. Titanium Dioxide Production	NA	NA	NA	NA	NA	NO
7. Sodium Carbonate Production	NA	NA	NA	NA	NA	NO
8. Petrochemical and Carbon Black Production	NA	NA	NA	NA	T1, D	NO
9. Fluorochemical Production	NO	NO	NO	NA	NA	NA
10. Other	NO	NO	NO	NO	NO	NO
C. Metal Industry	NO	NA	T1, IE	NA	NA/NO	NO
1. Iron and Steel Production	NA	NA	NA	NA	NO	NO
2. Ferroalloys Production	NA	NA	NA	NA	NO	NO
3. Aluminium Production	NO	NO	NA	NA	NA	NO
4. Magnesium Production and Casting	NO	NO	IE	NA	NA	NO
5. Lead Production	NA	NA	NA	NA	NA	NO
6. Zinc Production	NA	NA	NA	NA	NA	NO
7. Other	NO	NO	NO	NO	NO	NO

Source/Emission Gas	SF_6	PFCs	HFCs	N_2O	CH_4	CO_2
D. Non-Energy Fuel Products and Solvent Use	NA	NA	NA	NE	NE	NE
1. Lubricant Use	NA	NA	NA	NE	NE	NE
2. Paraffin/Wax Use	NA	NA	NA	NE	NE	NE
3. Solvent Use	NA	NA	NA	NE	NE	NE
4. Other	NA	NA	NA	NE	NE	NE
E. Electronics Industry	IE, NO	IE, NO	IE, NO	NA	NA	NA
1. Integrated Circuits or Semiconductors	IE	IE	IE	NA	NA	NA
2. TFT Panels	NO	NO	NO	NA	NA	NA
3. Photovoltaic	NO	NO	NO	NA	NA	NA
4. Heat Transfer Fluid	NO	NO	NO	NA	NA	NA
5. Other	NO	NO	NO	NA	NA	NA
F. Product Uses as Substitutes for Ozone-Depleting Substances	T3, CS	T3, CS	T3, T2,T1 CS,D	NA	NA	NA
1. Refrigeration and Air Conditioning	NA	NO	T2, CS, D	NA	NA	NA
2. Heat Pumps	NA	NO	NE	NA	NA	NA
3. Fire Protection	NA	NO	T1, CS, D	NA	NA	NA
4. Aerosols	NA	NO	T3, CS	NA	NA	NA
5. Solvents	NA	NE	NE	NA	NA	NA
6. Semiconductor Manufacture	T3, CS	T3, CS	T3, CS	NA	NA	NA
7. Electrical Equipment (Manufacture and Use of Transformer and Switching Systems)	T3, CS	NO	NO	NA	NA	NA
8. Other Applications	NO	NO	T3, CS	NA	NA	NA
G. Other Product Manufacture and Use	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO

T1=Tier 1, T2= Tier 2, T3= Tier 3, CS= Country-specific, D= IPCC default, NE= Not estimated, NA= Not applicable, NO= Not occurring, IE=Included elsewhere

4.4. 2.A Mineral Industry

4.4.1 Cement Production

4.4.1.1 CO_2 Emissions

Description of Emission Sources

CO_2 is emitted during the production of clinker, which is a raw material for cement. The emission rate depends on the quantity of clinker production; hence, emission calculations are based on this quantity.

Calculation Method

In the clinker production process, limestone is heated, and the calcium carbonate in the limestone undergoes a calcination process to produce lime. This process generates CO_2.

$$\mathrm{CaCO3\ (limestone) + heat \rightarrow CaO\ +\ CO_2}$$

The emissions were calculated using Tier 1 (T1). The emission factor recommended by the 1996 IPCC guidelines is 0.5071 tons of CO_2 per ton of clinker, based on the assumption that the average lime content in the clinker is 64.6%, and the molar mass ratio of lime (CaO) to CO_2 is 0.785. In Israel, average cement ("Portland") is used, so this factor can be applied.

According to the 2006 IPCC guidelines, a similar value of 0.5205 is obtained from these variables: the lime content in Israel (65%) and a default correction factor of 1.02 due to the ash produced (cement kiln dust or CKD).

$$\mathrm{Emissions = EFclinker\ \times Clinker\ Production\ \times\ CKD\ Correction\ Factor}$$

EFclinker – 0.785 ×CaOContent (weight fraction) in clinker

CaOContent (weight fraction) in clinker – 65%

CKD Correction Factor – 1.02

Information Sources

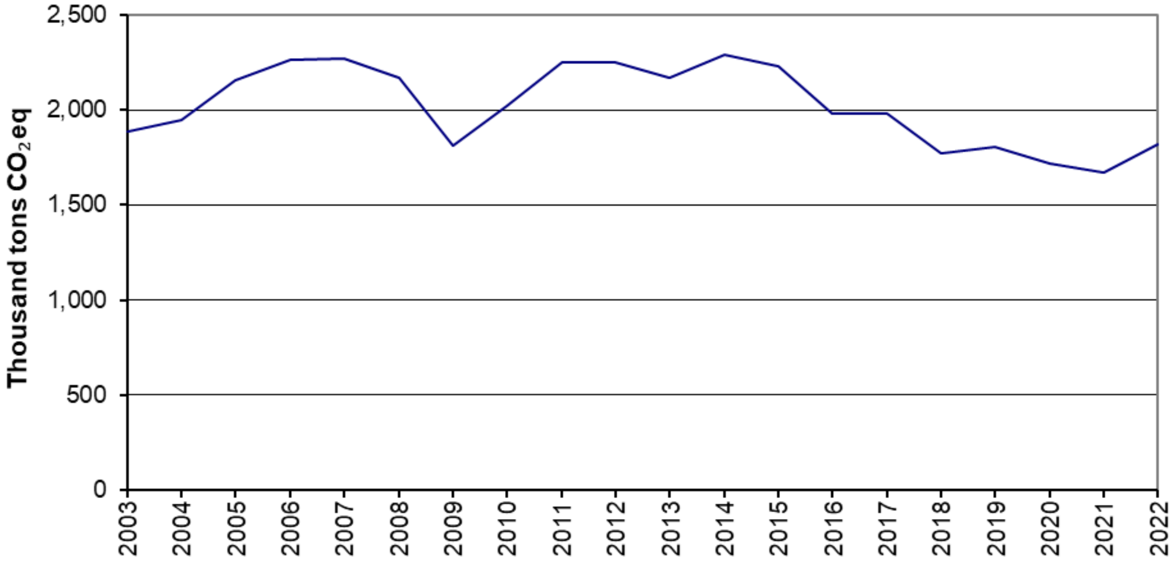
Information on the production volume of cement in the country was obtained from Nesher Israel Cement Enterprises Ltd. (hereafter: the Nesher Company).

In recent years, clinker has been imported to the country for cement production, but the emissions from this process are negligible, and were not included.

Emissions

In 2022, CO_2 emissions from cement production were approximately 1.8 million tons of carbon dioxide equivalent, accounting for 26.1% of all emissions from industrial processes and product use. Over the years, there has been variability in emission amounts due to fluctuations in cement production and demand.

DIAGRAM 4.4 CO_2 EMISSIONS FROM CEMENT PRODUCTION 2003–2022



4.4.1.2 SO_2 Emissions

Description of Emission Sources

In the clinker production process, SO_2 gases are emitted from the oxidation of sulfur found in the clay used in the limestone.

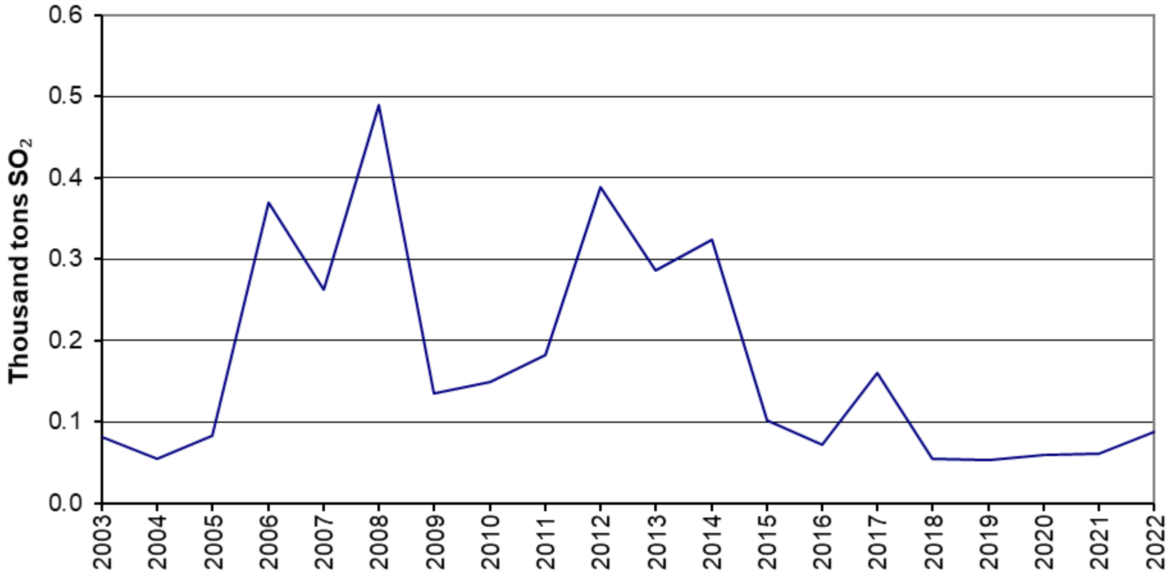
Calculation Method and Information Sources

SO_2 emission data for 2016–2022 were obtained from the Nesher Company's reports to the PRTR. Emission data from previous years were taken from Nesher's corporate responsibility reports. In the past, the calculation of emissions was based on default factors from the IPCC guidelines – 0.3 kg SO_2 per ton of clinker.

Emissions

SO_2 emissions from clinker production are not uniform over the years because they are influenced by the sulfur content in the clay, which changes over the years.

DIAGRAM 4.5 SO_2 EMISSIONS FROM CEMENT PRODUCTION 2003–2022



4.4.2 Lime Production

4.4.2.1 CO_2 Emissions

Description of Emission Sources

In the lime production process, CO_2 is emitted. The emission rate depends on the quantity of lime production; hence, emission calculations are based on this quantity. In Israel, regular lime is produced.

Calculation Method

In the lime production process, limestone is heated, and the calcium carbonate in the limestone undergoes a calcination process to produce lime. This process generates CO_2.

$$\mathrm{CaCO_3\ (limestone) +\ heat \rightarrow CaO\ (high\text{-}calcium\ lime)\ +\ CO_2}$$

Emissions were calculated according to Tier 1 (T1). The recommended emission factor according to the IPCC 1996 guidelines is 0.79 tons of CO_2 per ton of lime.

Information Sources

Data on lime production were obtained from the Ministry of Economy and Industry.

Emissions

The amounts of emissions from lime production cannot be published individually due to confidentiality restrictions. The emissions are included in the total emissions in the mineral industry.

4.4.3 Glass Production

4.4.3.1 CO_2 Emissions

Description of Emission Sources

In the glass production process, CO_2 is emitted The emission rate depends on the quantity of glass production.

Until 2020, two companies were operating in glass production in Israel. From 2020 onwards, only one factory has been operating.

Calculation Method

In the glass production process, emissions are generated from chemical processes involving limestone ($CaCO_3$) and sodium carbonate (Na_2CO_3). Emissions from the use of sodium carbonate (Na_2CO_3) were calculated separately based on the amount of the substance used in Israel, and these were deducted from the calculation of emissions from glass production in order to prevent double counting of emissions.

Emissions were calculated according to Tier 2 (T2), and according to the recommended emission factor in the IPCC 2006 guidelines, which is 0.2 tons CO_2 per ton of glass. In the production process, some factories add glass cullet (from an external source or from the production process), and the calculation must be adjusted according to the proportion of glass cullet in the production process. The calculation is adjusted for the production process in each company.

The calculation formula is as follows:

$$\mathrm{CO_2\ Emissions} = \mathrm{Mg} \times \mathrm{EF} \times (1 - \mathrm{CR})$$

CO_2 emissions – emissions of CO_2 from glass production, tons

Mg – mass of glass produced, tons

EF – default emission factor for manufacturing of glass, tons CO_2/tons glass

CR – cullet ratio for process (either national average or default), fraction

Information Sources

Data on glass production were obtained from the Ministry of Economy and Industry.

Emissions

The amounts of emissions from glass production cannot be published individually due to confidentiality restrictions. The emissions are included in the total emissions in the mineral industry.

4.4.3.2 NMVOC Emissions

Calculation of NMVOC emissions was discontinued in 2011.

4.4.4 Use of Carbonates in Other Processes

4.4.4.1 CO_2 Emissions

Description of Emission Sources

The different types of carbonate have various uses (besides those mentioned above) in which CO_2 emissions can be generated, such as agriculture, ceramics production, brick and tile manufacturing, and environmental pollution control systems. Emissions from the use of Na_2CO_3 were included, but emissions sources from the use of other carbonates exist that were not included in the inventory calculation.

Na_2CO_3 (soda ash, sodium carbonate) serves as a raw material in various industries: production of glass, soaps, paper, etc. Na_2CO_3 is not produced in Israel and is sourced exclusively through imports. The quantity of emissions depends on the quantity of Na_2CO_3 used, and emissions were calculated according to this quantity.

Calculation Method

The emissions were calculated according to Tier 1 (T1), and according to the emission factor recommended by the IPCC 1996 guidelines, which is 0.415 tons of CO_2 per ton of Na_2CO_3 used.

Information Sources

Data on Na_2CO_3 consumption were obtained from the Ministry of Economy and Industry. The consumption quantities of Na_2CO_3 in the glass production industries were deducted to prevent double counting of emissions.

Emissions

The amounts of emissions from Na_2CO_3 consumption cannot be published individually due to confidentiality restrictions. The emissions are included in the total emissions in the mineral industry.

4.5. 2.B Chemical Industry

4.5.1 Ammonia Production

Ammonia was produced in Israel in the past, but its production has ceased. Currently, ammonia is not produced in Israel.

4.5.2 Nitric Acid (HNO_3) Production

4.5.2.1 Emissions of N_2O and NO_X

Description of Emission Sources

In the HNO_3 production process, the byproducts N_2O and NO_X are produced.

The emission rate depends on the production quantities of HNO_3, and thus the emission calculations are based on these quantities. HNO_3 is produced at several sites in Israel.

Calculation Method

In the production of nitric acid, three main chemical reactions take place:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$3NO_2 + H2O \rightarrow 2HNO_3 + NO$$

Nitric oxide (NO), an intermediate product in the production of nitric acid, is involved in the formation of N_2O and NO_2.

There are three intermediate reactions during the oxidation of NH_3 that are likely to result in the formation of N_2O:

$$NH_3 + O_2 \rightarrow 0.5N_2O + 1.5H_2O$$

$$NH_3 + 4NO \rightarrow 2.5N_2O + 1.5H_2O$$

$$NH_3 + NO + 0.75O_2 \rightarrow N_2O + 1.5H_2O$$

The quantity of emissions depends on the operating practices in the factories and the operating pressure of the process.

N_2O Emissions – N_2O emissions were calculated according to Tier 3 (T3) based on emission measurements conducted in the factories. Emissions for the years 2012–2022 were obtained from the companies' reports to the PRTR. Emissions from previous years were calculated based on an average ratio between production quantities and emission quantities for the years 2012–2015.

NO_X Emissions – NO_X emissions were calculated based on the production quantity of HNO_3 (measured according to the operating pressure) and based on emission factors according to the 2006 IPCC guidelines (which refer to EEA [2016][1]). The factors are 7.5 kg NO_X per ton of HNO_3 for medium pressure and 3 kg NO_X per ton of HNO_3 for high pressure.

Information Sources

As mentioned, the emission data for 2012–2022 were obtained from the companies' reports to the PRTR. The transition to reliance on PRTR data was made because the emissions reported to the PRTR were calculated based on the unique technologies of each company and were checked by the Ministry of Environmental Protection.

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[1] European Environment Agency (2016). EMEP/EEA air pollutant emission inventory guidebook. EEA Report No. 21/2016. 2B: Chemical industry.

Emissions

Between 2003 and 2016, there was a downward trend in N_2O (and NO_X) emissions from HNO_3 production (along with fluctuations in emissions due to fluctuations in production), and N_2O emissions amounted to approximately 0.2 million tons of CO_2eq in 2016. In 2017, emissions declined sharply due to a reduction in HNO_3 production. In 2018, emissions increased slightly and since 2020, they have decreased. In 2022, they were approximately 0.05 million tons of CO_2eq (less than one-third of the emissions in 2003), accounting for 0.7% of all emissions from industrial processes and product use.

DIAGRAM 4.6 N_2O EMISSIONS FROM HNO_3 PRODUCTION
2003–2022

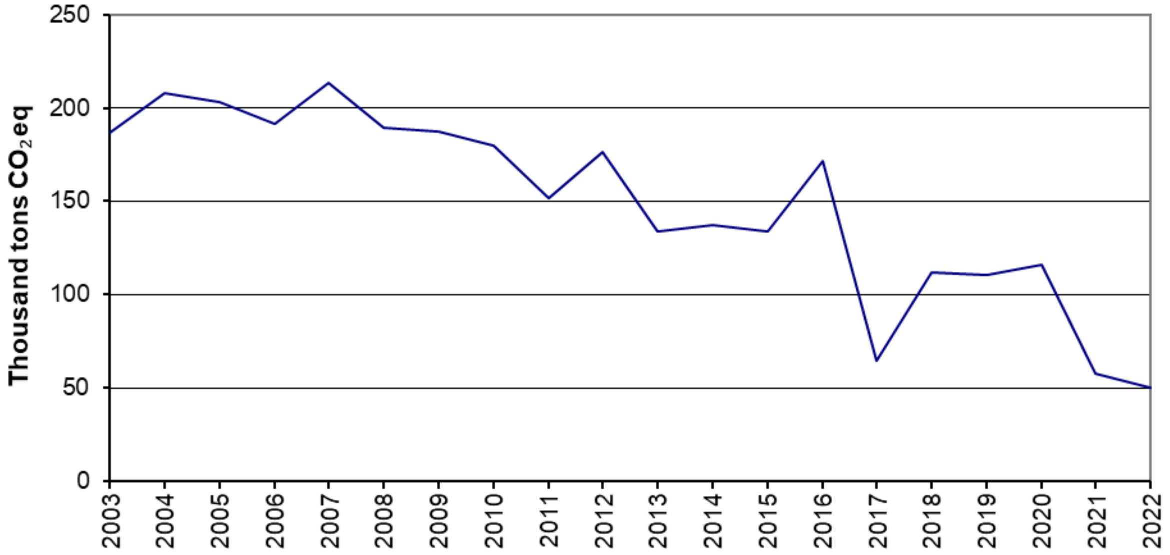
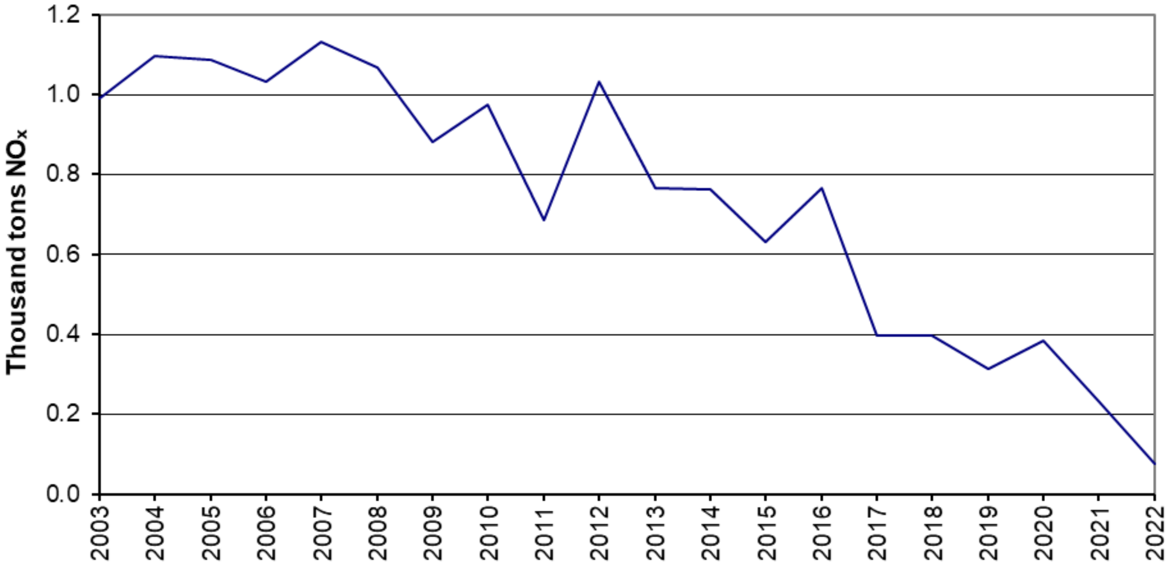


DIAGRAM 4.7 NO_x EMISSIONS FROM HNO_3 PRODUCTION
2003–2022



4.5.3 Adipic Acid Production

Adipic acid is not produced in Israel.

4.5.4 Production of Caprolactam, Glyoxal, and Glyoxylic Acid

Caprolactam, glyoxal, and glyoxylic acid are not produced in Israel. Some of these substances are imported into Israel.

4.5.5 Carbide Production

There is no production of carbide in Israel that emits GHGs.

GHGs are emitted during the production of silicon carbide (SiC) and calcium carbide (CaC_2), but these substances are not produced in Israel.

Tungsten carbide is produced in Israel, but it does not emit GHGs.

The production is carried out in two stages:

- The reduction stage of tungsten oxide with hydrogen gas at a temperature of about 1,000 degrees Celsius, to produce metallic tungsten, from which water is obtained as a byproduct:

$$\mathrm{W0_3 + 3H_2 \rightarrow W + 3H_20}$$

- The carburization stage: The bonding of tungsten and carbon atoms at a temperature of about 1,500 degrees Celsius:

$$\mathrm{W + C \rightarrow W}C$$

4.5.6 Titanium Oxides Production

Titanium oxides are not produced in Israel.

4.5.7 Sodium Carbonate (Na_2CO_3) Production

There is no production of Na_2CO_3 in Israel.

4.5.8 Petrochemicals and Carbon Black Production

Various gases are emitted during the production of organic chemicals. The gases CH_4 and NMVOC are emitted from such production in Israel. There is no production of carbon black in Israel.

Description of Emission Sources

The chemicals whose production process emits CH_4 and NMVOC are ethylene, propylene, polyethylene, polypropylene, polystyrene, formaldehyde, and polyvinyl chloride.

4.5.8.1 CH_4 Emissions

Calculation Method

The emissions were calculated based on the default factors from the 1996 IPCC guidelines.

Information Sources

Data on production quantities were obtained from the Ministry of Economy and Industry.

4.5.8.2 NMVOC Emissions

Calculation of NMVOC emissions was discontinued in 2011.

4.5.8.3 SO_2 Emissions from Sulfuric Acid (H_2SO_4) Production

Description of Emission Sources

SO_2 gases are emitted during the production of sulfuric acid (H_2SO_4).

Calculation Method and Information Sources

Emission data for H_2SO_4 for 2012–2022 were obtained from the ICL Group's (formerly Rotem Amfert) reports to the PRTR. Emissions for previous years were calculated based on the average ratio between production quantity and emission quantity for 2012–2015. An average emission factor of 2.33 kg SO_2 per ton of H_2SO_4 was obtained.

The data were compared with EPA factors. The recommended emission factor according to the EPA guidelines, suitable for the technology in Israel, is 3 kg SO_2 per ton of H_2SO_4, a magnitude similar to the emission factor in Israel.

4.5.9 Fluorochemical Production

There is no production of fluorochemical gases in Israel. These gases are imported.

4.5.10 Production of Other Chemical Substances

There are no emissions from the production of other chemical substances.

4.6. 2.C Metal Industries

4.6.1 Magnesium Production and Casting

4.6.1.1 CO_2 Emissions

Magnesium production and casting in Israel do not emit CO_2.

CO_2 is emitted from the combustion of carbonates in the combustion process of magnesite or dolomite. The raw material in magnesium production and casting in Israel is metallic magnesium. There is no combustion in the production process, and no CO_2 is emitted.

4.6.1.2 SF_6/HFC-134a Emissions

In the process of magnesium production and casting, a gas is used as an intermediate material. Between 2008 (when emission calculation began) and 2009, SF_6 was used. Thereafter, its use was discontinued, and it was replaced by HFC-134a. The emissions are included in product uses as substitutes for ozone-depleting substances.

4.7. 2.D Non-Energy Fuel Products and Solvent Use

4.7.1 Lubricant Use

4.7.1.1 CO_2 Emissions

These emissions, which are not calculated in Israel, are assumed to be negligible.

Description of Emission Sources

Lubricants, which are combusted in the usage process, are a source of CO_2 emissions in which only part of the substance is oxidized. There is no information on the consumption of these substances. In Israel, these substances are produced and imported, and possibly also exported.

Calculation Method

In calculating the emissions, it is necessary to rely on the consumption quantity and carbon content of the lubricants, and on the oxidation factor. There are default values for energy values (in the Energy chapter), and oxidation factors.

4.7.2 Paraffin Wax Use

4.7.2.1 CO_2 Emissions

These emissions, which are not calculated in Israel, are assumed to be negligible.

Description of Emission Sources

Paraffin/wax, which is combusted in the usage process (such as in candles), is a source of CO_2 emissions in which only part of the substance is oxidized. These emissions are not calculated in Israel, and there is no information on the consumption of these substances. In Israel, these products are produced and imported, and possibly also exported.

Calculation Method

In calculating the emissions, it is necessary to rely on the consumption quantity and carbon content of wax/paraffin, and on the oxidation factor. There are default values for energy values (in the Energy chapter) and oxidation factors. It is assumed that 20% of the wax/paraffin is burned (mainly in candles).

4.7.3 Asphalt Production and Use

4.7.3.1 NMVOC Emissions

Calculation of NMVOC emissions was discontinued in 2011.

4.7.4 Solvent Use

4.7.4.1 NMVOC Emissions

These emissions are not calculated in Israel.

Description of Emission Sources

NMVOC gases are emitted from the use of solvents. There are no guidelines regarding these gases in the IPCC 2006, but it references the EMEP/CORINAIR Emission Inventory Guidebook (EEA, 2005).

4.8. 2.E Electronics Industry

In Israel, emissions in the electronics industry are generated from the manufacture of semiconductors, and are included in the chapter Product Uses As Substitutes For Ozone-Depleting Substances.

4.9. 2.F Product Uses as Substitutes for Ozone-Depleting Substances

Description of Emission Sources

Products (GHGs containing fluorine) used as substitutes for ozone-depleting substances are used in various production processes: air conditioning and refrigeration systems, fire protection systems, aerosols, magnesium production and casting, semiconductor manufacture, and production and use of electrical transformation and switching systems. These gases do not exist in nature but are produced industrially.

These gases can be used in two ways:

- **Directly** – such as in the **process** of magnesium production and casting or in semiconductor manufacture. In this case, the gases are emitted wholly or in part during use.
- **Through a product** – such as in air conditioning and refrigeration **systems**. In this case, the gases remain in the system, and they may escape during one or several of the following stages:
    - During the **production** of the systems and while charging them with gas
    - During the **use** of the systems
    - When disposing of the systems after use (if the gas is not collected)
    - In the use and consumption of products containing these gases (such as aerosols)

To simplify the calculation, it was assumed that the amount of gas imported in a given year served the economy in that same year. In addition to the import of fluorine-containing gases, emissions from the import of fluorine-containing preparations (aerosols) were calculated.

Some of the gases used in these systems ("old gases") are included in the Montreal Protocol, and are not meant to be included in the calculation of GHG emissions. To deduct the share of these gases in the emissions, the quantity of emissions from replenishing old systems was multiplied by the ratio between the quantities of old gas imports and the quantities of new gas imports. New gases, which are not included in the Montreal Protocol, are included in the emission calculation.

Table 4.3 Old and New Gases, Out of All Fluorine-Containing Gases, 2010–2022

Percentages

Type of Gas	2010	2012	2014	2015	2016	2017	2018	2019	2020	2021	2022
New	54	61	62	85	86	85	87	87	99	99	98
Old	46	39	38	15	14	15	13	13	1	1	2

It can be seen that as a result of the Montreal Protocol, which mandates actions to reduce the use of ozone-depleting gases (old gases), there has been a shift to the use of new gases, which are included in the calculation.

Between 2010 and 2014, the share of new gases ranged from 54% to 67%. During the years 2015–2019, their share was about 86%, and from 2020 nearly all gases imported (99%) were new gases.

Information Sources on the Quantity of Imports

- During 2008–2010, data were collected from detailed customs records that contained information on the quantities and types of gas imports. From these records, data on the relevant imported gases were extracted.
- Since 2011, the data are obtained from two sources:
  - The data on the quantities of gas imports from the companies that imported these gases to Israel were collected in a survey of Import of Gases Containing Fluorine, conducted by the CBS.
  - Supplementary information on the quantities of gas imports was obtained from the Ministry of Economy and Industry based on import licenses. The data were obtained according to a division between old gases (which, as mentioned, are not reported as GHG emissions) and new gases.

Calculation Method

To estimate the emissions, the following information is required **for each imported gas**:

- The quantity of imports
- Out of the quantity of imports – the quantities of gas directed to each of the various purposes, such as air conditioning (industrial, commercial, etc.) and fire protection
- The distribution of the different uses in each purpose – charging or replenishing
- Appropriate emission factors, according to the various purposes and uses

The emissions from each of the emission sources were calculated according to the availability of data from that source. In Israel, all potential sources of emissions from GHG containing fluorine can be divided into four main groups, according to the calculation method:

Emissions from magnesium production and casting, semiconductor manufacture, and the production and use of electrical transformation and switching systems – The calculation was based on detailed information obtained from the companies about the quantity of use of the gases, as well as on companies' calculations or emission factors.

Emissions from mobile air conditioning and refrigeration systems – The calculation was based on the stock of vehicles and other mobile systems, and multiplying the quantity of gases by the appropriate emission factors for each source.

Emissions from aerosols – The calculation was based on detailed information from the companies about the quantity of gas imports in the medical inhalers.

Emissions from stationary air conditioning and refrigeration systems, and from fire protection systems – The remaining gases, not used in the previous sources, were attributed to stationary systems for air conditioning and cooling and to fire protection systems. Assumptions were made regarding the distribution of use in these systems according to charging (1/3) and replenishing (2/3), and the emissions were derived from this distribution.

After the quantities of gases in all uses were located, the emissions were calculated from them:

- **Emissions during the production of the systems and their charging** were calculated based on the quantity of gases used for the charging of the new systems, and multiplying this quantity by an appropriate emission factor.
- **Emissions during the use of the systems (dissipation of the gas)** were calculated based on the quantity of gases used for replenishing existing systems. It was assumed that the quantity of replenishing represents the quantity of gases emitted that year. That is, the gases in the replenishing replaced gases emitted that year. This calculation results in a higher actual emission rate, as these emissions may occur over several years and not necessarily in one year. Also, these gases may have replaced gases of a different type and not the same type.

Calculation Process

Stage A – Locating data on the quantities of gas imports to Israel (from the CBS survey and administrative sources).

Stage B – Calculating emissions from certain companies individually: emissions from magnesium production and casting, semiconductor manufacture, and the production and use of electrical transformation and switching systems, as well as emissions from mobile air conditioning and refrigeration systems (vehicles and other mobile systems).

Stage C – Deducting the quantities of gases attributed to sources, which was calculated in Stage B, from the total quantity of imports found in Stage A. Attributing the residual from this quantity to stationary systems for air conditioning and cooling and to fire protection systems.

Stage D – Calculating emissions from aerosols and from scrapping of vehicles.

4.9.1. Emissions

Total emissions from the product uses as substitutes for ozone-depleting substances were 5.0 million tons CO_2eq, which constituted about 71.8% of all emissions from industrial processes and product use. The largest source of emissions was air conditioning and refrigeration systems: about 4.4 million tons CO_2eq, which constituted about 87.1% of the emissions from product uses as substitutes for ozone-depleting substances.

DIAGRAM 4.8A. GHG EMISSIONS FROM PRODUCT USES AS SUBSTITUTES FOR OZONE-DEPLETING SUBSTANCES, BY SOURCE 2022

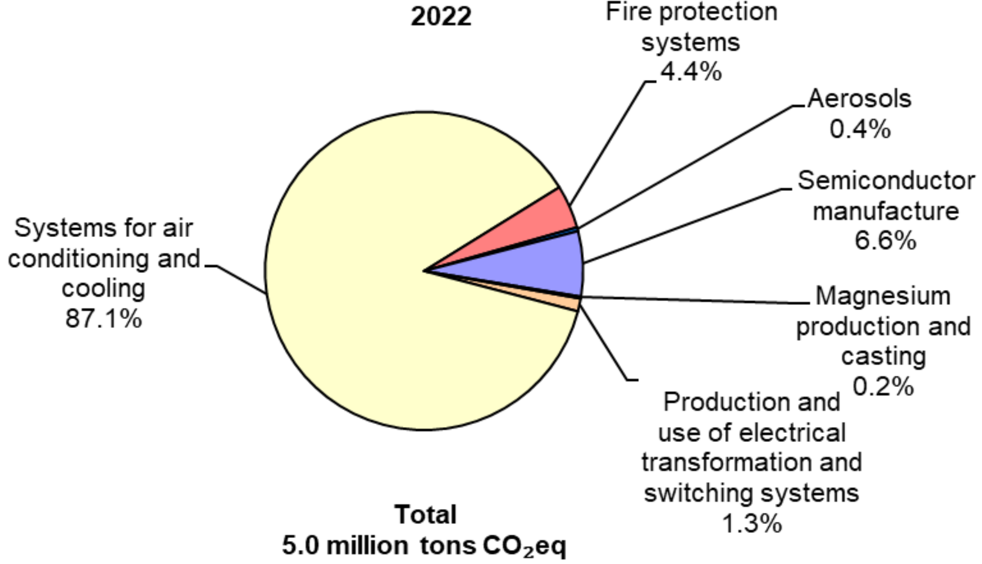
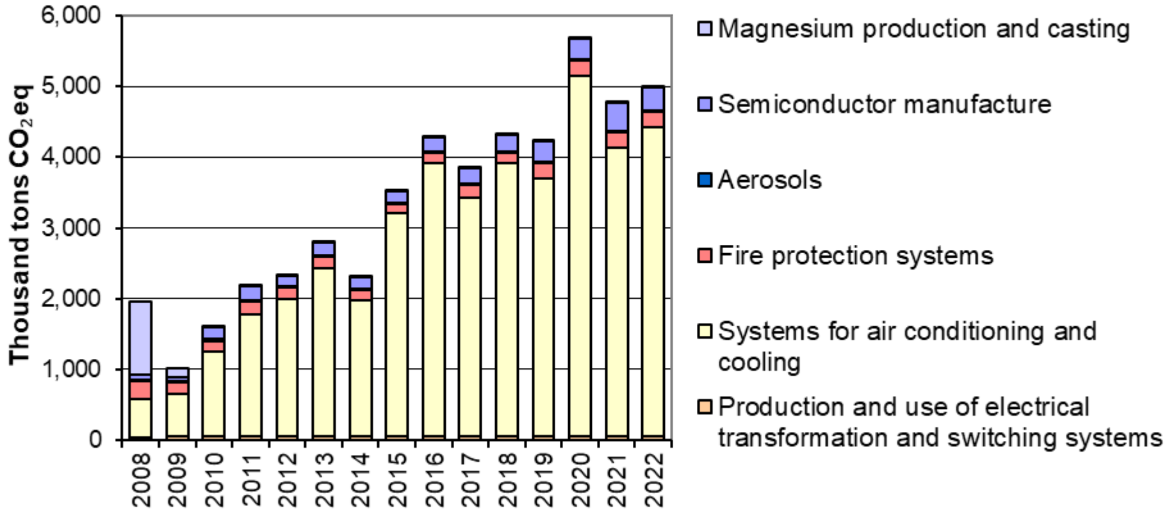


DIAGRAM 4.8B. GHG EMISSIONS FROM PRODUCT USES AS SUBSTITUTES FOR OZONE-DEPLETING SUBSTANCES, BY SOURCE 2008–2022



4.9.2. Air Conditioning and Refrigeration Systems

Description of Emission Sources

Air conditioning and refrigeration systems have a wide range of uses across all sectors of the economy: stationary systems for air conditioning and refrigeration in industry, commerce, and residences; and mobile systems for air conditioning and refrigeration in vehicles, trains, refrigerated containers, etc.

Calculation Method and Information Sources

Emissions from air conditioning and refrigeration systems were calculated separately for mobile systems and stationary systems, following methods T2, CS, and D from the IPCC 1996 guidelines.

4.9.2.1. Stationary Air Conditioning and Refrigeration Systems

The category "air conditioning" consists of different types of systems operating under various loads, containing different amounts of gases, and having different emission factors. Therefore, it was decided to divide this category into three sub-categories:

a. Domestic air conditioning – domestic air conditioners (window, split, mini-central, and central), operating with a power output of up to 20kW.

b. Commercial air conditioning – air conditioning systems operating with a power output of 21kW–200kW.

c. Industrial air conditioning (including chillers and heat pumps) – air conditioning systems in shopping centers, office buildings, and industrial centers operating with a power output of 201kW–1MW.

The category "refrigeration" also consists of different types of systems operating under various loads, containing different amounts of gases, and having different emission factors. Therefore, it was decided to divide this category into three sub-categories:

a. Domestic refrigeration – domestic refrigerators.

b. Commercial refrigeration – refrigerators in supermarket retail chains, restaurants, grocery stores, etc.

c. Industrial refrigeration – refrigerators used by food manufacturers, wholesale food storage centers, walk-in refrigerators, etc.

The calculation made use of emission factors for charging and replenishing. Charging refers to emissions from production processes, and replenishing refers to emissions from usage that requires refilling of gas. Emission factors for charging vary according to sub-category, while the factors for replenishing have a fixed value of 100%.

For stationary air conditioning and refrigeration systems that were replenished, it was assumed that the gases in the replenishing replaced gases emitted that year. The estimated emission quantity was multiplied by the percentage of new gases to take into account emissions from new gases only.

Table 4.4 Emission Factors
for Stationary Air Conditioning and Refrigeration Systems

Type of Filling and Category	Factor Value	Sources
Replenishing, Air Conditioning	100.00%	CS
Charging, Domestic Air Conditioning	0.60%	D
Charging, Commercial/Industrial Air Conditioning	1.75%	D
Replenishing, Refrigeration	100.00%	CS
Charging, Domestic Refrigeration	0.60%	CS
Charging, Commercial/Industrial Refrigeration	0.60%	D

CS = Country-specific; D = IPCC default

4.9.2.2. Mobile Air Conditioning and Refrigeration Systems

The calculation method for mobile air conditioning and refrigeration systems was based on an extension of the T2 method (the bottom-up approach). This method is based on the number of units of products or devices where the gases are used. This method was chosen because there is usually good information available, allowing for more accurate emission calculations and including emissions from scrapping of vehicles.

Emissions from vehicles were based on the vehicle inventory, which is available at the CBS, and on an estimate of the emissions from mobile air conditioning and refrigeration systems and scrapping of vehicles.

The emissions were calculated as follows:

- Data were collected on the number of vehicles in Israel, by type of system.
- The total number of vehicles was multiplied by an annual emission factor determined by the types of systems.
- The number of disposed vehicles was multiplied by a factor representing the gases emitted during disposal.

It was assumed that mobile air conditioning and refrigeration systems (unlike in vehicle disposal) were replenished during the year with gases imported that year, and that there is inventory offsetting from year to year.

Emissions from disposal of vehicles were defined separately because they do not result from the gases imported each year but rather from gases stored within the vehicles and emitted during disposal.

Emissions from trains were based on gas filling data obtained from Israel Railways. It was assumed that system filling resulted from emissions generated that year.

Emissions from refrigerated containers were based on the average gas quantities in a container, on Israel's share of the global container stock, and on the global refrigerated container stock according to World Bank data. The global refrigerated container stock is based on the global growth rate of these containers.

Limitations of the Calculation

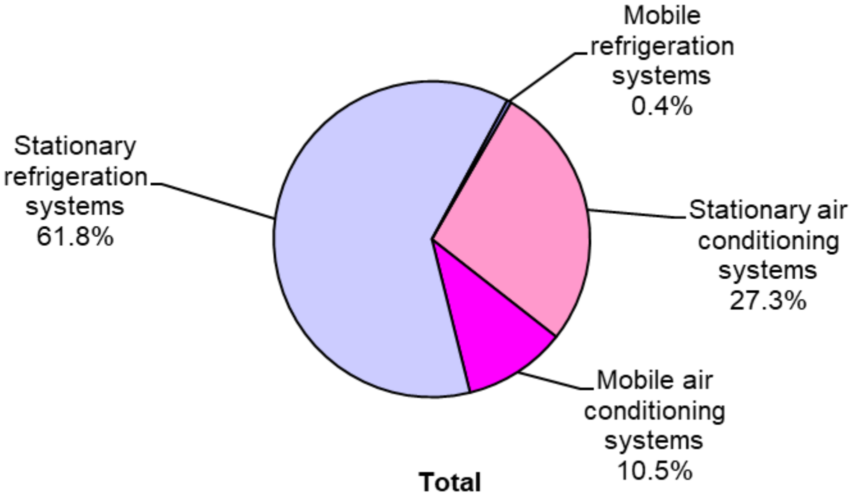
- Although it was assumed that emissions from old systems were generated during the past year, they usually occur over a longer period. However, when the calculation is consistent, the assumption is that over the years, the differences will balance out.
- The assumption that the distribution of import data of old gases compared with import data of new gases represents the gas distribution in systems is not necessarily accurate.

4.9.2.3. Emissions

In 2022, emissions from air conditioning and refrigeration systems were approximately 4.4 million tons of CO_2eq, constituting 62.5% of total emissions from industrial processes and product use and 87.1% of emissions from product uses as substitutes for ozone-depleting substances.

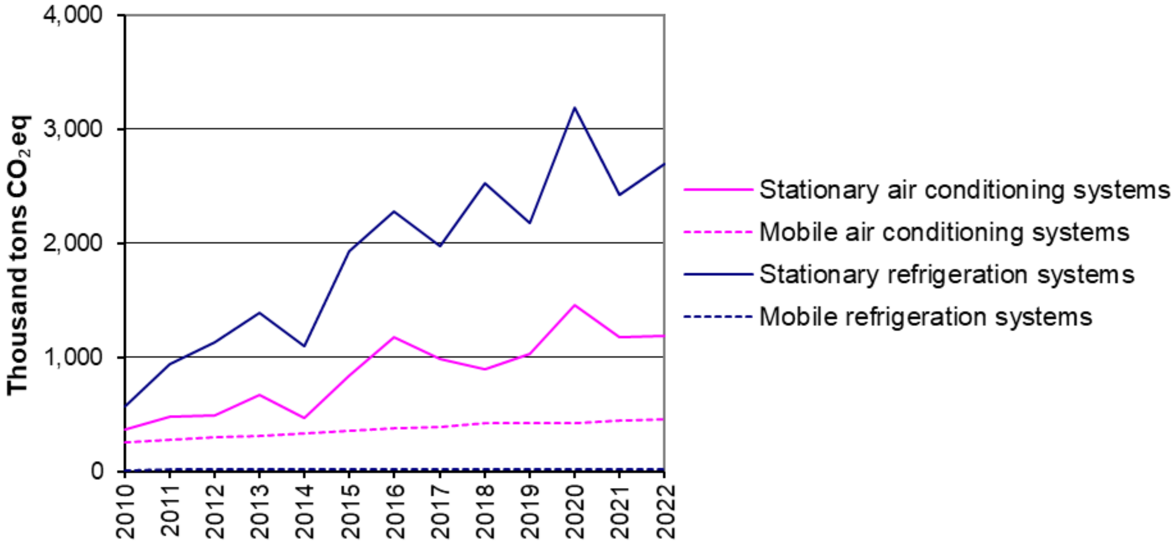
Between 2010 and 2022, there was an upward trend in emissions, along with fluctuations caused by changes in the quantities of these gases that were imported. As described above, emissions from mobile systems are calculated based on the number of vehicles, which steadily increases. Thus, the quantity of these emissions increases consistently and without fluctuations. The increase in emissions is partly due to restrictions on the use of gases that deplete the ozone layer and the transition to substitute products, which are GHGs and are included in the emissions inventory.

DIAGRAM 4.9A. GHG EMISSIONS FROM AIR CONDITIONING AND REFRIGERATION SYSTEMS, BY TYPE OF SYSTEM 2022



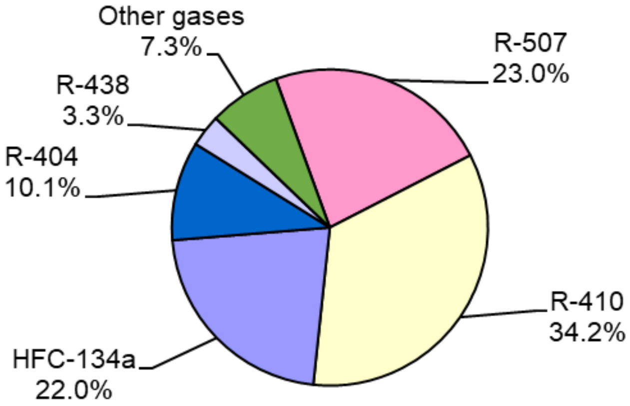
Total 4.4 million tons CO_2eq

DIAGRAM 4.9B. GHG EMISSIONSFROM AIR CONDITIONING AND REFRIGERATION SYSTEMS, BY TYPE OF SYSTEM 2010–2022



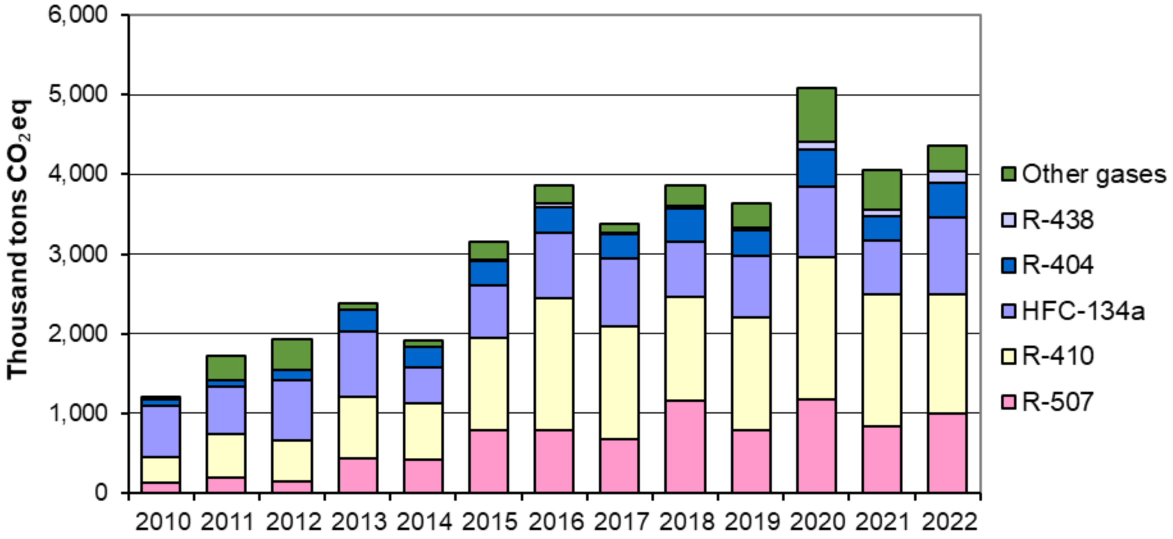
Various gases are emitted from stationary and mobile air conditioning and refrigeration systems. The vast majority of these gases are of types HFC-134a, R-410, R-507, R-404 and R-438, which constitute approximately 93% of the emissions from these systems.

DIAGRAM 4.10A. GHG EMISSIONS FROM AIR CONDITIONING AND REFRIGERATION SYSTEMS, BY GAS 2022



Total
4.4 million tons CO_2eq

DIAGRAM 4.10B. GHG EMISSIONS FROM AIR CONDITIONING AND REFRIGERATION SYSTEMS, BY GAS 2010–2022



4.9.3. Fire Protection

Description of Emission Sources

Emissions from fire protection systems are generated from the use of gases from the HFC family. There are two types of fire protection systems: stationary systems and mobile systems (extinguishers).

According to information obtained from experts in this field, stationary systems use gases from the HFC family, while the vast majority of mobile systems (extinguishers) in Israel use powder or CO_2.

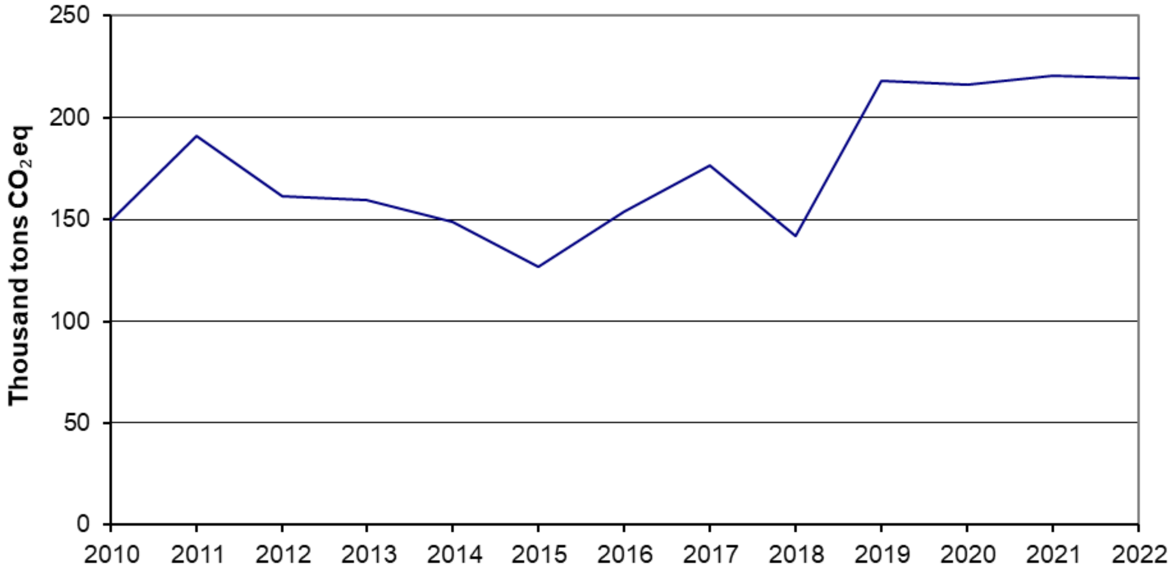
Calculation Method

The emission factors used were the default factors in the 1996 IPCC guidelines (T1): for charging, an emission factor of 1% was selected, and for replenishing, an emission factor of 100% was chosen, based on the assumption that the gases used during replenishing replaced gases emitted that year.

Emissions

In 2022, emissions from fire protection systems amounted to approximately 0.2 million tons of CO_2eq, accounting for about 3.2% of emissions from industrial processes and product use, and about 4.4% of product uses as substitutes for ozone-depleting substances. These emissions were generated from the use of HFC-227ea gas. The emissions varied over the years, with fluctuations caused by variations in the quantities imported of the gases contained in the emissions.

DIAGRAM 4.11 GHG EMISSIONS FROM FIRE PROTECTION SYSTEMS 2010–2022



4.9.4. Aerosols

Description of Emission Sources

One of the common treatments for respiratory diseases is an MDI (Metered Dose Inhaler). This aerosol, operated by pressing, releases a medicinal suspension directly into the patient's lungs using a propellant gas. In the past, CFC gases, which deplete the ozone layer, were used in these chemical preparations as propellant gases. However, due to decisions made under the Montreal Protocol, these gases were gradually replaced with HFCs, and currently, no CFCs are used in medical inhalers.

Calculation Method and Information Sources

Emissions were calculated using T3, CS methods from the 1996 IPCC guidelines.

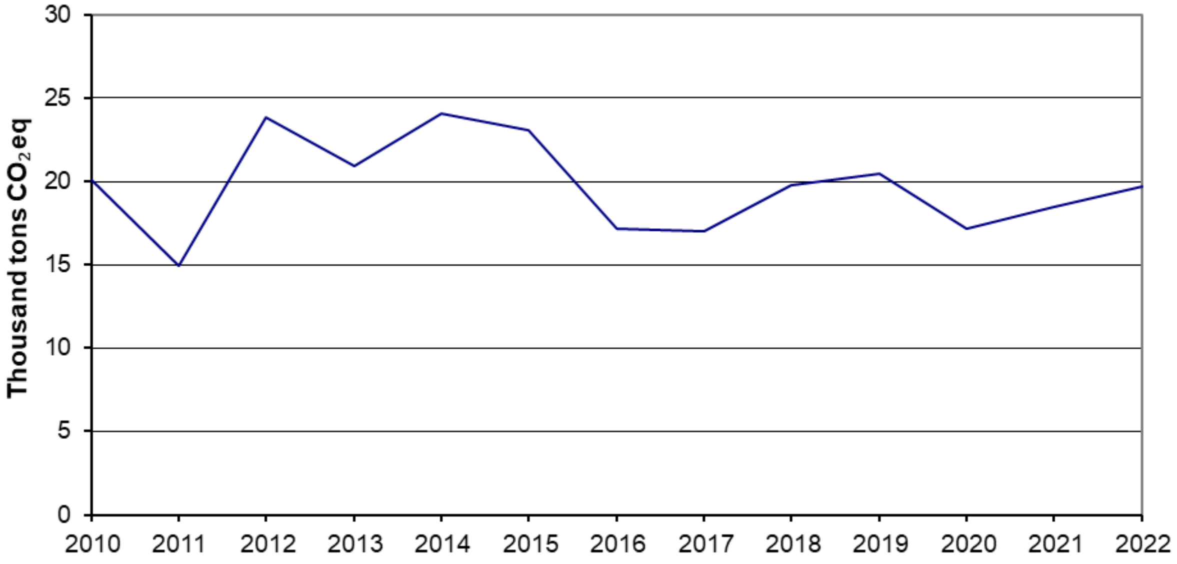
Israel does not manufacture medical inhalers for treating respiratory diseases; all inhalers are imported.

Information on the number of imported inhalers and the quantities of propellant gases they contain was obtained from importers. The gas used is HFC-134a. Since the average lifespan of this type of inhaler is less than a year, an emission factor of 100% was used during the year the inhalers were marketed.

Emissions

In 2022, GHG emissions from aerosols were approximately 0.02 million tons of CO_2eq, accounting for about 0.3% of emissions from industrial processes and product use, and about 0.4% of emissions from product uses as substitutes for ozone-depleting substances. These emissions were generated from the use of the gas HFC134a. The emissions varied over the years without a clear trend. The fluctuations in the emissions are caused by variations in the quantities imported of the gases contained in the emissions.

DIAGRAM 4.12 GHG EMISSIONS FROM AEROSOLS
2010–2022



4.9.5. Solvents

These emissions are not calculated in Israel.

4.9.6. Semiconductor Manufacturing

Description of Emission Sources

The semiconductor manufacturing industry is the sole source of PFC emissions in Israel. In this industry, the gases are used in various ways, such as cleaning chemical residue from chambers used for collection of gases that evaporate, and as cover gases to prevent air contact. In Israel, few companies operate in this field.

Calculation Method and Information Sources

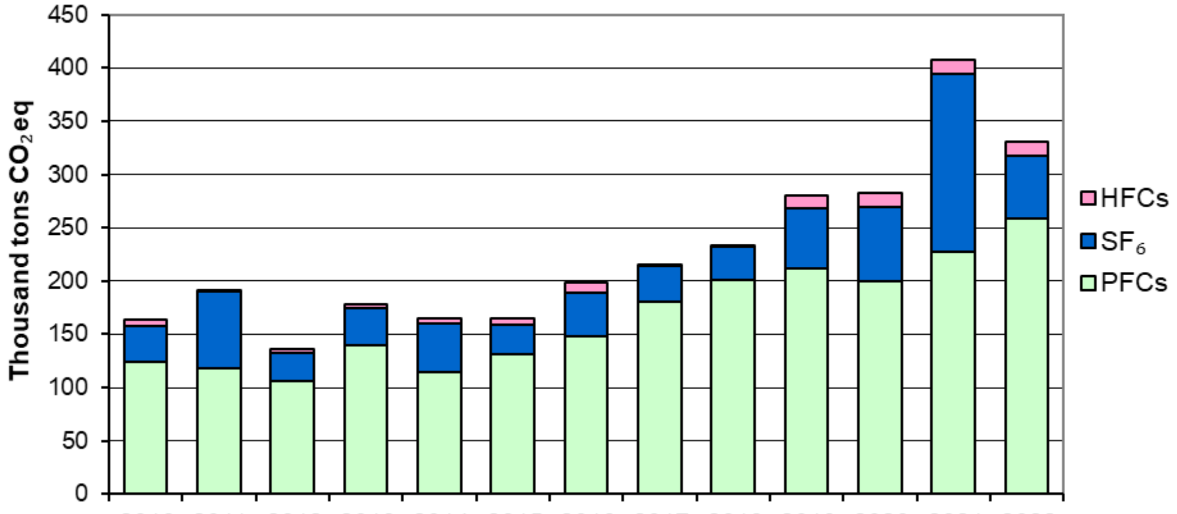
The emissions were calculated according to T3, CS methods from the 1996 IPCC guidelines, and were based on data obtained directly from the companies active in the field: the amounts of gases used and the amounts of gases emitted.

Emissions

In 2022, emissions from semiconductor manufacturing were approximately 330,000 tons of CO_2eq, which constituted about 6.6% of the emissions from product uses as substitutes for ozone-depleting substances, and about 4.7% of all emissions from industrial processes and product use. Between 2010 and 2015, emissions averaged about 170,000 tons of CO_2eq, and since 2015, they began to increase, reaching about 330,000 tons of CO_2eq in 2022.

In 2022, 78.2% of the emissions from semiconductor manufacturing were PFC gases.

DIAGRAM 4.13 GHG EMISSIONS FROM SEMICONDUCTOR MANUFACTURING, BY GAS 2010–2022



4.9.7. Electrical Equipment (Manufacturing and Use of Transformer and Switchgear Systems)

Description of Emission Sources

SF_6 gas is used as an insulating medium in Gas Insulated Switchgear (GIS) transformer and switchgear systems. These systems serve industry and electricity transmission systems.

SF_6 emissions from the manufacturing and use of GIS systems can occur during installation (charging) as well as during their use.

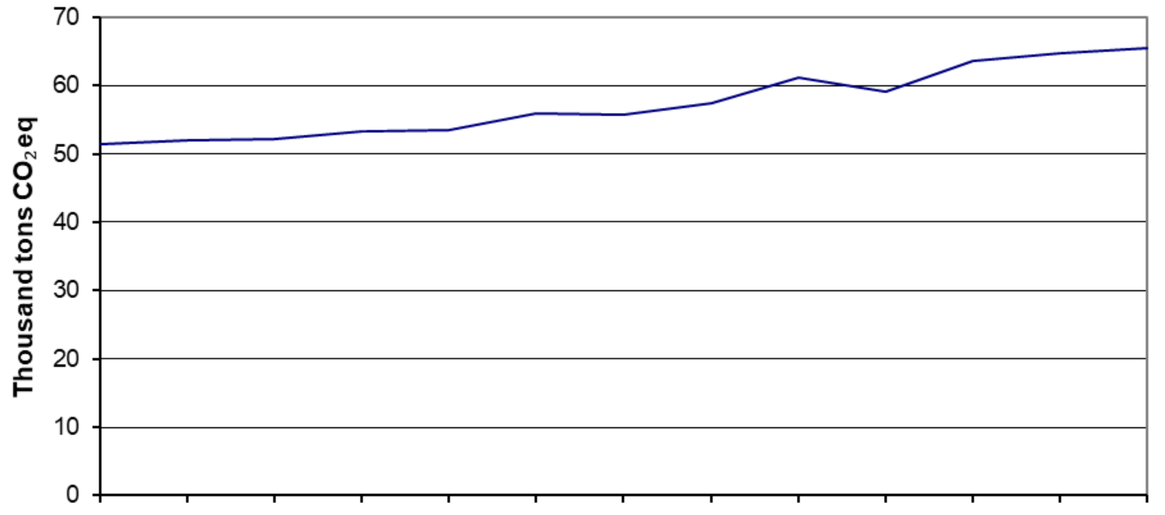
Calculation Method

The emissions were calculated according to T3, CS methods from the 1996 IPCC guidelines. Israel manufactures and uses transformer systems. The main user of these systems is the Israel Electric Corporation. The emission factors used are specific to Israel and based on data obtained from the companies active in the industry. All systems operating in the country comply with the standard allowing a maximum emission of 1% per year. In Israel, an emission factor of 0.6% of the regular use of the systems per year was chosen. Data on emissions from manufacture of the transformer systems (charging) were obtained from the companies active in the industry.

Emissions

In 2022, emissions from the use and manufacturing of GIS systems were about 0.07 million tons of CO_2eq, which constituted about 0.9% of all emissions from industrial processes and product use, and about 1.3% of emissions from product uses as substitutes for ozone-depleting substances. Emissions have risen moderately over the years due to the increase in the number of these systems and emissions from their regular use.

DIAGRAM 4.14 GHG EMISSIONS FROM MANUFACTURING AND USE OF GIS SYSTEMS 2010–2022



4.9.8. Other Uses

Magnesium Production and Casting

In the process of magnesium production and casting, gases are used as intermediaries to prevent contact between air and molten magnesium, thereby preventing the magnesium from oxidizing and igniting. In Israel, there are very few factories engaged in magnesium production and casting. These factories use GHGs for this purpose.

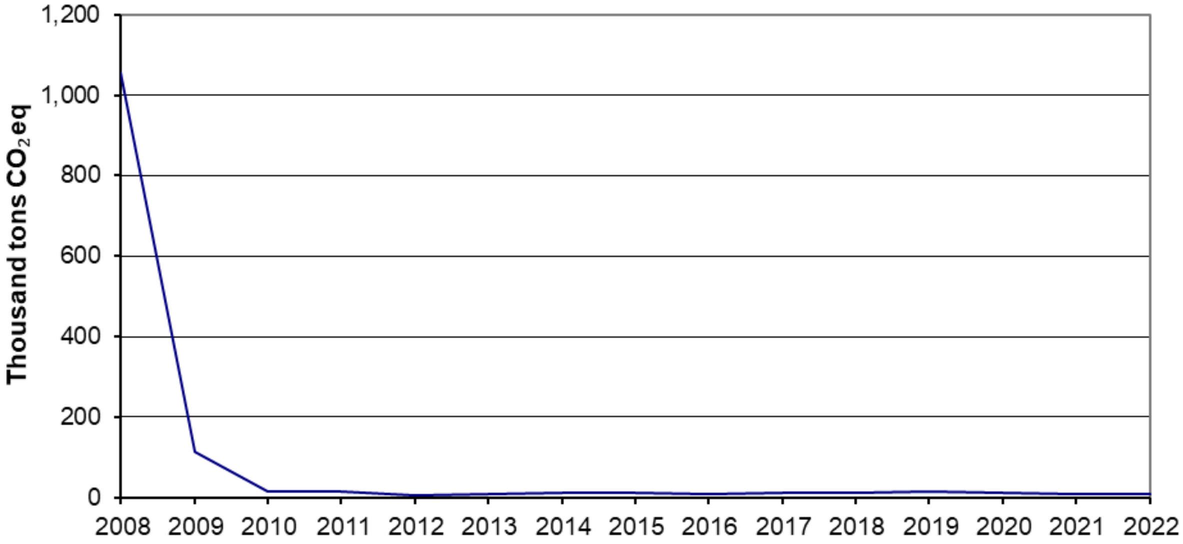
Calculation Method

The emissions were calculated using T3, CS methods from the 1996 IPCC guidelines. The calculation is based on data obtained directly from the companies and the quantities of gases consumed, and an estimate of the relevant gas emissions: SF_6 and HFC-134a.

Emissions

In 2022, emissions from magnesium production and casting were about 0.01 million tons of CO_2eq, which constituted about 0.2% of emissions from product uses as substitutes for ozone-depleting substances. In 2008, emissions sharply decreased due to a switch to other gases with a lower global warming potential factor.

DIAGRAM 4.15 GHG EMISSIONS FROM MAGNESIUM PRODUCTION AND CASTING 2008–2022



4.9.9. Data Limitations

Calculating emissions from product uses as substitutes for ozone-depleting substances is complex and depends on assumptions made during the process.

The process that was developed combines various methods that improve data quality and reduce the uncertainty in the calculation. Thus, customized calculations are performed where data are available, and where data are not available, emissions are calculated based on general assumptions. This method provides the best coverage given the available data and constraints on resources.

The general assumption is that emissions are based on the quantity of gases imported in a given year. Emissions were not calculated based on the consumption data of the systems using the gases themselves, but rather based on the gases intended for these systems.

Disposal – Emissions from the end of use of systems, from their disposal, and from the dissipation of gases remaining in them were not included in the calculation method, except for emissions from vehicle disposal.

Gas Imports in Products – Emissions from the use of products containing gases that are emitted during consumption were not included in the calculation method, except for aerosols such as in medical inhalers. This source is considered relatively small.

Gas Inventory – The stock in gas storage facilities in companies changes from year to year. However, in the calculation method, it was assumed that the stock is offset from year to year, such that significant changes in gas use due to stock changes are not expected. The basis for the calculation is the quantities of gases imported into Israel and the assumption that due to their high cost, all gases were transferred for use in the companies. Therefore, it is important to remember that significant increases or decreases in imports do not necessarily represent an increase or decrease in emissions in that year.

Calculating the Ratio Between Old and New Gases – The ratio between old and new gases is based on the quantity of imports. The quantity of imports can vary in a given year due to economic and operational reasons and due to legislation. The ratio between the gases does not necessarily represent the ratio between the quantities of new and old gases found in the system.

4.10. Future Improvements

Completing Missing Emission Sources

Emissions from the following sources were not included; it is very likely that such emissions were generated in Israel:

- **Use of fuel products not for energy and use of solvents**: use of lubricants, use of paraffin/wax, and use of solvents. Lubricants and paraffin/wax are combusted during use and are a source of CO_2 emissions. There is no information on the consumption of these substances. In Israel, these substances are produced and imported, and possibly also exported.

- **Consumption of various types of carbonate**: in various uses of carbonate (besides those included above), carbon emissions of CO_2 may occur, such as in agriculture, ceramics production, brick and roofing tile production, and environmental pollution control systems.

4.11. Updated Calculations

4.11.1. NMVOC Emissions

The calculation of NMVOC emissions ceased in 2011. In the years it was calculated, it included the following emission sources:

1. **Glass Production**

   The emission calculation was based on the emission factor in the 1996 IPCC guidelines: 4.5 kg NMVOC per ton of glass.

2. **Chemical Industry**

   NMVOC gases are emitted from the chemical industry during the production of various substances. The emission calculation was based on default emission factors from the 1996 IPCC guidelines.

Table 4.5 Emission Factors of NMVOC From the Chemical Industry

1 kg NMVOC **per ton production**

Substance	Emission Factor
Ethylene	1.4
Propylene	1.4
Polyethylene (low-density)	2
Polypropylene	12
Formaldehyde	5

3. **Asphalt Production and Use**

Asphalt is a viscous liquid that occurs naturally in crude oil. It is mixed with other components such as sand and gravel to produce asphalt concrete, used for road surfacing. The asphalt used for this purpose, which is called "bitumen" in many countries, consists of various substances that are combined in refineries to achieve the required hardness.

During asphalt production and use, NMVOC, CO, and SO_2 gases are emitted. NMVOC gases are emitted during asphalt production, road surfacing, and over time from the road surface. Default emission factors were chosen for the calculation. The recommended emission factor in the 1996 IPCC guidelines is 0.023 kg NMVOC per ton of produced asphalt and 320 kg NMVOC per ton of asphalt on the road surface.

Data on asphalt production were obtained from the Fuel and Gas Administration.

4.11.2. Emissions from HNO_3 Production

As mentioned, N_2O emissions from H_2SO_4 production were obtained from company reports. Previously, N_2O emissions were calculated based on the quantities of HNO_3 produced (according to production pressure), which were obtained from the companies active in the field, and based on emission factors. The emission factors according to the 1996 IPCC guidelines are 7 kg N_2O per ton of HNO_3 at medium production pressure and 9 kg N_2O per ton of HNO_3 at high production pressure. NOx emissions were previously calculated according to the 1996 IPCC guidelines: 12 kg NOx per ton of HNO_3.

4.11.3. Emissions from H_2SO_4 Production

As mentioned above, SO_2 emissions from H_2SO_4 production were obtained from company reports. Previously, SO_2 emissions were calculated using a factor of 17.5 kg SO_2 per ton of H_2SO_4, which is the default in the 1996 IPCC guidelines.

5. Chapter 5: Agriculture

5.1. Background

Emissions from agriculture are created from a variety of activities in the animal and plant industries, which include enteric fermentation (fermentation in the digestive system of farm animals), the treatment of animal manure (henceforth: manure management), and the cultivation of agricultural soils (henceforth: agricultural soils), which includes the use of synthetic and organic fertilisers, crop residues in the field, spreading animal manure in the fields, grazing, land use change and organic soil cultivation. These emissions do not include emissions from energy consumption in agriculture, which are included in the energy sector.

5.2. Overview of the Emissions

5.2.1. Total Emissions

In 2022, total GHG emissions from agriculture reached 2.4 million tons of CO_2eq, which were 3.0% of all emissions.

In 2022, emissions of nitrous oxide (N_2O) – direct and indirect – resulting from agricultural soils (use of synthetic and organic fertilisers, crop residues in the field, spreading of manure in the fields, grazing, land use change and organic soil cultivation) reached 0.97 million tons of CO_2eq (39.9% of all emissions from agriculture). Emissions from enteric fermentation amounted to 1.19 million tons of CO_2eq (49.1% of all emissions in agriculture), and emissions from manure management amounted to 0.27 million tons of CO_2eq (11.0% of all emissions from agriculture, 7.2% N_2O emissions and 3.8% CH_4 emissions from this source).

Table 5.1 GHG Emissions From Agriculture, by Source and Gas, 2022

Thousand tons of CO_2eq

Source of Emission \ Gas	**Total**	CO_2	CH_4	N_2O
3. Agriculture	**2,419.3**	**NA**	**1,277.9**	**1,141.4**
A. Enteric fermentation	1,187.0	NA	1,187.0	NA
B. Manure management	266.1	NA	90.9	175.2
C. Rice cultivation	NO	NO	NO	NO
D. Agricultural soils	966.2	NA	NA	966.2
E. Prescribed burning of savannas	NO	NO	NO	NO
F. Field burning of agricultural residues	NE	NA	NE	NE
G. Dispersion of lime	NO	NO	NA	NA
H. Use of urea	NE	NE	NA	NA
I. Other carbon-containing fertilizers	NE	NE	NA	NA
J. Other	NE	NE	NA	NA

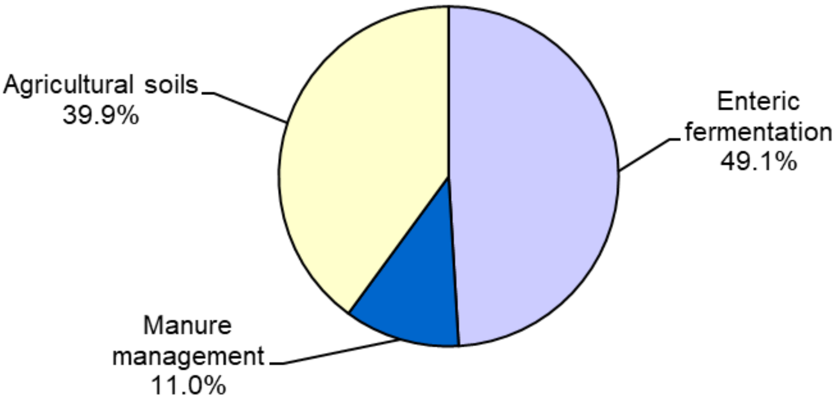
NE = not estimated, NA = not applicable, NO = not occurring

5.2.2. Trends

Greenhouse gas emissions from agriculture increased by 13.6% between 2011 and 2022, and increased by 1.3% between 2021 and 2022. In 2011, the calculation method was updated, and one cannot compare the period before this year with the period after it.

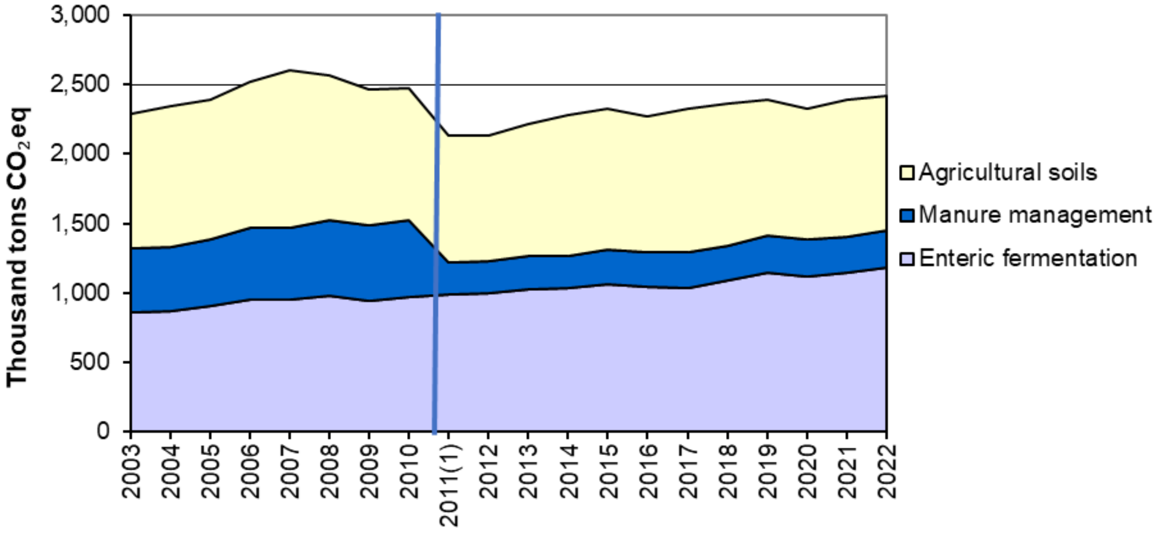
Emissions from agricultural soils, which in 2022 were 39.9% of all emissions in agriculture, increased in this year by 6.3% compared with 2011. Emissions from enteric fermentation and from manure management increased by 19.0% during this period.

DIAGRAM 5.1A. GHG EMISSIONS FROM AGRICULTURE, BY SOURCE 2022



Total
2.4 million tons CO_2e

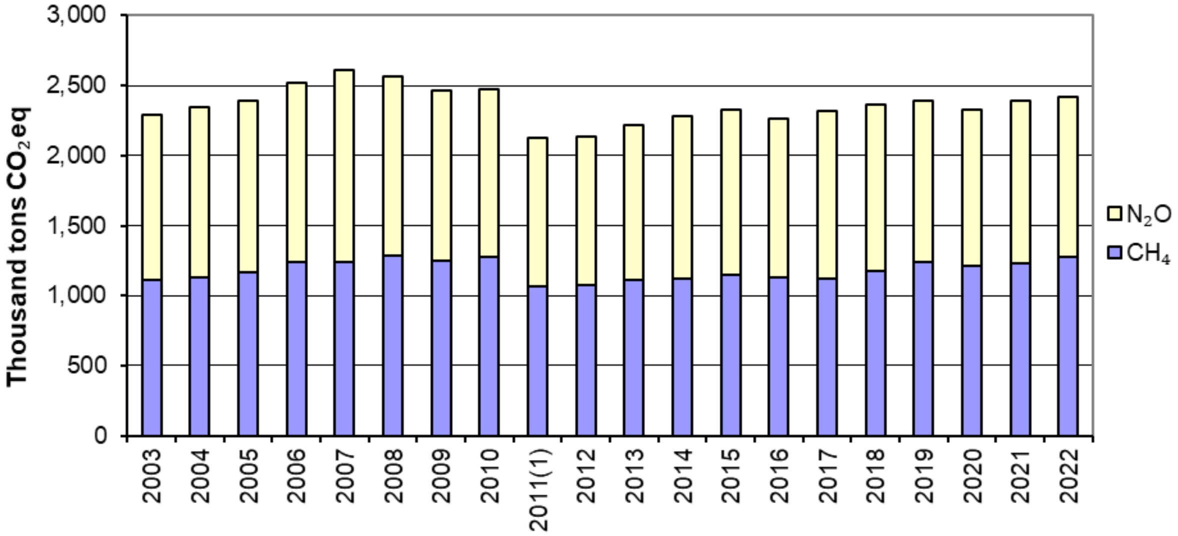
DIAGRAM 5.1B. GHG EMISSIONS FROM AGRICULTURE, BY SOURCE 2003–2022



(1) In 2011 the calculation method was updated.

Emissions from agriculture are divided into nitrous oxide, N_2O (about 47%), and methane, CH_4 (about 53%).

DIAGRAM 5.2 GHG EMISSIONS FROM AGRICULTURE, BY GAS 2003–2022



(1) In 2011 the calculation method was updated.

5.2.3. Sources of Emission

Enteric Fermentation

Methane emissions (CH_4) are a by-product of enteric fermentation, mainly ruminants (for example, cattle and sheep).

In 2022, CH_4 emissions from enteric fermentation was 1.2 million tons of CO_2eq, which were 49.1% of all emissions from agriculture. Of these emissions, 85.6% originated from cattle – dairy cattle (50.2%) and non-dairy cattle (35.4%).

Methane emissions from enteric fermentation are mainly affected by a change in the number of ruminants over the years. These emissions increased between 2011 and 2022 by 20.4%, and between 2021 and 2022 they increased by 3.7%.

Manure Management

During manure management, CH_4 and N_2O are emitted. Methane (CH_4) is emitted during animal manure storage and its treatment under anaerobic conditions; N_2O is emitted directly and indirectly during animal manure storage and handling.

In 2022, emissions from manure management were 266,100 tons of CO_2eq, which were 11.0% of all emissions in agriculture. Most of the emissions from manure management (mainly poultry manure) were direct and indirect emissions of N_2O – 175,200 tons of CO_2eq. Emissions from manure management are affected by a change in the number of animals and the manure management methods. Between 2011 and 2022, emissions increased by 13.2%, and between 2021 and 2022 they increased by 2.7%.

Agricultural Soils

Emissions of N_2O from agricultural soils are created from the following sources: use of synthetic fertilisers, use of organic fertilisers (spreading animal manure on fields, compost, sewage sludge and effluents), crop residues in the field, change in land use and organic soil cultivation.

In 2022, emissions from agricultural soils amounted to 966,200 tons of CO_2eq, which were 39.9% of all emissions from agriculture. In 2022, the main sources of emissions from agricultural soils were the spreading of animal manure in the fields (24.6%), the use of organic fertilisers (compost, sewage sludge and effluents) (18.6%), the use of synthetic fertilisers (16.9%),and crop residues in the field (15.3%) . Emissions of N_2O from agricultural soils increased between 2011 and 2022 by 6.3%, and decreased by 1.9% between 2021 and 2022.

5.3. Calculation Method and Sources of Information

Emissions were calculated using the best available method. The emissions from agricultural soils, which are the main source of emissions, were calculated for 2011–2022 using the IPCC 2006 guidelines default emission factors. In the years before that, the emissions were calculated according to the IPCC 1996 guidelines. The calculation of emissions from enteric fermentation was mostly (about 97%) based on factors adapted to the conditions in Israel.

The calculation of CH_4 emissions from manure management was mostly (about 60%) based on factors adapted to the conditions in Israel. Emissions of N_2O from manure management was based on the IPCC 2006 factors adapted to the management methods in Israel.

Table 5.2 Calculation Methods of GHG Emissions From Agriculture, by Source of Emission and Gas, 2022

Sources of Emission	CO_2	CH_4	N_2O
3. Agriculture			
A. Enteric fermentation	NA	T1 ,T2 ,D	NA
B. Manure management	NA	T1 ,T2 ,D	T2 ,D
C. Rice cultivation	NA	NO	NA
D. Agricultural soils	NA	NA	T1 ,D
E. Prescribed burning of savannas	NO	NO	NO
F. Field burning of agricultural residues	NE	NE	NE
G. Dispersion of lime	NO	NA	NA
H. Use of urea	NE	NA	NA
I. Other carbon-containing fertilizers	NE	NA	NA
J. Other	NE	NA	NA

T1 = Tier 1, T2 = Tier 2, D= IPCC default, NE = not estimated, NA = not applicable, NO = not occurring

5.4. 3.A Enteric Fermentation

5.4.1. CH_4 Emissions

5.4.1.1. Description of the Sources of Emission

Methane (CH_4) is emitted by herbivorous animals as a by-product of fermentation in the digestive process, in which microorganisms break down carbohydrates into simple molecules that are absorbed into the bloodstream. The amount of CH_4 emitted depends on the type of digestive system, the age and weight of the animal, as well as the quality and quantity of its feed.

Emissions were calculated only from farm animals raised by humans, and emissions from animals in the wild were not included.

Type of Digestive System

Ruminant animals (for example, cattle and sheep) are the main sources of emissions from enteric fermentation, since the structure of their intestines allows fermentation of the food. Small amounts of CH_4 that are included in the calculation are emitted from non-ruminant animals (for example, horses and swine).

Food Consumption

Methane is produced from the fermentation of food within the digestive tract of animals. In general, the higher the food consumption, the higher the CH_4 emissions. Food consumption depends on the weight of the animal, its growth rate and the product produced from it (for example, sheep for milk and wool or pregnant animals).

5.4.1.2. Method of Calculation

The calculation of emissions is based on an emission factor of kg CH_4 per head per year for each type of animal. Up until the 2010 inventory (inclusive), the emissions were calculated according to the IPCC 1996 guidelines. From 2011 onwards, the inventories were calculated based on the emission factors from the IPCC 2006 guidelines according to the first Tier (T1), and in some cases unique factors were calculated for Israel according to the second Tier (T2) using detailed information on the breeding characteristics of animals in Israel.

Table 5.3 Emission Factors of CH_4 From Enteric Fermentation

Animals	Inventory 2011–2022 – Factor of kg CH_4 per head per year	Factor source	Inventory until 2010 – Factor of kg CH_4 per head per year	Factor source
Cattle – dairy	163.06	IPCC 2006 T2	148	IPCC 1996, T2
Cattle – non-dairy	33.28	IPCC 2006, T2	42	IPCC 1996, T2
Sheep	8.51	IPCC 2006, T2	8	IPCC 1996, T1
Goats	5	IPCC 2006, T1	5	IPCC 1996, T1
Camels	46	IPCC 2006, T1	46	IPCC 1996, T1
Horses	18	IPCC 2006, T1	18	IPCC 1996, T1
Mules and asses	10	IPCC 2006, T1	10	IPCC 1996, T1
Swine	1.5	IPCC 2006, T1	1.5	IPCC 1996, T1

5.4.1.2.1. Calculation of emission factors for dairy cattle and non-dairy cattle

Emission factors for dairy cattle and non-dairy cattle were calculated based on detailed information received from the Ministry of Agriculture and Rural Development on characteristics of the cattle. The information includes average weight, daily milk yield, growth rate, rate of pregnant cows, milk fat percentage and rearing conditions.

Separate factors were calculated for cattle for each type (see Table 5.4). An individual factor was obtained for each type - kg CH_4 per year per head. A weighted factor for dairy cattle and non-dairy cattle was calculated based on the weighting of the relative part according to the number of heads of each type of cattle.

Table 5.4 Emission Factors of CH_4 From Enteric Fermentation, Dairy Cattle and Non-Dairy Cattle, 2022

Animals – Grouped Type	Animals – Detailed Type	Detailed Factor (kg CH_4 per head per year)
Dairy cattle	Dairy farm, cows after first birth	158.23
Dairy cattle	Dairy farm, mature cows	165.43
Non-dairy cattle	Dairy farm, dry cows	67.09
Non-dairy cattle	Dairy farm, calves	43.25
Non-dairy cattle	Meat, pasture, mothers, age 2–4	90.66
Non-dairy cattle	Meat, pasture, mothers, age 4–10	95.14
Non-dairy cattle	Meat, pasture, rearing cattle	67.75
Non-dairy cattle	Meat, pasture, mature cattle	81.40
Non-dairy cattle	Meat, pasture, male calves	16.49
Non-dairy cattle	Meat, pasture, female calves	16.55
Non-dairy cattle	Meat, corral, male calves from pasture	11.51
Non-dairy cattle	Meat, corral, female calves from pasture	10.48
Non-dairy cattle	Meat, corral, calves from dairy farm	9.45
Non-dairy cattle	Meat, corral, imported calves, age 2–3	12.63
Non-dairy cattle	Meat, corral, imported calves, mature	10.55

The weighted factors obtained are 163.06 kg CH_4 per year per head for dairy cattle and 33.28 kg CH_4 per year per head for non-dairy cattle.

5.4.1.2.2. Calculation of emission factors for sheep

Emission factors for sheep were calculated based on detailed information received from the Ministry of Agriculture and Rural Development on various characteristics of the sheep. The information includes average weight, daily milk yield, growth rate and wool production per day.

Separate calculations were made for the various types of sheep (see Table 5.5). A factor was obtained for each type – kg CH_4 per year per head. A weighted factor calculation was made based on the weighting of the relative part according to the number of heads of each type of sheep.

Table 5.5 Emission Factors of CH_4 From Enteric Fermentation – Sheep

Animals – Detailed Type	Detailed Factor (kg CH_4 per head per year)
Weighted factor	**8.51**
Sheep, milk, female mature	31.82
Sheep, meat, female mature	9.99
Sheep, milk, lambs	5.19
Sheep, meat, lambs	5.93
Sheep, milk, males	10.00
Sheep, meat, males	13.28

5.4.1.3. Calculation of Emission Factors for Other Animals

For goats, camels, horses, mules and asses, and swine, the default IPCC 2006 guidelines (T1) emission factors were selected. The entries were selected from the category of developed countries.

5.4.1.4. Limitations of the Data

The number of animals – there is no current information on the number of camels, horses, donkeys and mules, and swine, and the data are based on estimates.

The emission factors – the emission factors calculated for Israel (dairy cattle and non-dairy cattle and sheep) are weighted factors calculated based on the weighting of the relative part according to the number of heads of each type of animal. Also, the factors were calculated according to the characteristics of the animals (average weight, daily milk yield, etc.) for the year 2011, and were not updated for the following years. It is assumed that these characteristics do not change significantly from year to year.

In the calculation of the emissions from sheep, the number of animals, including adults only, is taken into account, while in the calculation of the emission factors, all types are included.

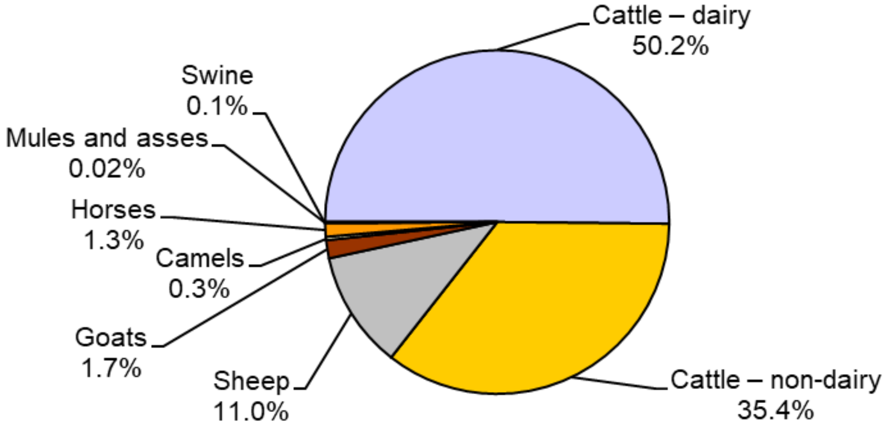
5.4.1.5. Sources of the Information

To calculate the emissions, current data on the number of animals are required, and they were received by the CBS from the animal breeders' organizations and the Ministry of Agriculture and Rural Development.

5.4.1.6. Emissions

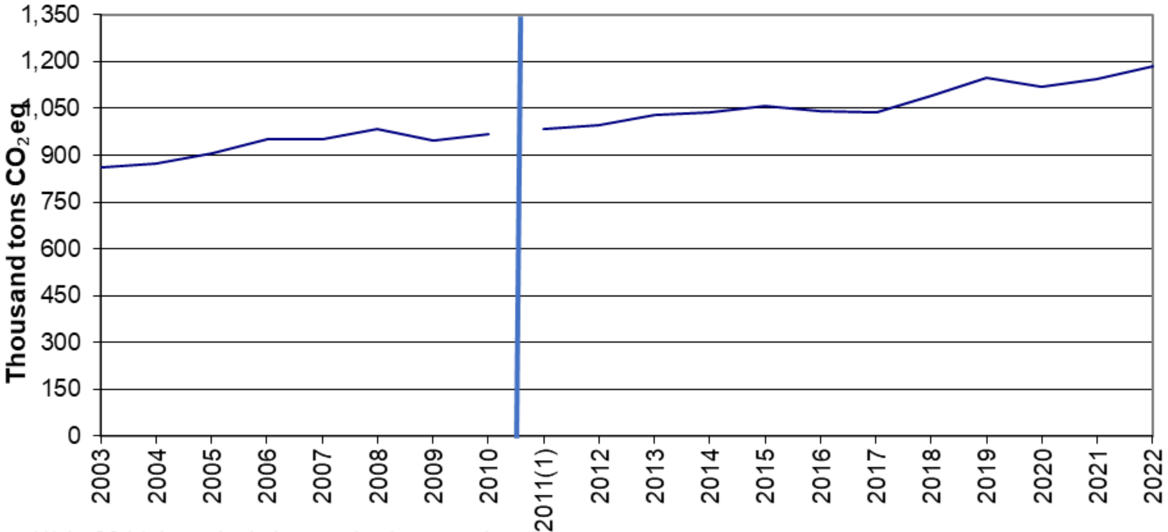
In 2022, CH_4 emissions from enteric fermentation amounted to 1.2 million tons of CO_2eq, which were 49.1% of all emissions from agriculture. Of the emissions from enteric fermentation, 85.6% originate from cattle – dairy cattle (50.2%) and non-dairy cattle (35.4%). Emissions of CH_4 from enteric fermentation are mainly affected by a change in the number of ruminating animals over the years. From 2011 to 2022, the emissions increased by 20.4%, and from 2021–2022 they increased by 3.7%.

DIAGRAM 5.3A. CH_4 EMISSIONS FROM ENTERIC FERMENTATION, BY SOURCE
2022



Total
1.2 million tons CO_2eq

DIAGRAM 5.3B. CH_4 EMISSIONS FROM ENTERIC FERMENTATION
2003–2022



(1) In 2011 the calculation method was updated.

5.5. 3.B Manure Management

5.5.1. Description of the Sources of Emission

In the process of treating animal manure, methane (CH_4) and nitrous oxide (N_2O) are emitted. "Manure" includes both dung and urine (i.e. the solids and liquids) that animals produce.

Methane (CH_4) Emissions

When manure is stored and treated under anaerobic conditions (i.e. in the absence of oxygen), CH_4 is produced. These conditions are even more prevalent when a large numbers of animals are managed in a limited area (for example, barns, cattle pens, swine and poultry farms) and when manure is disposed of in liquid-based systems.

The main factors affecting CH_4 emissions are the amount of manure produced and the portion of manure that decomposes anaerobically. The first factor depends on the waste production rate for all animals and the number of animals, and the second factor depends on how the animal manure is treated. When the manure is stored or treated as a liquid (for example in lagoons, ponds or pits), it decomposes anaerobically and can produce a significant amount of CH_4. The temperature and holding time of the storage unit greatly affect the amount of CH_4 emitted. When manure is handled as a solid (for example in piles) or when it is spread in fields, it is more likely to break down under aerobic conditions, and less CH_4 is emitted.

Nitrous Oxide (N_2O) Emissions

Nitrous oxide (N_2O) is produced directly and indirectly during manure storage and management. Emissions of N_2O from organic fertilisers (spreading animal manure, compost, sewage sludge and effluents), are reported in the category "agricultural soils".

Direct emissions of N_2O occur following combined processes of nitrification and denitrification of nitrogen contained in manure. Emissions of N_2O from manure storage and its management depend on the nitrogen and carbon content of the manure, the duration of its storage and the method of its management. Nitrification (oxidation of ammonia to nitrite) is a necessary condition for N_2O emissions from animal manure storage. Nitrification occurs in animal manure provided there is a supply of oxygen, i.e. it does not occur under anaerobic conditions, where nitrites and nitrogen become N_2O and N_2 in a natural, anaerobic process of denitrification. That is, the production and emissions of N_2O from manure requires nitrites or nitrogen in an anaerobic environment, preceded by aerobic conditions necessary for the creation of these forms of oxidation. Conditions must also exist that prevent the reduction of N_2O to N_2, such as low pH or limited humidity.

Indirect emissions of N_2O result from the loss of volatile nitrogen, which occurs mainly in the forms of ammonia and nitrogen oxides. The part of the organic nitrogen excreted into ammonia during the collection and storage of the manure depends mainly on time and less on temperature. Simple forms of organic nitrogen such as urea (from mammals) and uric acid (from poultry) are quickly converted to ammoniacal nitrogen, which is highly volatile and easily dispersed in the air. Nitrogen loss begins at the point of discharge in other animal breeding areas (for example, dairies), continues in the animal manure storage systems and its management, and is also created from runoff and is leached onto the ground during its storage.

5.5.2. Methane (CH_4) Emissions

5.5.2.1. Method of Calculation

The calculation of emissions is based on an emission factor of kg of CH_4 per head per year for each type of animal. The emission factors were taken from the IPCC 2006 guidelines according to the first Tier (T1) and in some cases unique factors were calculated for Israel according to the second Tier (T2) using detailed information on methods of manure management.

Until the 2010 inventory (inclusive), emissions were calculated according to the IPCC 1996 guidelines. In the 2011 inventory, the calculation method was updated, the emission factors were updated and the IPCC 2006 guidelines were used.

For goats, camels, horses and donkeys and mules the IPCC default factors (T1) were taken. The entries were selected from the category of developed countries. For dairy cattle, non-dairy cattle, sheep and swine, emission factors were calculated according to the unique characteristics of Israel (T2). The calculation of emissions from poultry manure is based on the default factors of the IPCC and their adaptation to the types of poultry.

Table 5.6 Emission Factors of CH_4 From Manure Management

Animals	Inventory 2011–2022 – kg CH_4 per head per year	Factor source	Inventory until 2010 (inclusive) – kg CH_4 per head per year	Factor source
Cattle – dairy	5.60	IPCC 2006, T2	25.09	IPCC 1996, T2
Cattle – non-dairy	1.80	IPCC 2006, T2	6.92	IPCC 1996, T2
Sheep	0.31	IPCC 2006, T2	0.28	IPCC 1996, T1
Goats	0.2	IPCC 2006, T1	0.18	IPCC 1996, T1
Camels	2.37	IPCC 2006, T1	2.40	IPCC 1996, T1
Horses	2.34	IPCC 2006, T1	2.10	IPCC 1996, T1
Mules and asses	1.1	IPCC 2006, T1	1.14	IPCC 1996, T1
Swine	13.68	IPCC 2006, T2	19.26	IPCC 1996, T2
Poultry	0.0251	IPCC 2006, T1	0.117	IPCC 1996, T1

5.5.2.2. Data Limitations

Number of animals – there is no current information on the number of camels, horses, donkeys and mules, and swine, and the data is based on estimates.

Emission factors – the emission factors calculated for Israel (dairy cattle, non-dairy cattle, sheep and swine) are weighted factors calculated based on the weighting of the relative part according to the number of heads of each type of animal. Additionally, the factors were calculated according to the characteristics of the animals for 2011 (average weight, daily milk yield, etc.) and were not updated for subsequent years.

In the calculation of the emissions from sheep, the number of animals includes adults only, while in the calculation of the emission factors all the sheep were included.

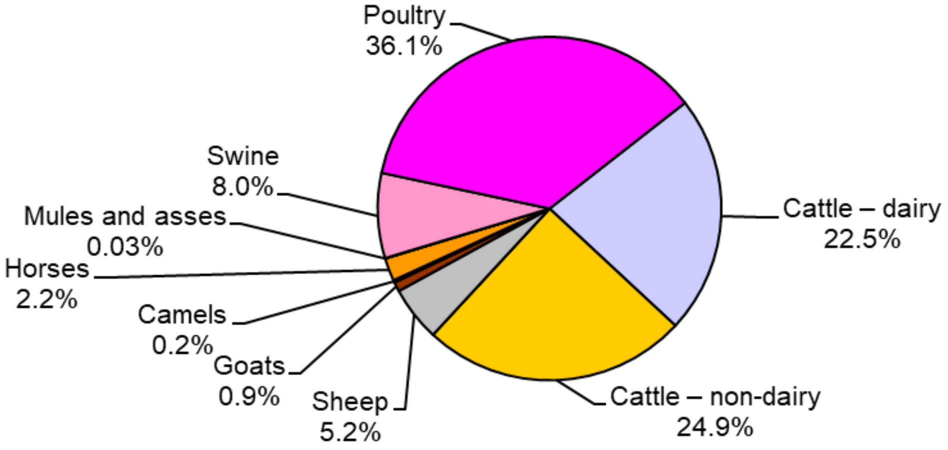
5.5.2.3. Sources of Data

To calculate the emissions, current data on the number of animals are required, and they were received by the CBS from the organizations of animal breeders and the Ministry of Agriculture and Rural Development.

5.5.2.4. Emissions

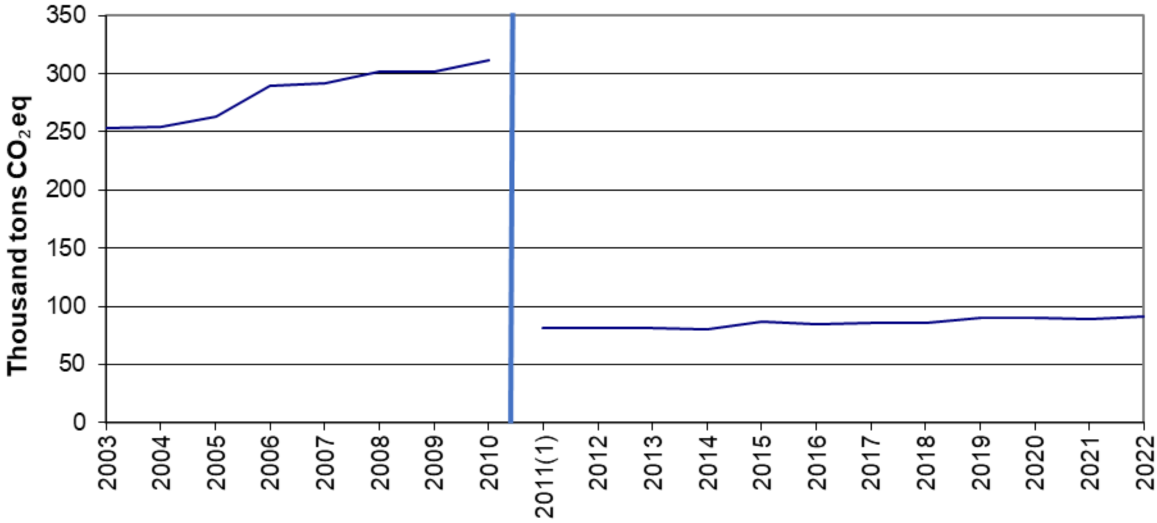
In 2022, CH_4 emissions from manure management were 90,900 tons CO_2eq, which were 3.8% of all emissions in agriculture. Of the emissions from manure management, 47.7% were created from the management of cattle manure – dairy cattle (22.5%) and non-dairy cattle (24.9%), and 36.1% were created from poultry manure. The increase in CH_4 emissions from animal manure management was influenced by the increase in the number of animals. Between 2011 and 2022, emissions increased by 11.2%, and between 2021 and 2022 they increased by 2.4%. In 2011, the calculation method was updated, and it is not possible to compare the period before this year and the period after it.

DIAGRAM 5.4A. CH_4 EMISSIONS FROM MANURE MANAGEMENT, BY SOURCE
2022



Total
0.09 million tons CO_2eq

DIAGRAM 5.4B. CH_4 EMISSIONS FROM MANURE MANAGEMENT
2003–2022



(1) In 2011 the calculation method was updated.

5.5.3. Nitrous Oxide (N_2O) Emissions

5.5.3.1. Method of Calculation

5.5.3.1.1. Direct Emissions

Direct emissions of nitrous oxide (N_2O) were calculated in four steps:

Step A – Calculation of annual nitrogen (N) excreted per head of animal: number of animals multiplied by the weight of the animals multiplied by factors of daily nitrogen (N) excreted per kg for each type of animal.

Step B – Calculation of the nitrogen available in manure for each type of animal and management method: annual nitrogen excreted (N) per head of animal (from Step A) times the proportions of the management method for each type of animal.

Step C – Calculation of the available nitrogen for N_2O emissions: the available nitrogen for each type of animal and management method (from Step B) times the available nitrogen for N_2O emissions factor for each type of animal and management method.

Step D – Calculation of N_2O emissions based on the nitrogen available for N_2O emissions for each type of animal and management method.

The emission factors were taken from the IPCC 2006 guidelines according to the second Tier (T2). The management methods were chosen according to the management methods of each type of animal in Israel.

Up to the 2010 inventory (inclusive), emissions were calculated according to the IPCC 1996 guidelines. In the 2011 inventory, the calculation method, the emission factors and the distribution of management methods were updated, and the IPCC 2006 guidelines were also used. The calculation principles are similar in the various guidelines, but there are differences in the details of the information and the factors.

Table 5.7 Factors of Daily Nitrogen (N) Excreted From Manure Management

Animals	Inventory 2011–2022 – Daily kg nitrogen (N) excreted per 1,000 kg (animal weight) IPCC 2006	Until 2010 inventory (inclusive) – Daily kg nitrogen (N) excreted per head IPCC 1996
Cattle – dairy	0.440	100
Cattle – non-dairy	0.310	70
Sheep	0.420	16
Goats	0.450	20
Camels	0.380	25
Horses	0.300	25
Mules and asses	0.300	25
Swine	0.500	25
Poultry	1.013	0.6

Table 5.8 Factors of Available Nitrogen for N_2O Emissions From Manure Management, by Management Method

Method of Management	Inventory 2011–2022 – kg N_2O-N (kg Nitrogen excreted)	Until 2010 inventory (inclusive) – kg N_2O-N (kg Nitrogen excreted)
Pasture/Range/Paddock	Calculated in "Agricultural Soils”	Calculated in "Agricultural Soils”
Solid Storage	0.005	0.02
Daily Spread	0	0
Dry Lot	0.02	-
Composting – Passive Windrow	0.01	-
Anaerobic Digester	0	-
Liquid Systems	0	0.001
Other	-	0

Table 5.9 Manure Management, by Animal and Method of Management, 2011–2022

Percentages

Animal/ Method of Management	Pasture/ Range/ Paddock	Solid Storage	Daily Spread	Dry Lot	Composting – Passive Windrow	Anaerobic Digester	Liquid Systems
Cattle – dairy	-	35.0	30.0	-	17.5	17.5	-
Cattle – non-dairy	30.1	53.0	7.8	-	4.6	4.6	-
Sheep	78.3	-	-	21.7	-	-	-
Goats	16.7	-	-	83.3	-	-	-
Camels	100.0	-	-	-	-	-	-
Horses	100.0	-	-	-	-	-	-
Mules and asses	100.0	-	-	-	-	-	-
Swine	-	-	-	-	5.5	-	94.5
Poultry	-	69.5	-	14.1	16.4	-	-

Table 5.10 Manure Management, by Animal and Method of Management, Until 2010 (Inclusive)

Percentages

Animal/ Method of Management	Pasture/ Range/ Paddock	Solid Storage	Daily Spread	Dry Lot	Composting – Passive Windrow	Anaerobic Digester	Liquid Systems
Cattle – dairy	-	85	-	-	-	15	-
Cattle – non-dairy	43	38	-	-	-	19	-
Sheep	88	2	-	-	-	-	10
Goats	-	92	-	-	-	-	8
Camels	-	92	-	-	-	-	8
Horses	-	92	-	-	-	-	8
Mules and asses	-	92	-	-	-	-	8
Swine	-	-	-	-	-	100	-
Poultry	-	6	-	-	-	4	90

5.5.3.1.2. Indirect Emissions

Indirect emissions of nitrous oxide (N_2O) were calculated in three steps:

Step A – Calculation of annual nitrogen (N) excreted for each type of animal and management method (which were obtained in Step B of the calculation of the direct emissions above).

Step B – Calculation of the nitrogen volatilised as NH_3 and NO_X: the proportions of the nitrogen volatilised as NH_3 and NO_X for each type of animal and management method times the annual nitrogen (N) excreted (obtained from Step A).

Step C – Calculation of the nitrogen available for N_2O emissions: the nitrogen volatilised for each type of animal and management method (from Step B) times the factor of nitrogen available for N_2O emissions for each type of animal and management method.

kg N_2O–N (kg NH_3–N + NO_X–N volatilised) = 0.01

Step D – Calculation of N_2O emissions based on the nitrogen available for emission.

The emission factors were taken from the IPCC 2006 guidelines according to the second Tier (T2). The distribution of methods of management of animal manure by type of animal were determined according to the management methods in Israel.

Up to the 2010 inventory (inclusive), emissions were calculated according to the IPCC 1996 guidelines. In the 2011 inventory, the calculation method, the emission factors and the distribution of management methods were updated, and the IPCC 2006 guidelines were also used. The calculation principles are similar in the various guidelines, but there are differences in the details of the information and the factors.

Table 5.11 Proportions of Nitrogen Volatilised as NH_3 and NO_X, by Animal and Method of Management, 2011–2022

Percentages

Animal/ Method of Management	Pasture/ Range/ Paddock	Solid Storage	Daily Spread	Dry Lot	Composting – Passive Windrow	Anaerobic Digester	Liquid Systems
Cattle – dairy	-	30	7	-	0	35	-
Cattle – non-dairy	-	45	7(1)	-	0	35	-
Buffalo	-	-	-	-	-	-	-
Sheep	-	-	-	20(1)	-	-	-
Goats	-	-	-	20(1)	-	-	-
Camels	-	-	-	-	-	-	-
Horses	-	-	-	-	-	-	-
Mules and asses	-	-	-	-	-	-	-
Swine	-	-	-	-	0	-	48
Poultry	-	-	7(1)	20	0	-	-

(1) Determined according to another animal in the absence of a factor.

5.5.3.2. Limitations of the Data

The number of animals – There is no current information on the number of camels, horses, mules and asses, and the data is based on estimates. The number of these animals is relatively small.

The emission factors – The emission factors calculated for Israel were weighted factors calculated based on the weighting of the relative proportion according to the number of heads of each type of animal. Additionally, the factors were calculated according to the characteristics and distribution of the management methods in 2011 and were not updated for subsequent years.

5.5.3.3. Sources of Information

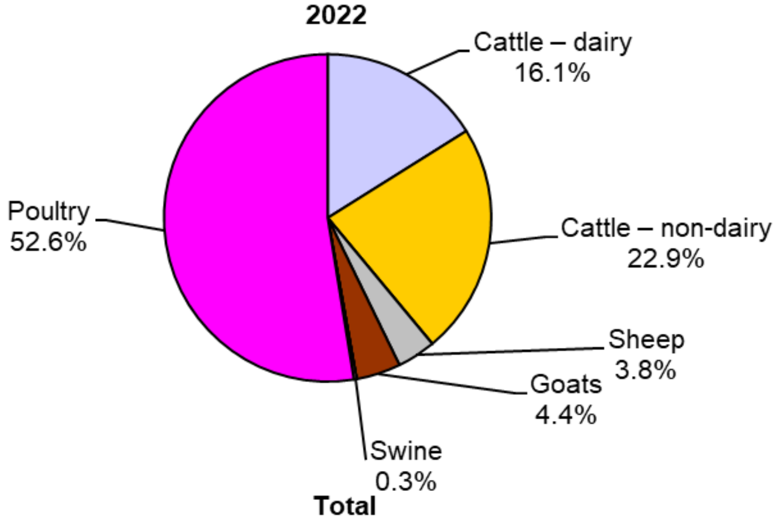
To calculate the emissions, current data on the number of animals are required, and they were received by the CBS from the organizations of animal breeders and the Ministry of Agriculture and Rural Development.

5.5.3.4. Nitrous Oxide Emissions (N_2O)

In 2022, N_2O emissions (direct and indirect) from manure management were 175,200 tons of CO_2eq, which were 7.2% of all emissions in agriculture. Of these emissions, 52.6% were from the poultry manure management, and 39.0% were from cattle manure management – dairy cattle (16.1%) and non-dairy cattle (22.9%).

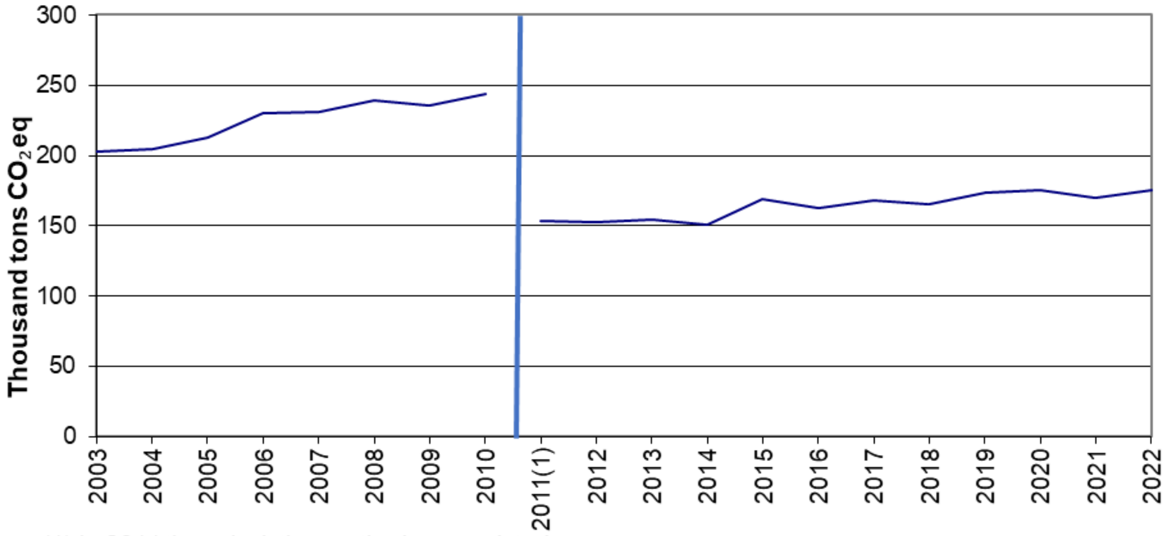
Emissions of N_2O from animal manure management are affected by the change in the number of animals. Between 2011 and 2022, emissions increased by 14.3%, and between 2021 and 2022 they increased by 2.9%.

DIAGRAM 5.5A. N_2O EMISSIONS FROM ANIMAL MANURE MANAGEMENT, BY SOURCE
2022



Total
0.18 million tons CO_2eq

DIAGRAM 5.5B. N_2O EMISSIONS FROM ANIMAL MANURE MANAGEMENT
2003–2022



(1) In 2011 the calculation method was updated.

5.6. 3.C Cultivation of Rice

There is no rice cultivation in Israel.

5.7. 3.D Agricultural Soils

5.7.1. Emissions of Nitrous Oxide (N_2O)

5.7.1.1. Description of Emission Sources

This section presents the anthropogenic (direct and indirect) emissions of N_2O from the cultivation of agricultural soils.

Nitrous oxide is naturally produced in the soil through the processes of nitrification and denitrification. Nitrification is the aerobic oxidation of ammonium to nitrate, and denitrification is the anaerobic bacterial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is an intermediate gaseous product in the sequence of denitrification reactions and a by-product of nitrification that leaks from microbial cells into the soil and eventually into the atmosphere. One of the main factors controlling this reaction is the availability of inorganic nitrogen in the soil.

In the current calculation method, N_2O emissions are estimated based on the net additions of nitrogen to the soil due to human activity (e.g., synthetic or organic fertilisers, manure, crop residues, sewage sludge) and due to the mineralisation of nitrogen present in organic materials in the soil, which occurs after changes in land use or the cultivation of organic soils.

Nitrous oxide emissions resulting from anthropogenic nitrogen inputs or nitrogen mineralisation occur both through a direct pathway (i.e., directly from the soils to which the nitrogen is added or released) and through two indirect pathways: (1) following the volatilisation of NH_3 and NO_X from the cultivation of agricultural soils and from fossil fuel combustion and biomass burning, and the redeposition of these gases and their products – $^+NH_4$ and $^-NO_3$ – onto soils and water; (2) following the leaching and runoff of nitrogen, mainly as $^-NO_3$, from cultivated soils. Direct and indirect emissions of N_2O from the cultivation of agricultural soils are estimated separately but using a common database.

In most soils, an increase in nitrogen availability accelerates the rate of nitrification and denitrification and thereby increases N_2O production. The available nitrogen can increase due to nitrogen additions from human activities or from changes in land use.

Direct and indirect emissions from the cultivation of agricultural soils arise from the following sources: the use of synthetic fertilisers, the use of organic fertilisers (animal manure, compost, sewage sludge), crop residues in the field, the cultivation of organic soils, and changes in land use.

5.7.1.2. Calculation Method

Nitrous oxide emissions from agricultural soils result from an increase in nitrogen availability in the soil. The estimate of the added nitrogen was calculated based on activity data (quantities of fertilisers, manure, etc.) and on coefficients for estimating the available nitrogen for N_2O production. Finally, the emissions were calculated based on the nitrogen estimate and the molar ratio between nitrogen and oxygen in N_2O emissions.

5.7.1.2.1. Emissions From the Use of Synthetic Fertilisers

Emissions from the use of synthetic fertilisers were calculated as follows:

Step A – Calculation of the amount of nitrogen in fertilisers spread on the soil in a given year.

Step B – Multiplication of the amount of nitrogen by emission factors: Direct emissions were calculated based on the nitrogen concentration in the fertilisers and indirect emissions were calculated based on the relative proportion of volatilised nitrogen and the relative proportion that was leached.

The emission factors were taken from the IPCC 2006 guidelines according to Tier 1 (T1).

Table 5.12 Direct and Indirect Emission Factors From the Use of Synthetic Fertilisers

Emission Type	Description	Units of Measurement	Inventory 2011–2022 – Emission Factors
Direct	Coefficient for available nitrogen for N_2O production	[kg N_2O-N (kg N input)-1]	0.0100
Indirect	Proportion of nitrogen volatilised	(kg NH_3-N + NO_X -N) (kg of N applied)-1	0.1000
Indirect	N_2O emission factor from the volatilisation of N from the cultivation of agricultural soils	(kg N_2O-N) (kg NH_3-N + NO_X -N volatilised)-1	0.0100
Indirect	Proportion of nitrogen leached	[kg N (kg of N additions)-1]	0.3000
Indirect	N_2O emission factor from the leaching of N from the cultivation of agricultural soils	[kg N_2O-N (kg N leaching and runoff)$^{-1}$]	0.0075

5.7.1.2.2. Emissions From Organic Fertilisers (Spreading Animal Manure, Compost, Sewage Sludge, and Effluents)

Emissions from organic fertilisers (spreading animal manure, compost, sewage sludge, and effluents) were calculated as follows:

Step A – Calculate the amount of available nitrogen in organic fertilisers applied to the soil in a specific year:

The estimate of nitrogen emissions from animal manure was obtained from the stage of calculating emissions from manure management. The available nitrogen in animal manure was multiplied by 1 minus the fraction of nitrogen lost during manure management, resulting in the amount of nitrogen available to the soil.

Table 5.13 Proportion of Nitrogen Lost During the Stage of Animal Manure Management, by Animal and Management Method, 2011–2022

Percentages

Animal/ Method of Management	Pasture/ Range/ Paddock	Solid Storage	Daily Spread	Dry Lot	Composting – Passive Windrow	Anaerobic Digester	Liquid Systems
Cattle – dairy	-	40	22	-	100	77	-
Cattle – non-dairy	-	50	22(1)	-	100	77	-
Sheep	-	-	-	(1)30	-	-	-
Goats	-	-	-	(1)30	-	-	-
Camels	-	-	-	-	-	-	-
Horses	-	-	-	-	-	-	-
Mules and asses	-	-	-	-	-	-	-
Swine	-	-	-	-	100	-	48
Poultry	-	-	22(1)	(1)30	100	-	-

(1) Determined according to another animal in the absence of a factor.

Estimation of nitrogen from sewage sludge was calculated based on the quantities of sewage sludge sent for recycling, multiplied by 23 kg of nitrogen per ton of sludge (data provided by the Ministry of Environmental Protection).

Estimation of nitrogen from compost was calculated based on the quantities of organic material and prunings that underwent composting. Here is the nitrogen estimation from compost in percentages:[1] prunings – 0.7%, household waste – 1.3%, pomace – 22%.

Estimation of nitrogen from treated wastewater used for irrigation was calculated in the chapter "Waste and Sewage," and it is based on the quantities of effluents used for irrigation and their nitrogen concentration.

Step B – Calculation of available nitrogen for N_2O emissions: The available nitrogen (from Step A) multiplied by the available nitrogen factor for N_2O emissions from each source.

Step C – Calculation of N_2O emissions based on the available nitrogen for emission.

The emission factors were taken from the IPCC 2006 guidelines according to the first Tier (T1).

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[1] From: Ben HaGai N., and others. "Characterization of organic materials for agriculture", Alon Hanotea (Planter Bulletin) 65, 16–20. (Hebrew only).

Table 5.14 Direct and Indirect Emission Factors From the Use of Organic Fertilisers (Spreading Animal Manure, Compost, Sewage Sludge, and Effluents)

Emission Type	Description	Units of Measurement	Inventory 2011–2022 – Emission Factors
Direct	Coefficient for available nitrogen for N_2O production	[kg N_2O-N (kg N input)-1]	0.0100
Indirect	Proportion of nitrogen volatilised	(kg NH3-N + NO_X -N) (kg of N applied or deposited)-1	0.2000
Indirect	N_2O emission factor from the volatilisation of N from the cultivation of agricultural soils	(kg N2O-N) (kg NH3-N + NO_X -N volatilised)-1	0.0100
Indirect	Proportion of nitrogen leached	[kg N (kg of N additions)-1]	0.3000
Indirect	N_2O emission factor from the leaching of N from the cultivation of agricultural soils	[kg N_2O-N (kg N leaching and runoff)$^{-1}$]	0.0075

5.7.1.2.3. Emissions From Grazing

The distribution of manure management methods by animal type is detailed above in Table 5.9. Emissions from grazing were calculated as follows:

Step A – Calculation of the amount of nitrogen from grazing applied to the soil in a specific year (obtained from the step of calculating emissions from manure management).

Step B – Multiplication by emission factors. Direct emissions were calculated based on the nitrogen content in the material, and indirect emissions were calculated based on the relative amount of volatilised and leached nitrogen.

Emission factors were taken from the IPCC 2006 guidelines according to Tier 1 (T1).

Table 5.15 Emission Factors From Grazing by Animal Type

Animal	Emission Type	Description	Units of Measurement	Inventory 2011–2022 – Emission Factors
Cattle	Direct	Coefficient for available nitrogen for N_2O production	[kg N_2O-N (kg N input)-1]	0.0100
Sheep, Goats, Camels, Horses, Donkeys	Direct	Emission factor for available nitrogen for N_2O production	[kg N_2O-N (kg N input)-1]	0.0200
Total	Indirect	Proportion of nitrogen volatilised	(kg NH3-N + NO_X -N) (kg of N applied or deposited)-1	0.2000
Total	Indirect	N_2O emission factor from the volatilisation of N from the cultivation of agricultural soils	(kg N2O-N) (kg NH3-N + NO_X -N volatilised)-1	0.0100
Total	Indirect	Proportion of nitrogen leached	[kg N (kg of N additions)-1]	0.3000
Total	Indirect	N_2O emission factor from the leaching of N from the cultivation of agricultural soils	[kg N_2O-N (kg N leaching and runoff)$^{-1}$]	0.0075

5.7.1.2.4. Emissions From the Cultivation of Organic Soils

Emissions from the cultivation of organic soils were calculated based on the area of organic soils in Israel and multiplying it by the coefficient for available nitrogen for oxidation.

Emission factors were taken from the IPCC 2006 guidelines according to Tier 1 (T1).

Table 5.16 Direct and Indirect Emission Factors From the Cultivation of Organic Soils

Emission Type	Description	Units of Measurement	Inventory 2011–2022 – Emission Factors
Direct	Coefficient for available nitrogen for N_2O production	kg N_2O-N ha-1 yr-^{1}	8

5.7.1.2.5. Emissions From Crop Residues in the Field

Emissions from crop residues in the field were calculated based on the estimated nitrogen in crop residues (above-ground and below-ground) and multiplying it by the emission factors.

The available nitrogen was calculated as follows:

Step A – Calculate the area and annual crop amounts by crop type:

Grains, Beans & Pulses, Tubers, Root Crops, N-Fixing, Non-N-Fixing, Forages, Perennial Grasses, Grass-Clover Mixtures, Wheat, Barley, Maize, Other.

Step B – Calculate the dry matter above-ground and below-ground.

Step C – Calculate the available nitrogen above-ground and below-ground.

Then the available nitrogen was multiplied by the emission factors. Direct emissions were calculated based on the amount of nitrogen, and indirect emissions were calculated based on the relative amount of volatilised and leached nitrogen.

Emission factors were taken from the IPCC 2006 guidelines according to Tier 1 (T1).

Table 5.17 Direct and Indirect Emission Factors From Crop Residues in the Field

Emission Type	Description	Units of Measurement	Inventory 2011–2022 – Emission Factors
Direct	Coefficient for available nitrogen for N_2O production	[kg N_2O-N (kg N input)-1]	0.0100
Indirect	Proportion of nitrogen leached	[kg N (kg of N additions)-1]	0.3000
Indirect	N_2O emission factor from the leaching of N from the cultivation of agricultural soils	[kg N_2O-N (kg N leaching and runoff)$^{-1}$]	0.0075

5.7.1.2.6. Emissions From Land-Use Changes

There is a close relationship between the quantities of carbon (C) and nitrogen (N) in soil organic matter. Land-use changes or cultivation cause the loss of soil carbon (due to oxidation processes), resulting in the loss of nitrogen through mineralization processes. This nitrogen is available for N_2O emissions.

In the same way that nitrogen released from the decomposition of crop residues becomes a source of N_2O emissions, so too, nitrogen from land-use changes becomes a source of N_2O emissions. The same default emission factor, which is applied to nitrogen causing direct emissions from fertiliser and nitrogen inputs into agricultural soils, is also applied to nitrogen from land-use changes. This is because the ammonium and nitrate resulting from the mineralization of organic materials in the soil are equally available as substrates for microorganisms producing N_2O through nitrification and denitrification, regardless of whether the nitrogen originates from the loss of soil organic matter due to land use, changes in cultivation, decomposition of crop residues in the field, or the use of synthetic fertilisers.

The amount of available nitrogen from land-use changes was calculated in two steps: In the first step, the average annual carbon loss (tons) in land use was calculated, and in the second step, based on this amount, the available nitrogen from land-use changes was calculated.

Step A – Calculation of the average annual amount of carbon (tons) lost in land use. Only negative values indicating lost carbon were taken.

$$\Delta\text{C Mineral} = \frac{\text{SOC}_0 - \text{SOC}_{(0-T)}}{D}$$

$$\text{SOC} \quad = \sum_{c,s,i} \left(\text{SOC}_{REF_{c,s,i}} \times \text{F}_{LU_{c,s,i}} \times \text{F}_{MG_{c,s,i}} \times \text{F}_{I_{c,s,i}} \times \text{A}_{c,s,i} \right)$$

Table 5.18 Emission Factors From Land-Use Changes – Change in Organic Carbon Stock

Description	Name
Annual change in carbon stock in mineral soils (tons of carbon)	ΔC Mineral
Organic carbon stock in the soil in the last year (tons of carbon)	SOC_0
Organic carbon stock in the soil at the beginning of the inventory period (tons of carbon)	$\text{SOC}_{(0\text{-}T)}$
Calculation period (years)	T
Time to equilibrium (default value of 20 years)	D
C – Climate regions (in Israel - hot and dry) S – Soil types: Volcanic soils Low activity clay soils (LAC soils) Sandy soils High activity clay soils i – Soil management system	C S i
Carbon stock per year tons of carbon per area (hectare) (by soil type and climate)	SOC_{REF}
F_{LU} – Stock change factor by soil type and climate	F_{LU}
F_{MG} – Stock change factor according to soil management by soil type and climate	F_{MG}
F_{I} – Stock change factor for organic material input by soil type and climate	F_{I}
Area of the evaluated soil layer (hectare)	A

Step B – After calculating the average annual amount of carbon (tons) lost in land use, the available nitrogen due to carbon loss was calculated.

$$\mathbf{F_{SOM}} = \sum_{LU}\left[\left(\mathbf{\Delta C_{Mineral,\mathit{LU}}} \times \frac{\mathbf{1}}{\boldsymbol{R}}\right) \times \mathbf{1000}\right]$$

Table 5.19 Emission Factors From Land-Use Changes – Available Nitrogen Due to Carbon Loss

Description	Name
Net annual amount of nitrogen (kg) mineralized in mineral soils due to carbon loss from land-use changes or cultivation	F_{SOM}
Average annual amount of carbon (tons) in soil lost in each type of land use ($\Delta C_{Mineral}$, LU). LU is calculated separately for different soil types and various land-use changes	LU, ΔC Mineral
C:N ratio of soil organic matter. A default value of 10 was chosen for cultivated agricultural soils still being cultivated (compared to change from forests to cultivated soils)	R

5.7.1.3. Limitations of Data

Synthetic Fertilisers: The amount of nitrogen in fertilisers consumed in a specific year was calculated based on the amount of fertilisers sold in a specific year. There may be a discrepancy between the two due to inventory changes.

Organic Fertilisers (Compost and Sewage Sludge): The estimated quantities of nitrogen spread are based on the quantities of recycled compost and sewage sludge, which may not necessarily have been used in the investigated year.

Crop Residues in the Field: Some of the crop areas are updated once every several years.

Land-Use Changes: The distribution of crop types and soil types is for 2011, assuming there was no significant change since then. Some of the crop areas are updated once every several years.

5.7.1.4. Sources of Information

These are the sources for the current data required for emission calculations:

Synthetic Fertilisers: The amount of fertilisers consumed in a specific year was calculated based on the amount of fertilisers sold in a specific year according to a survey conducted in the Senior Sector of Agriculture, Environment, and Energy at the Central Bureau of Statistics.

Sewage Sludge: Data on the amount of sludge sent for recycling were obtained from the Ministry of Environmental Protection.

Organic Fertilisers and Compost: Data on the amount of organic material and compost were obtained from the Recycling Survey at the Central Bureau of Statistics.

Manure From Grazing: Data were obtained based on the number of animals received at the Central Bureau of Statistics from organizations of animal breeders and the Ministry of Agriculture and Rural Development, based on the proportion of grazing animals among them.

Cultivation of Organic Soils: The data refer to the area of Hula Valley soils in northern Israel.

Crop Residues in the Field: Crop areas and crop quantities for each year were obtained from the Senior Sector of Agriculture, Environment, and Energy at the Central Bureau of Statistics, where the information is collected from various administrative sources.

Mineral Soils: Crop areas and crop quantities for each year were obtained from the Senior Sector of Agriculture, Environment, and Energy at the Central Bureau of Statistics. Historical data were obtained from previous publications of the Central Bureau of Statistics.

5.7.1.5. Emissions

In 2022, N_2O emissions (direct and indirect) from the cultivation of agricultural soil were 966,200 tons CO_2eq, accounting for 39.9% of total agricultural emissions.

Emissions of N_2O from the cultivation of agricultural soil are influenced by increases or decreases in crop production, fertiliser sources, and livestock numbers. Between 2011 and 2022, emissions increased by 6.3%, and between 2021 and 2022, they decreased by 1.9%.

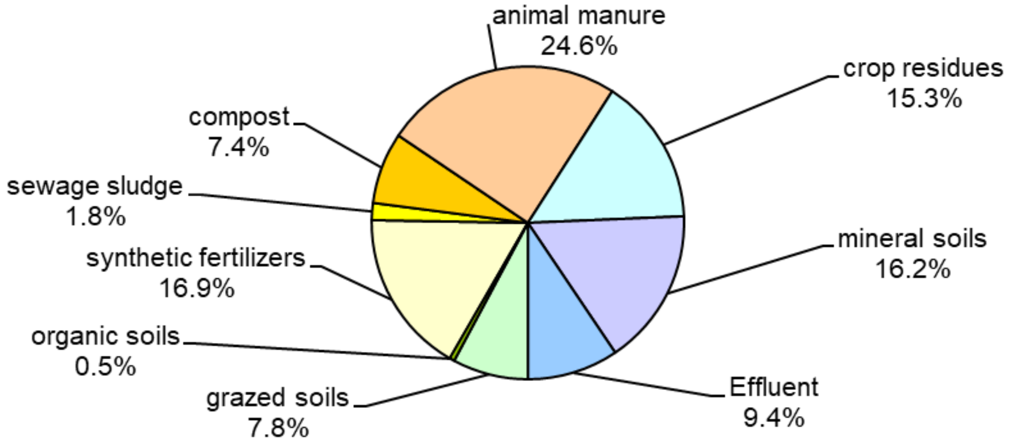


DIAGRAM 5.6A. N_2O EMISSIONS FROM AGRICULTURAL SOIL CULTIVATION, BY SOURCE 2022

Total
0.97 million tons CO_2eq

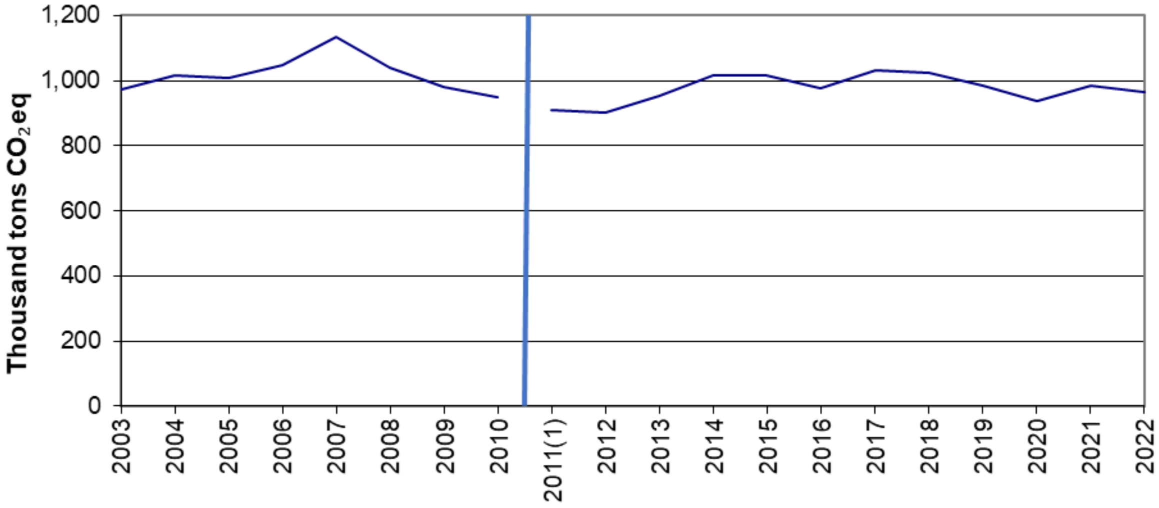


DIAGRAM 5.6B. N_2O EMISSIONS FROM AGRICULTURAL SOIL CULTIVATION 2003–2022

(1) In 2011 the calculation method was updated.

5.8. 3.F Field Burning of Agricultural Residues

Emissions from the field burning of agricultural residues were not calculated because there is no information on the extent of the burning.

5.9. 3.G Dispersion of Lime

Description of the Sources of Emissions

Lime is used to reduce soil acidity and improve plant growth in cultivated systems, especially agricultural soils and cultivated forests. Adding carbonate (limestone) to soils in the form of lime (e.g., calcitic limestone [$CaCO_3$] or dolomite [$CaMg(CO_3)_2$]) leads to CO_2 emissions: The carbonate in the lime dissolves, releasing bicarbonate, which then develops into CO_2 and water (H_2O).

Lime is not used in Israel for soil improvement. In the past, gypsum was added for a different purpose (improving sodic soils), but this process is not relevant for CO_2 emissions.

5.10. 3.H Use of Urea

Description of the Sources of Emissions

Adding urea to soils during fertilisation causes CO_2 loss. In the process of urea ($CO[NH_2]_2$) decomposition, CO_2 and water are released, similar to the soil reaction to lime application.

At this stage, the extent of urea use in Israeli agriculture is unknown, and emissions from it have not been calculated.

5.11. Future Improvements

Updating Emission Factors for Enteric Fermentation of Animals and Manure Management

As mentioned, some of the emission factors calculated for Israel (e.g., dairy cows or non-dairy cattle) are weighted factors based on information from 2011:

- The relative proportion by head count of each animal type
- Animal characteristics – average weight, daily milk yield, etc.
- Distribution of manure management methods for each animal type

The calculation of emission factors needs to be updated according to current conditions for the inventory year.

Completing Missing Emission Sources

Emissions from the use of urea were not included. Urea is marketed and used in Israel, and its usage amounts need to be assessed, and emissions from it should be calculated accordingly.

Emissions from the field burning of agricultural residues were not calculated because there is no information on the extent of the burning. In the Ministry of Environmental Protection there are estimates of the extent of the emissions, however, they need to be examined and the way in which they can be used.

6. Chapter 6: Land Use Change and Forestry

6.1. Overview of Emissions

6.1.1 Total Emissions

Sinks from forest land come from forest growth and carbon sinks, while emissions from forest land come from harvested wood products (tree felling) and the cultivation of organic soils. In 2022, the net sum of GHG sinks (sinks minus emissions) from the land use change and forestry sector came to 285,800 tons of CO_2eq.

Table 6.1 GHG Emission Sources and Sinks From Land Use Change and Forestry, by Source and Gas, 2022

Thousand tons of CO_2eq

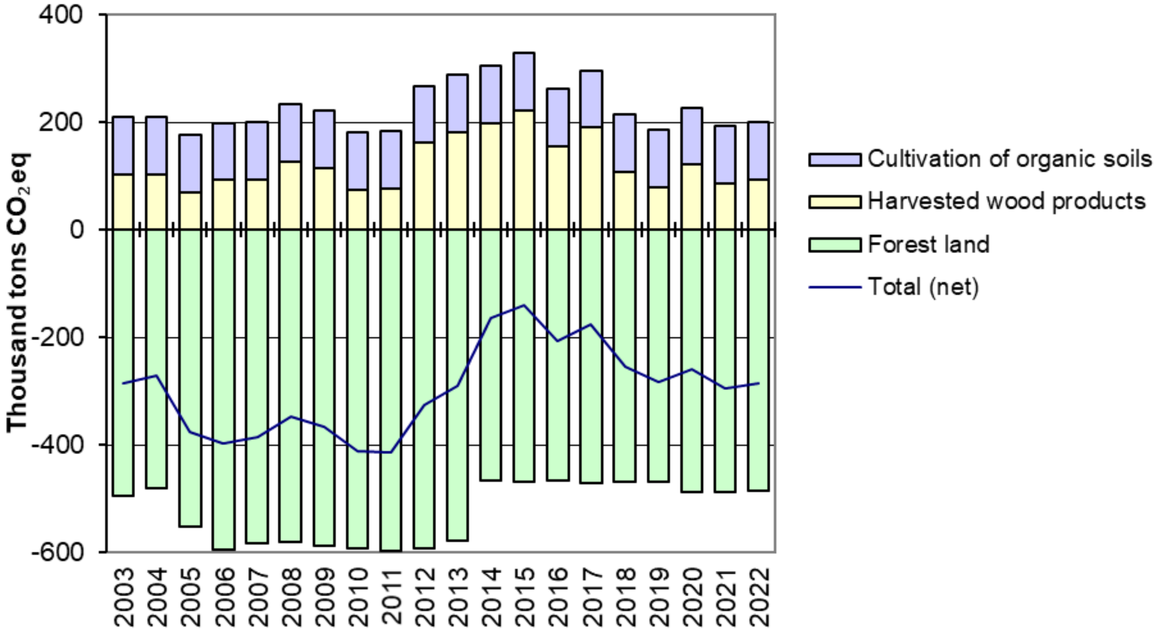
Source and Sink/ Gas	Total	N_2O	CH_4	CO_2
4. Land use change and forestry	**-285.8**	**NE**	**NE**	**-285.8**
A. Forest land	-486.3	NE	NE	-486.3
B. Cropland	NE	NE	NE	NE
C. Grassland	NE	NE	NE	NE
D. Wetlands	NE	NE	NE	NE
E. Settled areas	NE	NE	NE	NE
F. Other land	NE	NE	NE	NE
G. Harvested wood products	93.8	NA	NA	93.8
H. Other (cultivation of organic soils)	106.6	NA	NA	106.6

NE = not estimated, NA = not applicable

6.1.2 Trends

Between 2003 and 2022, sinks from land use change and forestry fluctuated, with an average sink of approximately 300,000 tons of CO_2eq each year during this period.

DIAGRAM 6.1 EMISSIONS FROM LAND USE CHANGE AND FORESTRY, BY SOURCE 2003–2022



6.1.3 Emission Sources

CO_2 emissions come from the use of harvested wood products, which releases the carbon stored in the wood. Another source of emissions is the cultivation of organic soils, during which carbon is released. On the other hand, carbon sinks occur from forest growth.

6.2. Calculation Method and Sources of Information

The emissions were calculated according to the methods recommended in the IPCC 1996 guidelines, after adapting them to the conditions in Israel. The calculation of sinks in forestry was based on the growth rate according to assessments obtained from the Jewish National Fund (JNF), which is responsible for managing the planted forests in Israel.

Table 6.2 Methods of Calculating Emission Sources and Sinks From Land Use Change and Forestry, by Emission Source and Gas, 2022

Source and Sink/ Gas	N_2O	CH_4	CO_2
4. Land use change and forestry			
A. Forest land	NE	NE	D ,T1/CS
B. Cropland	NE	NE	NE
C. Grassland	NE	NE	NE
D. Wetlands	NE	NE	NE
E. Settled areas	NE	NE	NE
F. Other land	NE	NE	NE
G. Harvested wood products	NA	NA	T1/D
H. Other (cultivation of organic soils)	NA	NA	D ,T1

T1 = tier 1, CS = Country-specific, D = IPCC default, NE = not estimated, NA = not applicable

6.3. 4.A Forest Land

6.3.1 Description of Sinks

Trees in forests take in CO_2 from the atmosphere during the process of photosynthesis.

6.3.2 Calculation Method

Forest growth – the sinks from forest growth were calculated based on the forest area and its rate of growth, and in accordance with the methods recommended in the IPCC 1996 guidelines.

The rate of growth of tree biomass was calculated according to the type of forest. For each forest type, the forest area was multiplied by its growth rate. Table 6.3 shows the growth rate ranges, from which averages were taken for the calculation.

Table 6.3 Rate of Forest Growth, by Type of Forest, 2022

cubic meter per year per hectare

Type of Forest	Growth Rate Ranges
Planted forest – eucalyptus	0.2–0.9
Planted forest – coniferous	0.2–0.7
Planted forest – broadleaf and others	0.01–0.3
Natural forest – dense and sparse	0.01–0.1

$$\text{Emissions} = \text{Area of Forest} \times \text{AG} \times 0.45 \times 44/12$$

Emissions – Emissions or sinks from forest growth (thousand tons of carbon dioxide)

Area of Forest – thousand hectares

AG – growth rate factor (Ton of dry matter meter per year per hectare)

0.45 – carbon fraction stored in the tree

44/12 – conversion to CO_2

6.3.3 Sources of Information

Forest area

Until 2013, the data on forest area were obtained from reports of the JNF and the Israel Nature and Parks Authority (INPA).

In 2014, the area data were updated based on work done in the Geography and GIS Sector of the CBS, in which the forest area data underwent a process of data cleansing and areas without trees were deducted.

The JNF's geographic forest layer contains both planted forests and natural groves. Areas without trees or with scarcely any trees were removed from the planted forest layer, leaving 68,206 hectares characterized as afforested. The natural groves layer was added to this layer, bringing the total to 158,068 hectares.

The 2014 calculation was carried out as follows:

- The area defined as forested in the JNF forest layer came to 68,206 hectares. This area in actuality contained both planted forests and part of the natural groves, and the distinction between them was based on the distribution of these areas in the JNF data:
  - Planted forests – 60,524 hectares
  - Natural groves – 7,682 hectares
- In addition, the JNF provided data on the natural groves layer area, which came to 89,862 hectares. In total, the forest and natural grove area came to:
  - Planted forests – 60,524 hectares
  - Natural groves – 97,544 hectares
  - Total area (planted forests and natural groves) – 158,068 hectares

Due to the fact that the forest area was only calculated for 2014, and has not been updated at the CBS since then, the calculations for subsequent years were carried out in the manner presented here for the year 2015:

1. The base for the calculation was the forest area for each category, as of 2014.
2. The changes that took place in each category in 2014–2015, according to the differences between 2014 and 2015 as seen in the JNF reports for each forest type, were then added to the 2014 base.

Data on the quantity of trees felled for commercial purposes were obtained from the JNF and the INPA.

6.3.4 Limitations of the Data

The information on forest area is based on the 2014 data and changes in relation to these data.

6.4. 4.G Harvested Wood Products

6.4.1 Description of Emission Sources

The use of harvested wood products (tree felling) causes decomposition of the wood and emission of CO_2. The presumption is that the wood is combusted and CO_2 is emitted during the combustion process.

6.4.2 Calculation Method

Tree felling for commercial purposes – the emissions from tree felling for commercial purposes were calculated based on the weight of the tree and the emission factors and in accordance with the methods recommended in the IPCC 1996 guidelines:

$$\text{Emissions} = \text{Commercial Harvest} \times \text{EF} \times 0.45 \times 44/12$$

Emissions – emissions from tree felling for commercial purposes (thousand tons of carbon dioxide)

Commercial Harvest – quantity of trees felled (thousand tons)

EF – inclusion of branches factor (1.9)

0.45 – carbon fraction of the dry matter

44/12 – conversion to CO_2

6.4.3 Sources of Information

Data on trees felled for commercial purposes were obtained from the JNF and the Northern District of the INPA.

6.4.4 Limitations of the Data

There may be other cases of trees felled for commercial purposes that have not been reported.

6.5. 4.H Other (Cultivation of Organic Soils)

6.5.1 Description of Emission Sources

Organic agricultural soils emit CO_2 during their cultivation. According to the IPCC 1996 definition, soil is considered organic if more than 20% of it is organic matter. In Israel, such soils exists only in the Hula Valley.

6.5.2 Calculation Method

The emissions from cultivation of organic soils were calculated based on the area of these soils and in accordance with the methods recommended in the IPCC 1996 guidelines.

The emission factor of carbon from cultivation of organic soils was taken from the IPCC 1996 (T1) guidelines – 20,000 tons of carbon per hectare per year.

$$\text{Emissions} = \text{Land Area} \times \text{EF} \times 44/12$$

Emissions – emissions from cultivation of organic soils (thousand tons of carbon dioxide)

Land Area – in hectares

EF – emission factor of thousand tons of carbon per hectare per year (20)

44/12 – conversion to CO_2

6.5.3 Sources of Information

Information on the area of cultivated organic soils was obtained from the Development Projects Department of the JNF. This land is located in the Hula Valley, and covers an area of 1,454 hectares.

6.6. Future Improvements

In the future, the area data must be updated and the quantities of trees felled for commercial purposes in the southern region, which is mostly arid, must be added.

7. Chapter 7: Waste and Wastewater

7.1. Survey of Emissions

7.1.1 Total Emissions

In 2022, the total amount of greenhouse gas emissions (GHGs) from waste and wastewater amounted to 9.1 million tons of CO_2eq, which accounted for 11.2% of all GHG emissions in Israel. Emissions from waste and wastewater in Israel are generated from disposal and treatment of solid waste and from the treatment and discharge of household and industrial wastewater. In 2022, methane (CH_4) emissions from disposal of waste amounted to 8.068 million tons of CO_2eq, which accounted for 88.6% of all emissions from waste and wastewater. Emissions from treatment and discharge of wastewater amounted to 862,200 tons of CO_2eq, the vast majority of which were CH_4 emissions from industrial wastewater. Emissions from biological treatment of solid waste amounted to 177,800 tons of CO_2eq.

Table 7.1 GHG Emissions From Waste and Wastewater, by Source, 2022

Thousand tons of CO_2eq

Emission source	Total	N_2O	CH_4	CO_2
5. Waste and wastewater	**9,107.9**	**72.1**	**9,035.8**	**NA**
A. Solid waste disposal	8,068.0	NA	8,068.0	NA
B. Biological treatment of solid waste	177.8	54.5	123.3	NA
C. Incineration and open burning of waste	NE	NE	NE	NE
D. Treatment and discharge of wastewater	862.2	17.6	844.6	NA

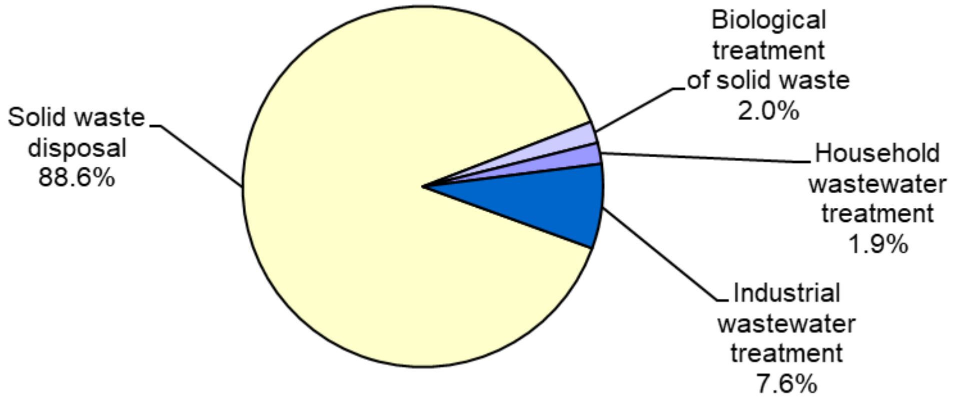
NE = not estimated, NA = not applicable

7.1.2 Trends

Emissions from waste and wastewater increased between 2003 and 2010 by 42.0%. Between 2011 and 2022, the upward trend was moderate and the emissions increased by 15.3%.

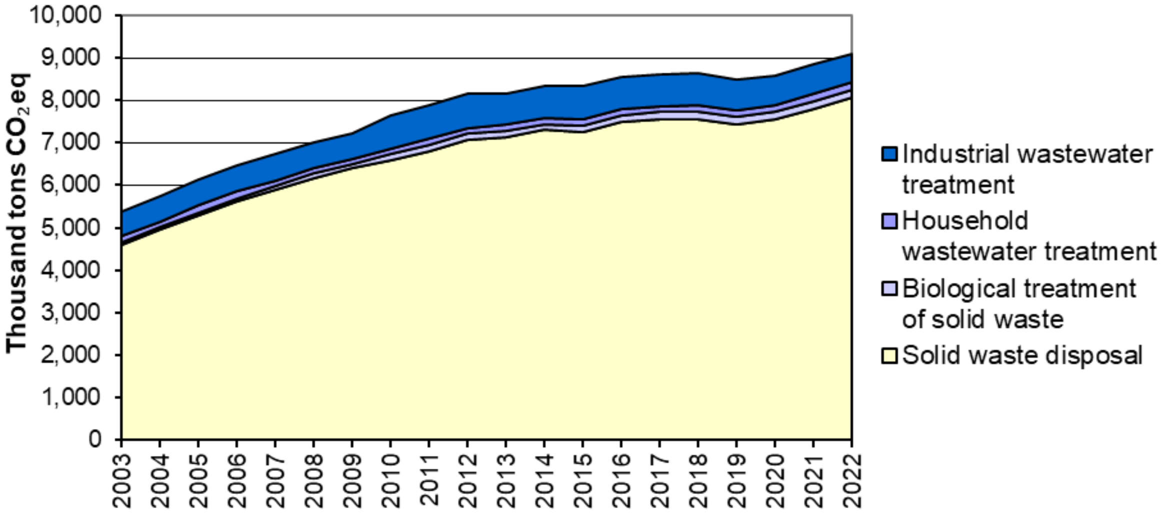
The vast majority of the emissions (88.6%) were produced from disposal of waste. These emissions have moderated in the last decade because of the increase in recycling and the subsequent reduction in the amount of solid waste disposal, and due to the collection and incineration of the CH_4 gas emitted in landfills (incineration with or without energy recovery). The second largest emission source, considerably smaller, was the treatment and discharge of industrial wastewater (7.6%).

DIAGRAM 7.1A. GHG EMISSIONS FROM WASTE AND WASTEWATER, BY SOURCE
2022



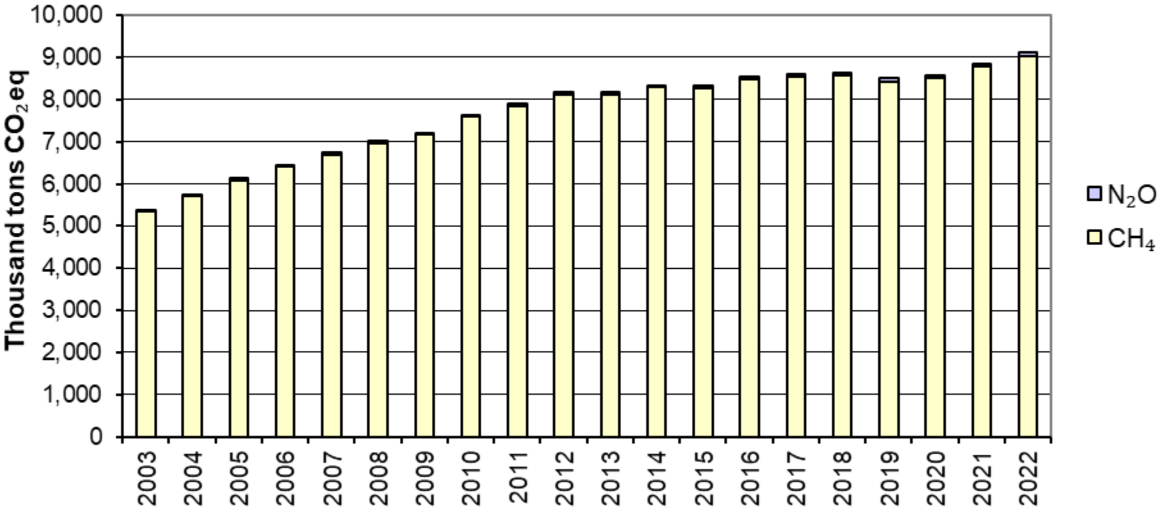
Total
9.1 million tons CO_2eq

DIAGRAM 7.1B. GHG EMISSIONS FROM WASTE AND WASTEWATER, BY SOURCE 2003–2022



The vast majority of emissions from waste and wastewater (99%) are CH_4 and are produced mainly from disposal of solid waste.

DIAGRAM 7.2 GHG EMISSIONS FROM WASTE AND WASTEWATER, BY GAS 2003–2022



7.1.3 Emission Sources

Disposal of Solid Waste

CH_4 is emitted during disposal of solid waste as a result of anaerobic decomposition of the organic matter in the disposed waste. In 2022, CH_4 emissions from disposal of waste amounted to 8.068 million tons of CO_2eq, which accounted for 88.6% of all emissions from waste and wastewater.

CH_4 emissions from disposal of waste have increased over the years because of the increase in waste production and disposal. These emissions have moderated in the last decade because of recycling and the reduction of the amount of waste disposal, and due to the collection and incineration of CH_4 gas emitted in landfills (from incineration with energy recovery or without it). Between 2003 and 2022, CH_4 emissions increased by 76.0%.

Biological Treatment of Solid Waste

The benefit of biological treatment of solid waste (food waste, yard waste, and sludge) – composting and anaerobic digestion of the waste – includes reduction of the volume of waste disposal, stabilization of the waste, destruction of pathogens, and the production of biogas for the production of energy. The final products of the biological treatment can be used as fertilizer or be disposed of, depending on their quality.

During these processes of treatment, methane (CH_4) and nitrous oxide (N_2O) are emitted.

In 2022, CH_4 and N_2O emissions from biological treatment of solid waste amounted to 177,800 tons of CO_2eq, which accounted for 2.0% of all emissions from waste and wastewater. Between the years 2003 - 2022, emissions from biological treatment of solid waste increased by 164.5%, following an increase in composted materials.

Treatment and Discharge of Wastewater

CH_4 and N_2O are emitted from treatment and discharge of household and industrial wastewater.

CH_4 is emitted when anaerobic processes take place, during which the organic matter in wastewater decomposes. Emission of N_2O can be a direct emission in the purification plants or an indirect emission from the wastewater after its discharge into effluent reservoirs, streams, or the sea.

In 2022, CH_4 and N_2O emissions from treatment and discharge of wastewater amounted to 862,200 tons of CO_2eq, which accounted for 9.5% of the total amount of emissions from waste and wastewater. Between the years 2003 and 2022, the emissions increased by 18.4%.

7.2. Calculation Methods and Sources of Information

The emissions were calculated using the optimal method available. The emissions from disposal of solid waste, which is the main source of emission, were calculated according to the model recommended in the 1996 IPCC guidelines (T2) after adaptation to conditions in Israel. The calculation of emissions from wastewater and biological treatment of solid waste was based on default factors in the guidelines, after adjustment to conditions and activity in Israel.

Table 7.2 Calculation Methods of Emissions From Waste and Wastewater, 2022

Emission source	N_2O	CH_4	CO_2
5. Waste and wastewater			
A. Disposal of solid waste	NA	T2, D, CS	NA
B. Biological treatment of solid waste	T1	T1	NA
C. Incineration and open burning of waste	NE	NE	NE
D. Treatment and discharge of wastewater	T1,D	T1,D	NA

T1 = tier 1, T2 = tier 2, CS = country-specific, D = IPCC default, NE = not estimated, NA = not applicable

7.3. 5.A Disposal of Solid Waste

7.3.1 Description of Emission Sources

CH_4 is emitted from disposal of solid waste due to anaerobic decomposition of the waste (that is in oxygen-deficient conditions) during which bacteria decompose the organic matter in the disposed waste. The sources of solid waste disposal are household, commercial, and industrial waste.

Up to the 1990s, hundreds of small landfills operated in Israel, where the waste collected in the local authorities was disposed of. These uncontrolled sites caused environmental hazards and were a constant bother to residents. In order to solve the problem of treating this waste, those sites were closed, and in their place, a number of central waste disposal sites were established that are required to meet appropriate environmental standards under the supervision of the Ministry of Environmental Protection. Concurrently, transit stations were established throughout the country, to which the waste is transferred. In some transit stations, sorting is done by mechanical and manual means to separate recyclable materials – which are sent to relevant factories for recycling – from other waste, destined for disposal.

Parallel to regulating the disposal of waste, the Ministry of Environmental Protection worked to increase recycling in various ways:

- Separation at the source and sending it directly for recycling – collection containers for categories of waste (paper and cardboard, plastic, and glass) were placed in commercial and industrial areas in the local authorities.
- Separation and sorting of the waste at transit stations and sending it to recycling plants.
- Enforcing a waste disposal levy for beverage containers, that encourages the recycling of plastic, glass and metal containers.
- Use of waste for the production of energy – the dry, combustible components of the waste are separated, such as plastic, cardboard, wood, and textile. At the end of the process, RDF (Refuse Derived Fuel) is obtained, which is used as fuel in the kilns of the cement industry in Israel.

Emissions of CH_4 from waste disposal are generated from the degradable organic part of the waste. However, not every type of waste contains degradable organic matter and therefore, the relevant amounts of disposed waste must be isolated for calculating the emission.

In general, it is possible to divide the waste produced into three types:

Dry waste – Waste produced from construction, demolition, and infrastructure activity which contains dirt and leftover building materials. This waste does not contain organic matter and therefore, CH_4 is not emitted from it.

Hazardous waste – Waste containing poisons, pollutants, radioactive substances and flammable substances. Because of its content, it poses a real or potential risk to people's health, living organisms and the environment. This waste is treated in a special way, and according to the recommendations of the 1996 IPCC guidelines, it is not included in the calculation of the emissions resulting from disposal of solid waste.

Mixed waste – Waste produced from household, commercial, or industrial activity that contains food waste, waste from packaging, waste from production processes and yard waste. This waste contains organic matter and is a source of CH_4 emissions from disposal of solid waste.

In 2022, there were eleven solid mixed waste landfills in Israel for the disposal of municipal, commercial, industrial and yard waste, and this waste amounted to approximately 7.5 million tons. About 80% of the mixed waste was household and commercial waste.

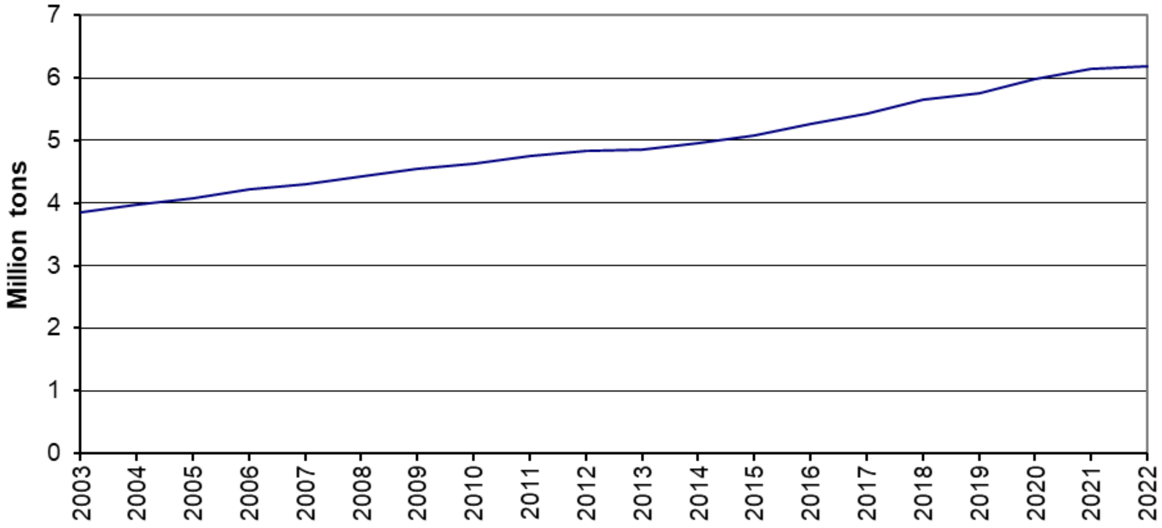
Table 7.3 Mixed Waste, by Source, 2020

Source	Quantity (in million tons)	Quantity (percent)
Total	7.52	100.0
Household and commercial waste	5.98	79.5
Industrial waste	1.54	20.5

The quantity of household and commercial waste increased steadily over the years, mainly due to the increase in the population, and between the years 2003 and 2022, the quantity of household and commercial waste collected and treated increased by approximately 60%. Another factor causing an increase in the quantity of waste is a rise in the standard of living. Between the years 2003 and 2022, the quantity of household and commercial waste per capita increased from 1.58 to 1.79 kg (an increase of 13.3%).

The actions to increase recycling in the local authorities have contributed to an increase in the amounts of recycling. Between 2014 and 2022, the percentage of waste sent for recycling of household and commercial waste collected in local authorities, increased from 18% to 24%. In 2022, about 75% of recycling originated in separation at the transit stations, and about 25% – in separation at the source (collection facilities for paper and cardboard, plastic and glass, etc.).

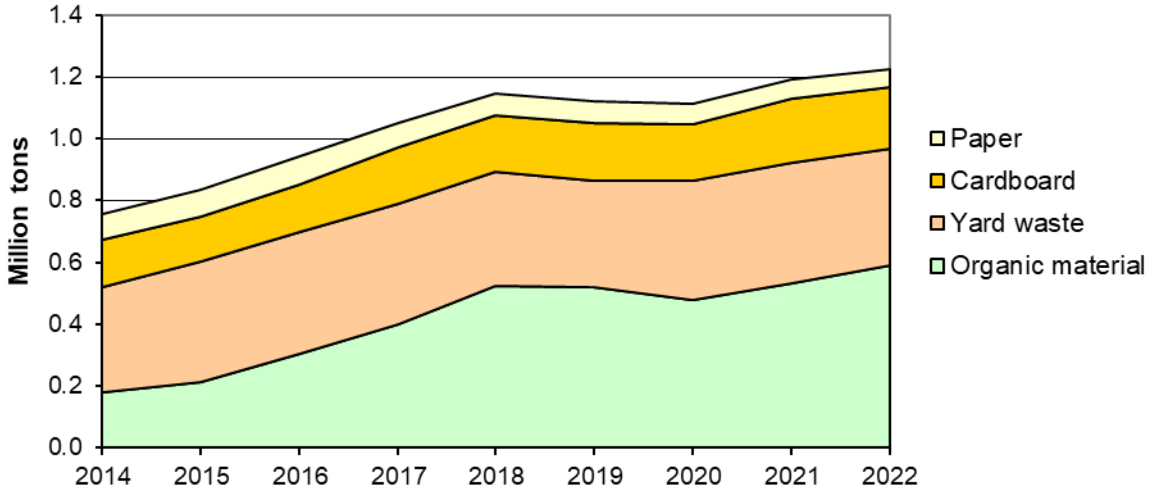
DIAGRAM 7.3 HOUSEHOLD AND COMMERCIAL WASTE COLLECTED IN THE LOCAL AUTHORITIES 2003–2022



The increase in recycling of household and commercial waste affects the quantity of waste disposal and its composition. When organic materials (which contribute to CH_4 emissions) are not disposed of in waste disposal sites, but are sent for recycling, the amount of emissions from waste disposal decreases.

The following diagram shows the increase in the amount of recycling of selected materials from household and commercial waste during the years 2014–2022.

DIAGRAM 7.4 SELECTED MATERIALS IN HOUSEHOLD AND COMMERCIAL WASTE SENT FOR RECYCLING AND RE-USE IN THE LOCAL AUTHORITIES, BY MATERIAL 2014–2022



7.3.2 Calculation Methods

7.3.2.1 An Overview of Calculation Methods

The emissions from disposal of solid waste were calculated using the method recommended in the IPCC guidelines and by means of specific information on the unique nature of the activity in Israel, when data on that were available.

In the guidelines for calculating the emissions, two calculation methods are presented:

- The Mass Balance method (T1)
- First Order Decay (FOD) method (T2)

The first calculation method (The Mass Balance method) is based on the quantities of waste disposal in year X and attributes all the emissions generated from that waste disposal to year X. When the data are calculated continuously by this method over years, it is possible to get a reasonable estimate of the emissions during those years.

The calculation carried out at the CBS during the years 2003–2011, as well as additional calculations of previous emission inventories carried out by the Ministry of Environmental Protection in 1996 and in 2000, were based on this calculation method.

In the second calculation method (FOD method), the distribution of emissions over the years is weighted. The disposed waste, that contains organic matter, decomposes over a number of decades, and the FOD model is based on an exponential decay rate of the amount of organic matter that decomposes each year. The amount of organic matter and the length of the decomposition period differ for the various materials, and the emissions must be calculated separately for each material.

Unlike the 1996 IPCC guidelines, in the updated 2006 IPCC guide, it is recommended not to use the Mass Balance method, but rather the FOD method. In order to improve the calculation of emissions from disposal of solid waste in Israel, the calculation method was updated, and the emissions for all years of the inventory calculation were recalculated according to the FOD method.

The FOD calculation method, which was used for this report, corresponds with the parameters in the 1996 IPCC guidelines, according to which the State of Israel was instructed to calculate the emissions. The calculation methods in the 2006 IPCC and

1996 IPCC guidelines are similar, but the parameters and the default factors are different. In calculating the emissions, the default factors of the 1996 IPCC guidelines were used, and where no factors or parameters were given, information from the 2006 IPCC guidelines was used.

7.3.2.2 The First Order Decay (FOD) Calculation Method

In the FOD calculation method, the distribution of emissions is weighted over the years. For this, it is necessary to know the quantity of waste disposal each year, the emissions from waste disposal over the years, the composition of the disposed waste (to find the degradable organic fraction), the characteristics of the landfill and the amount of CH_4 collected.

According to the IPCC guidelines, CH_4 emissions from disposal of solid waste were calculated in three steps:

Step A – Calculation of the amounts of degradable organic carbon disposed each year.

Step B – Calculation of the amount of CH_4 produced each year. This calculation weighs the rate of decomposition of the organic matter over the years.

Step C – Subtraction of the oxidized part and the amount of CH_4 collected, from the amount of CH_4 that was produced.

7.3.2.3 Step A – Calculation of the Amounts of Degradable Organic Carbon Deposited Each Year

During this stage, the amounts of degradable organic carbon deposited each year must be calculated:

DDOCm = mass of decomposable DOC deposited

The formula below refers to a specific type of material. For each material, the calculation must be adjusted to the parameters.

$$\mathrm{DDOCm} = \mathrm{W} \times \mathrm{Composition} \times \mathrm{DOC} \times \mathrm{DOC_f} \times \mathrm{MCF}$$

Below are explanations of the components of the formula:

W – The quantity of waste disposal in Israel during the year that contains degradable organic matter. The quantity is based on the quantity of mixed waste disposal that contains degradable organic matter (DOC), the source of which is households, commerce, industry, etc.

Composition – The composition of the waste corresponds with the content of degradable organic carbon. The composition is based on the National Waste Composition Survey of the Ministry of Environmental Protection.

DOC – Degradable Organic Carbon – The amount of degradable organic carbon. CH_4 is produced from the decomposition of organic carbon in waste, and to calculate the amount of carbon, an examination of the degradable organic carbon content is needed. The default values for the share of this content are given in the IPCC guidelines.

DOC_f – Fraction of DOC that can decompose – the part of organic carbon that can decompose.

MCF – Methane Correction Factor – CH_4 emission correction factor. CH_4 emissions are affected by the type of landfill and the conditions in it. In an uncontrolled landfill, less CH_4 is emitted, since the volume of the waste decomposing in the upper layer expands, and the aerobic conditions in this layer do not enable the production of CH_4.

Below are details of the calculation method according to the components of the formula:

W – Quantity of waste disposal

Calculating emissions using the method based on the decomposition of organic matter over years requires data on the quantities of waste disposal over decades in the past. For that purpose, information must be collected on disposal of waste throughout the years, the extent of which must be assessed.

The availability of data on disposal of mixed waste in Israel and their quality has varied over the years. In 2007, a waste disposal levy was enforced on the disposal of waste. This levy collection made it possible to obtain relatively good data on the quantities of waste disposal. From 2004 to 2006, estimates of the quantities of mixed waste disposal were obtained from the Ministry of Environmental Protection.

For preceding years (namely, up to 2003), for which there is no information on quantities of waste disposal, the quantity of waste disposal was estimated as follows: First, the quantity of all mixed waste produced was estimated, comprised of industrial waste, and household and commercial waste. Thereafter, the amount of recycled waste was estimated. The calculation of the quantity of waste disposal was based on an estimate of the quantity of waste produced, from which the amount of recycled waste was subtracted.

The amount of landfill waste was calculated as follows:

$$Total\ landfilled = IndustrialWaste + ResdComWaste \times (1 - RecycleResCom)$$

Where:

IndustrialWaste – Disposal of industrial waste

ResdComWaste – Production of household and commercial waste

RecycleResCom – Recycled household waste

The quantity of industrial waste disposal was estimated based on the quantity transferred for disposal and subtraction of the recycled waste from that. The household and commercial waste produced were estimated separately, and the recycled waste was subtracted from that.

Because of differences in the sources of information, household and commercial waste were not calculated in the same way as industrial waste.

Below are details of the components of the formula for calculating the quantity of waste disposal:

IndustrialWaste – Disposal of industrial waste

Disposal of industrial waste was estimated based on the relationship between the quantity of waste and the extent of industrial production. The assumption is that the quantity of waste produced in industry is related to the extent of industrial production. The quantity of industrial waste disposal was estimated based on the industrial production index, calculated at the Central Bureau of Statistics (CBS), which has data available since 1958.

The base point for calculation refers to data on industrial waste obtained in the survey on industrial waste, which was carried out by the CBS in 2010 and in 2012, and by means of the industrial production index, the waste was estimated for the other years.

Table 7.4 Mixed Industrial Waste, by Treatment Method, Selected Years

Tons

	2010	2012
Total	1,129,974	1,169,911
Sent for disposal / to transit station	622,581	611,458
Sent for recycling	507,393	558,453

ResdComWaste – Household and commercial waste produced

Data on quantities of household and commercial waste produced are collected by the CBS in a dedicated survey. Accurate and consistent data (in terms of the collection method) have been available since 2003. According to the IPCC guidelines, for years without information, the data must be estimated based on finding a relationship with the population and with appropriate economic indices.

The quantity of household and commercial waste is related to the size of the population – the more residents there are, the larger the quantity of waste, and similarly, regarding economic well-being – as the standard of living rises, the quantity of waste increases.

After researching the subject, it has been found that in Israel, there is a strong relationship between the quantity of waste per capita and the GDP. Based on this relationship, the quantity of waste per capita was estimated, taking into account changes in the standard of living over the years. After an estimate of the quantity of waste per capita was obtained, this estimate was multiplied by the population of that year, and the total waste produced was obtained.

The regression formula obtained for the relationship between waste per capita and the GDP is:

$$Waste\ per\ capita\ (WpC) = 506.47999 + 0.12533 \times GDP$$

R-square 0.9047

When waste per capita is estimated based on the regression at the beginning of the period studied (1958), a value of approximately 1.4 kg per capita per day is obtained for 1958. This estimate represents a 20% increase in waste per capita over 55 years and consequently, it is not reasonable. Therefore, it is difficult to use regression, as is, to estimate the waste, and another method was chosen for that purpose.

The assumption is that the regression correctly represents the relationship between the rate of increase of the GDP and the rate of increase of waste per capita. Namely, based on the regression factor 0.12533 × GDP, when the GDP increased by 10%, the waste per capita increased by 1.253%. Thus, it is possible to estimate the waste per capita retroactively for preceding years, step by step, from the year for which there is information on waste per capita (2003), according to the increase of the GDP. The waste was estimated in this way for each year, back to the first year of assessment – 1958, for which a value of 1.1 kg. of waste per capita was obtained.

Experts in the field have examined the results and determined that they are reasonable.

RecycleResCom – Recycled household waste

National surveys on the composition of waste show that in the past, the main materials recycled were paper and cardboard (17%–25% of recycled materials), textile (4%) and metal (8%–13.5%). It was assumed that about 5% of each material was recycled, and it was found that the overall amount of recycling accounted for about 2% of the total quantity of household waste.

Composition – Composition of Waste

The IPCC guidelines present a list of materials containing degradable organic matter, from which the materials relevant to Israel were chosen according to the findings of surveys on waste composition. The information available each year on the relevant materials is not uniform because different surveys were conducted at different levels of detail. Partial and local surveys on composition of waste were conducted in 1975, 1983 and 1986. In 1995, 2005 and 2013, more comprehensive surveys were carried out to check the composition of waste.

Below is the composition of solid waste according to categories of the IPCC for the years in which surveys on waste composition were carried out.

Table 7.5 Composition of Solid Waste, by Survey Year

Percentages

Definition of types of waste in surveys for 1975, 1983, 1986	Definition of types of waste in surveys for 1995*, 2005, 2013	1975	1983	1986	1995	2005	2013***
Paper and cardboard	Paper and cardboard	16.9	17.3	21.1	22.37	25.01	22.05
Textile	Textile	3.5	3.9	3.6	3.27	3.86	3.35
	Processed wood					0.87	0.9
	Organic matter that is not food (garden waste and other)				5.66	3.39	2.2
Types of organic matter	Organic matter – food	64.8	60.4	49.2	37.81	36.35	39
	Disposable diapers**				4.29	5.04	5.35

* Except for processed wood, which was not included in the 1995 survey.

** Widespread use of disposable diapers began after the 1980s.

*** Average of household waste from storage containers and trucks.

In the years when surveys were conducted, the composition of waste was taken from the surveys. For years when no survey was conducted, values were taken from the nearest survey. Below are the years of waste disposal and the survey years chosen for each of them.

Table 7.6 Years of Disposal of Solid Waste, According to Survey Year From Which the Composition Value Was Taken

Survey year from which the composition value of the waste was taken	1975	1983	1986	1995	2005	2013
Years of disposal of solid waste	Up to 1979	1980–1984	1985–1990	1991–2000	2001–2009	2009 onwards

DOC – Degradable Organic Carbon – Fraction of degradable organic carbon

Each material has a different fraction of degradable organic carbon. These values were taken from the default values in the 1996 IPCC guidelines. Below are default values of the fraction of degradable organic carbon in the waste (the percentage is according to the weighted part when the material is in a wet state).

Table 7.7 Default Values of the Fraction of Degradable Organic Carbon Content in Waste, by Material (IPCC 1996)

Weight percentage

Type of waste	Default value
Organic matter – food	0.15
Organic matter that is not food (garden waste and other)	0.17
Paper and cardboard	0.4
Wood and straw	0.3
Textile	0.4
Disposable diapers	0.17

DOC_f – Fraction of organic carbon (DOC) that can decompose

During the process of solid waste decomposition, only part of the degradable organic carbon is used in the production of CH_4. This situation is caused by the formation of conditions that do not allow the production of CH_4 (aerobic conditions) in which carbon dioxide (CO_2) is emitted. According to the IPCC 1996 guidelines, the default value of DOC_f is 0.77.

MCF – Methane Correction Factor – CH_4 emission correction factor

CH_4 emissions are affected by the type of landfill and the way it is operated, which affect the presence of oxygen in it and consequently, CH_4 emissions are affected as well. Over the years, the treatment of waste in the State of Israel has been regulated and has undergone a process of control. In the past, waste was deposited in dozens of uncontrolled landfills and caused a great deal of damage to the environment (pollutants seeping into groundwater, annoying odours, damage to open areas, etc.). From 2000, the regularization of landfills began, and uncontrolled landfills were closed throughout the country. Today, waste is deposited in controlled landfills where the treatment of waste enables protection against damage to the environment (such as preventing pollutants from seeping into groundwater).

In the 1996 IPCC guidelines, a series of waste treatment methods is presented and the CH_4 treatment factor is defined accordingly. In general, there are two types of waste disposal – controlled disposal and uncontrolled disposal, and each type has sub-types.

Waste transferred for disposal was divided into two types according to the treatment method during each period:

- Waste sent for disposal **up to the year 2000** was transferred to uncontrolled landfills. The IPCC guidelines present two methods of disposal in uncontrolled landfills depending on the depth of the landfill – above five meters or below five meters. Because there were dozens of different types of sites up to the year 2000 and there is no information on how the waste disposal was done, it was decided to use an average value of 0.6, as recommended in the IPCC guidelines.

- Waste sent for disposal **from the year 2000 onwards** was transferred to controlled landfills. The IPCC guidelines show two **methods of disposal** according to two types of controlled landfills – **anaerobic and semi-anaerobic**.

A landfill can be defined as semi-anaerobic only if it has all the components that allow penetration of air: permeable cover material, a leachate drainage system and a gas ventilation system. Since the landfills in Israel do not meet all these requirements, they are not defined as semi-anaerobic landfills. Therefore, a value of 1 was chosen for them, which corresponds with an anaerobic landfill.

7.3.2.4 Step B – Calculation of the Amount of CH_4 Produced Each Year

Based on amounts of the degradable organic carbon deposited each year, calculated in the previous step, the amount of CH_4 produced was calculated. For the emission calculation, it was assumed that the amount of organic matter that decomposes originates from organic matter remaining at the site from previous waste disposals.

The calculation was carried out as follows:

- **In Step 1**, the waste that accumulated up to year T was calculated, which is equal to the quantity of waste disposal in year T, plus the waste accumulated up to year T-1, minus the part of waste that decomposed throughout the preceding years. The remaining quantity (up to year T-1), after the decomposition, was calculated by multiplying it by the decay factor e^{-k}. k represents the decay factor corresponding with the specific material. The k values are calculated based on the half-life (that is, the time it takes for half of the material to decompose. These factors are presented below). k is equal to $\ln(2)/t_{1/2}$, and $t_{1/2\ -1}$ is the half-life.

- **In Step 2**, waste that decomposed in year T was calculated based on waste that accumulated up to that point (obtained from Step 1). This quantity is equal to the amount of material that accumulated up to the year, T-1, multiplied by $(1-e^{-k})$.

- **In Step 3**, the amount of CH_4 generated was calculated based on the waste that decomposed in year T (obtained from Step 2).

$$CH_4\ generated = \text{waste decomposed in a year}\ T \times 16/12 \times F$$

To calculate the amount of CH_4 emitted, the amount of carbon that decomposed must be multiplied by:

- **Molar ratio** – The ratio between the weight of CH_4 and carbon, which is equal to 16/12. This ratio makes it possible to calculate the amount of CH_4 emitted according to the carbon used to produce CH_4.

- **F** – The fraction of CH_4 that is generated from landfill gas. This value is taken from the default value recommended in the IPCC guidelines: 0.5.

Half-Life – $t_{1/2}$

'Half-life' is the time it takes for half of the material to decompose. This time varies from material to material according to the content of organic matter and the environmental conditions in the country. Moisture, heat and precipitation affect the decomposition rate of the materials.

Below is a table of default values recommended in the 2006 IPCC guidelines (these values were not presented in the 1996 IPCC guidelines). For Israel, the following geographical features were chosen:

o Tropical, MAT (Mean Annual Temperature) > 20°C

o Dry, MAP (Mean Annual Precipitation) < 1000 mm

Table 7.8 Default Values for Half-Life of Waste, by Material (IPCC 2006)

Material	Half-life
Organic matter – food	8
Non-food organic matter (garden waste and other)	11
Paper and cardboard	15
Wood and straw	28
Textile	15
Disposable diapers	11

7.2.3.5 Step C – Subtraction of the Oxidized Part and the Amount of CH_4 Collected From the Amount of CH_4 Generated

Below is the formula for calculating the emission. From the amount of CH_4 generated, the amount of CH_4 collected was subtracted, and the result was multiplied by the amount of CH_4 that did not undergo oxidation.

$$CH_4\ Emissions = [\sum CH_4 generated - R\,] \times (1 - OX)$$

R – The amount of CH_4 collected

OX – The oxidation factor

The oxidation factor (OX): OX represents the amount of CH_4 that underwent oxidation in the soil or in other materials covering the waste. In the IPCC 2006 guidelines, it is noted that theoretically, this value can be between 0% and 100%. It is further stated that according to research, at landfill sites which are maintained and managed in a controlled manner, the oxidation value is higher than the value at sites which are not maintained and managed in this way. The recommended default value in the IPCC guidelines is 0. For waste disposal sites maintained and managed well, a value of 0.1 must be used, but no higher than that. For Israel, the default value of 0 has been taken.

CH_4 collection factor (R): CH_4 collection began in the last decade in active and inactive waste disposal sites. Information was obtained from the Ministry of Environmental Protection concerning the starting date of CH_4 collection, and amounts of gas flow were received in units of cubic meters of gas per hour.

The amount of CH_4 collected was estimated based on a number of assumptions:

- The flow rate is equal throughout all hours of the day and night and throughout the whole year.
- The flow quantities refer to biogas, and the relative part of CH_4 in biogas must be chosen. The amount of CH_4 in biogas is 50%. This value was recommended in the IPCC guidelines and approved by the Ministry of Environmental Protection.
- The amount of volumetric CH_4 was converted to a weight unit by multiplying the amount of volumetric CH_4 collected, by a conversion factor of 0.66 (kg per cubic meter).

Below is the formula for calculating the amount of CH_4 collected in thousands of tons at a waste disposal site where the flow rate is Y cubic meters of gas per hour:

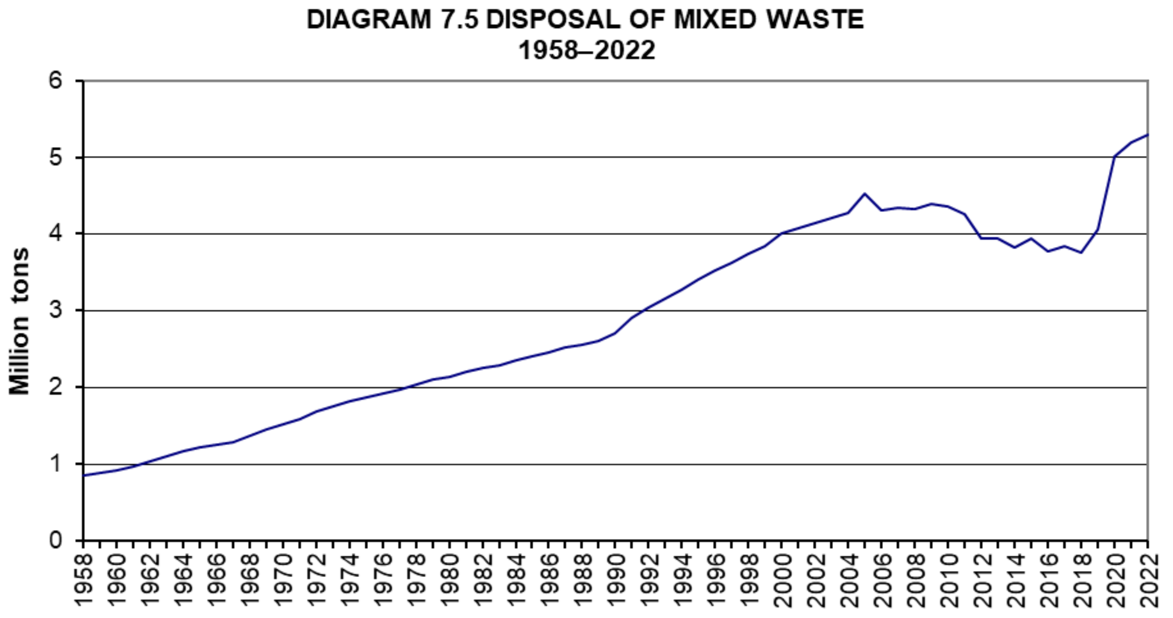
$$Total\ methane\ collected\ (Gg) = Y \times (\,365\ \times\ 24) \times 50\% \times 0.66 \times 10^{-6}$$

7.3.3. Sources of Information

The current data required to calculate the emissions are the quantity of mixed waste disposal, composition of the waste and the amount of CH_4 collected. Data on quantities of waste disposal and the amount of CH_4 collected are obtained annually from the Ministry of Environmental Protection. Information on the composition of the waste is not updated every year, but every few years.

Below is a diagram showing the quantities of waste disposal used to calculate the emissions. As mentioned above, the quantities of waste disposal up to 2003 are unknown. The quantities from 1958 to 2003 were estimated, and during those years, estimates of waste disposal appear to be stable and increase at a uniform rate.

Since 2003, the trend has moderated, and the quantity of waste disposal has even been decreasing, rather than increasing. The trend since 2003 has not been uniform due to changes in recycling rates, and in the quality of the data reports received by the Ministry of Environmental Protection from the waste disposal sites.



7.3.4 Data Limitations

Quantity of waste disposal – As mentioned, there is no historical information on quantities of waste disposal, and they have to be estimated.

Estimate of industrial waste disposal – There is no continuous annual information on the quantities of industrial waste disposal. These quantities were estimated based on data from surveys on quantities of waste conducted by the CBS in 2010 and 2012, and based on an estimate of a relationship between quantities of industrial waste produced and the industrial production index. This index quantifies the changes in the extent of production over the years, the assumption being that the quantity of industrial waste disposal changes according to the extent of production.

Estimate of household and commercial waste disposal – The CBS has administrative data on the quantities of household and commercial waste since 2003. There is no information for preceding years, and it must be evaluated. As mentioned above, a regression was calculated to find the factors that influence the quantities of waste produced, and a high correlation was obtained between the quantity of waste per capita and the GDP of the State of Israel. In order to make the estimation, the relationship between the increase in the GDP and the increase in the quantity of waste per capita was used. The quantities of waste were obtained from the landfill sites that treat mixed waste. Small quantities of bulky waste, that may contain materials such as wood, are deposited in landfills that treat dry waste, and they were not included in calculating the emissions.

There may be additional quantities of waste disposal that have been deposited in an uncontrolled manner. These quantities are negligible relative to the total quantity of waste disposal.

Estimate of recycling rates – Recycling rates since 2004 have been estimated based on waste production data and data on recycling. For preceding years, it was assumed that recycling rates in 2004 were the same as in the past and had not changed significantly, because recycling rates have actually increased considerably in the last decade.

Estimate of waste composition – Based on the composition of waste, the amounts of each type of material in the waste are estimated**,** which affect the amounts decomposed and the rate of decomposition of the various materials in it. Surveys to check the composition of waste have been conducted a number of times over the years, but information on the composition of waste is not available for all the years. To complete the information for missing years, the waste composition is chosen from the survey conducted in the nearest year.

The last national survey on waste composition was conducted in 2013, and since 2013, the calculation of emissions has been based on the data from that survey. As a result of the increase in recycling in recent years, it can be assumed that the composition of waste disposal has changed, and that the data from the national survey on waste composition of 2013, do not necessarily reflect the composition of waste for the years 2014–2022.

Collection of CH_4 – The amounts of the flow of CH_4 are average, and the assumption is that the flow is equal throughout all hours of the day and night and throughout the entire year.

7.3.5 Emissions

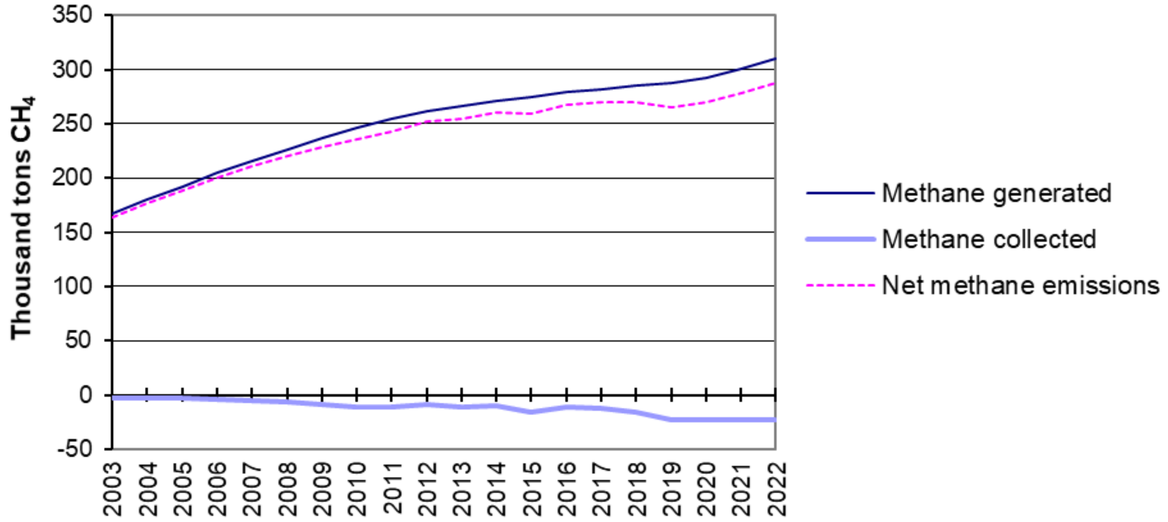
7.3.5.1 CH_4 Emissions

In 2022, CH_4 emissions from disposal of solid waste amounted to 8.068 million tons of CO_2eq, which accounted for 88.6% of the total amount of emissions from waste and wastewater.

CH_4 emissions from disposal of solid waste have increased over the years as a result of increased waste production and disposal of solid waste. These emissions have moderated in the last decade because of increased recycling and the reduction of the quantity of waste disposal, and as a result of more extensive collection and recovery of the CH_4 emitted in the landfills (incineration with energy recovery or without it).

The diagram shows the amounts of CH_4 generated, the amounts of CH_4 collected and the net emissions released into the atmosphere. Between 2003 and 2022, the amounts of CH_4 generated increased by 85.9% while the amounts of CH_4 emitted increased by only 76.0%, as a result of the increase in the collection of CH_4.

DIAGRAM 7.6 CH_4 EMISSIONS GENERATED AND COLLECTED AND NET EMISSIONS OF CH_4 FROM DISPOSAL OF SOLID WASTE 2003–2022



As mentioned, emissions from disposal of solid waste are generated as a result of decomposition of the organic matter in waste. In 2022, the materials from which the majority of emissions in waste were generated, were paper and cardboard (47.4%) and organic matter – food (37.1%).

Most of the emissions were generated from these materials due to the high content of degradable organic carbon in them (paper and cardboard – about 40% and organic matter – food – about 15%–17%) and their relatively large proportion in waste (paper and cardboard – about 25% and organic matter – food – about 36%). Such properties enable these materials to have a great impact on the emissions from disposal of solid waste.

In the diagram, CH_4 emissions are shown, by material, over the years and in 2022.

DIAGRAM 7.7A. CH_4 EMISSIONS FROM DISPOSAL OF SOLID WASTE, BY MATERIAL
2022

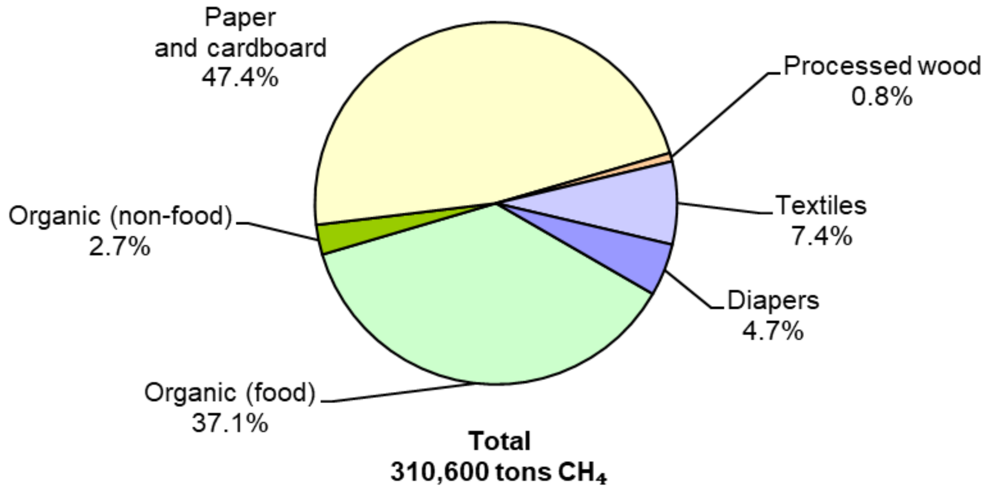
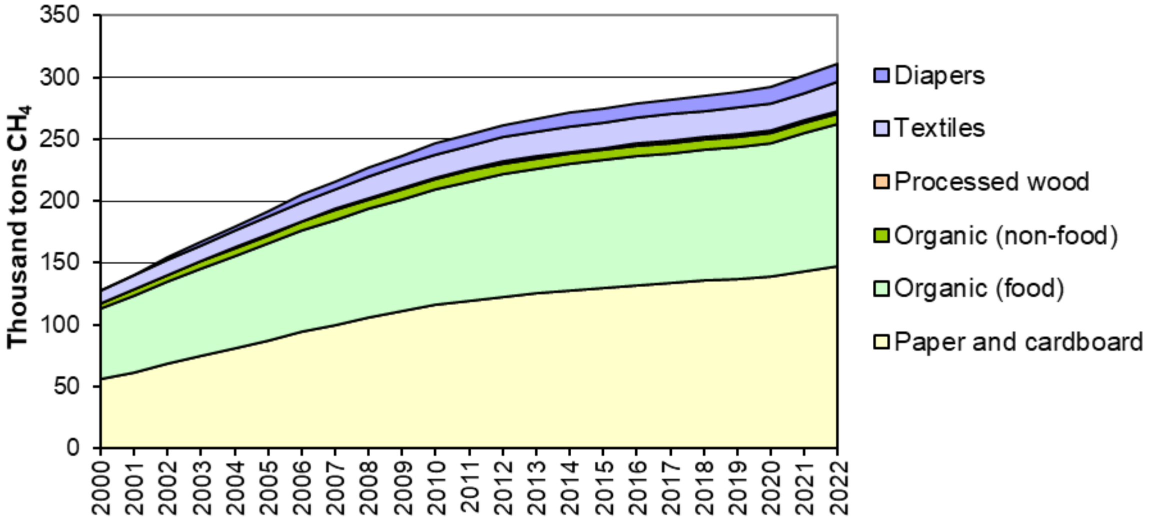


DIAGRAM 7.7B. CH_4 EMISSIONS FROM DISPOSAL OF SOLID WASTE, BY MATERIAL
2000–2022



7.4. 5.B Biological Treatment of Solid Waste

7.4.1 Description of Emission Sources

Composting and anaerobic digestion of organic waste (food waste, yard waste and sludge) are carried out for the purpose of reducing the volume of waste disposal, stabilizing the waste, destroying pathogens, and producing biogas for the production of energy. The final products of biological treatment can be used as fertilizer or transferred for disposal, according to their quality.

In these treatment processes, methane (CH_4) and nitrous oxide (N_2O) are emitted.

Composting is an aerobic process during which a large part of the degradable organic carbon in waste is converted into carbon dioxide (CO_2). CH_4 is formed in the anaerobic stages of composting, although it is mostly oxidized in the aerobic stages of composting. The CH_4 released into the atmosphere, generated from the initial carbon content in the material, is estimated to be only a few percent of the total amount of carbon. During the composting process, N_2O is also emitted as a result of the oxidation of nitrogen in the waste.

Composting and anaerobic digestion of organic waste accelerates the natural decomposition of oxygen-free organic matter by maintaining its temperature, moisture content, and its pH at optimal values. CH_4 emission can be generated due to unintentional leakage during the process or as a result of unexpected occurrences. Technical standards of biogas plants guarantee zero rates of unintentional CH_4 emission. The CH_4 generated can be used to produce heat or electricity, and emissions reported from this process are included in the energy section. It has been assumed that the extent of N_2O emission from composting and anaerobic digestion of organic waste is negligible.

The emissions from anaerobic treatment of sludge in wastewater treatment plants (WTPs) should be reported in the "wastewater" category. When the sludge from wastewater treatment is transferred to an anaerobic facility where the sludge is treated with municipal solid waste or other waste, all CH_4 and N_2O emissions must be reported in the section Biological treatment of solid waste.

7.4.2 Methodology

7.4.2.1 Emission Factors

Emissions from composting of mixed waste and sludge were calculated. As mentioned above, the assumption is that emission of N_2O from composting and anaerobic digestion is zero and negligible, and that the CH_4 which has leaked out, has been collected and incinerated and is used for the production of energy. The calculation of the emissions is based on the amount of material sent for composting (yard waste, organic matter and sludge), and multiplying that by the emission factors.

CH_4 and N_2O emissions from composting were calculated according to the IPCC 2006 guidelines (T1) and by means of the default factors (kg of CH_4 or N_2O per kg of treated waste), or the emission factors in the guidelines for reporting, in the Pollutant Release and Transfer Register (PRTR) of Israel.

Table 7.9 Emission Factors of CH_4 and N_2O From Composting, by Material

Material	Kg CH_4/ton	Kg N_2O/ton	Description	Source
Sludge	1.750	0.240	Open compost, sludge from wastewater facility or animal manure mixed with yard waste	CH_4 – USEPA SCAQMD(1) N_2O – IPCC 2006(2)
Yard waste and organic matter	2.700	0.079	Open compost Organic household waste	German Federal Environment Agency (UBA)

(1) USEPA SCAQMD0. Estimating Ammonia Emissions From Anthropogenic Nonagricultural Sources, Final Report 2004. Table II-8: Recommended NH_3 Emission Factors for Composting Operations.

(2) IPCC 2006. Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste. Chapter 4: Biological Treatment of Solid Waste.

7.4.2.2 Mixed Waste

Mixed waste is sent for composting from the following sources: transit stations that collect mixed waste and yard waste produced in commerce, industry and households, agricultural sources from which animal manure is sent, and industrial plants from which residual organic matter is sent.

The appropriate emission factor is that of "open compost (exposed to air), organic household waste".

7.4.2.3 Sludge

Sludge from municipal sludge wastewater treatment plants (WTPs) is sent for composting and anaerobic digestion . Since yard waste is added to the sludge, it is included in the emissions from biological treatment of solid waste. For each WTP, the purpose of the sludge treatment is checked and accordingly, the treatment method used for it. Sludge can be treated in the WTPs themselves or in designated facilities.

These are the goals of sludge treatment and the treatment methods used for each one:

- **Composting facilities** – The assumption is that the appropriate treatment (and accordingly, the emission factor chosen) is "open compost, sludge from the WTP or animal manure mixed with yard waste".
- Treatment in WTPs – The treatment consists of **composting** in closed containers and anaerobic digestion (assuming that the CH_4 is incinerated and not emitted) and treatment using coal ash (N-Viro).

The emissions were calculated according to availability of the data over the years.

For the years 2008–2022, the amount of sludge removed is known according to the treatment destination of each facility, and accordingly, the corresponding emission factor as well.

For the years 2003–2007, the amount of sludge removed for treatment, that has emission potential, is known, but the destination of its removal is not known. Since no substantial difference in the factor was recognized over the years, an average emission factor for the total amount of sludge was calculated for the years 2008–2009 (thousand tons of CH_4 per ton of sludge, dry matter). To obtain an estimate of the emissions, the emission factor obtained was multiplied by the amount of sludge produced in the years 2003–2007.

These are the average factors obtained for the years 2008–2009 (thousand tons of CH_4 and N_2O per ton of sludge, dry matter):

- CH_4 – 8.58E-06
- N_2O – 1.18E-06

7.4.3 Sources of Information

The quantity of mixed waste sent for composting was obtained from the Recycling in Israel survey, carried out by the CBS. The data include quantities of mixed waste sent for composting from the following sources: mixed waste produced from commerce, industry, and households and collected at transit stations, agricultural sources (animal manure), and residual organic matter from industrial plants.

Data on the amount of sludge from municipal WTPs that was composted were obtained from the Ministry of Environmental Protection.

7.4.4 Data Limitations

A negligible part of the sludge was transferred to unknown sites, and emissions for that part were not calculated.

For the years 2003–2007, the emissions were estimated.

Some of the yard waste is mixed together with the sludge. The quantities of the mixed yard waste are unknown, and emissions from them were calculated according to waste factors for organic household waste.

Composting in households or by other private entities was not taken into account.

7.4.5 Emissions

In 2022, CH_4 and N_2O emissions from biological treatment of solid waste amounted to 177,800 tons of CO_2eq, which accounted for 2.0% of the total amount of emissions from waste and wastewater.

The diagram shows CH_4 and N_2O emissions from biological treatment of solid waste – organic matter, sludge and yard waste. Between the years 2003 and 2022, emissions increased 1.64-fold due to an increase in the quantity of composted materials.

DIAGRAM 7.8A. CH_4 AND N_2O EMISSIONS FROM BIOLOGICAL TREATMENT OF WASTE 2022

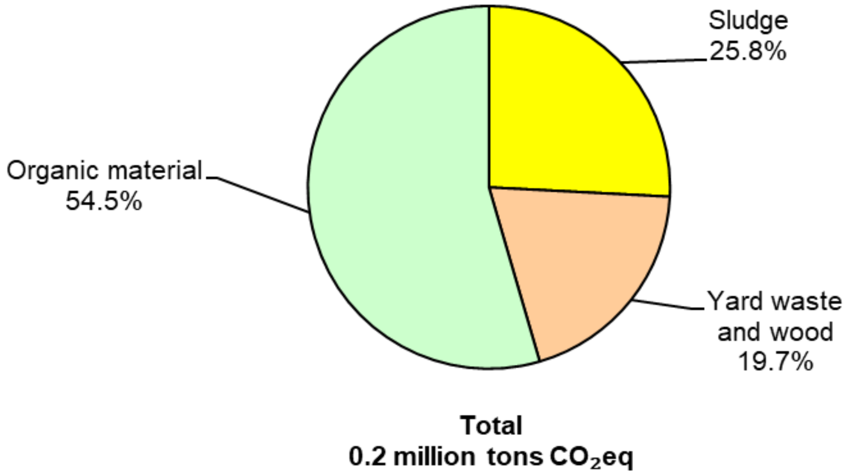
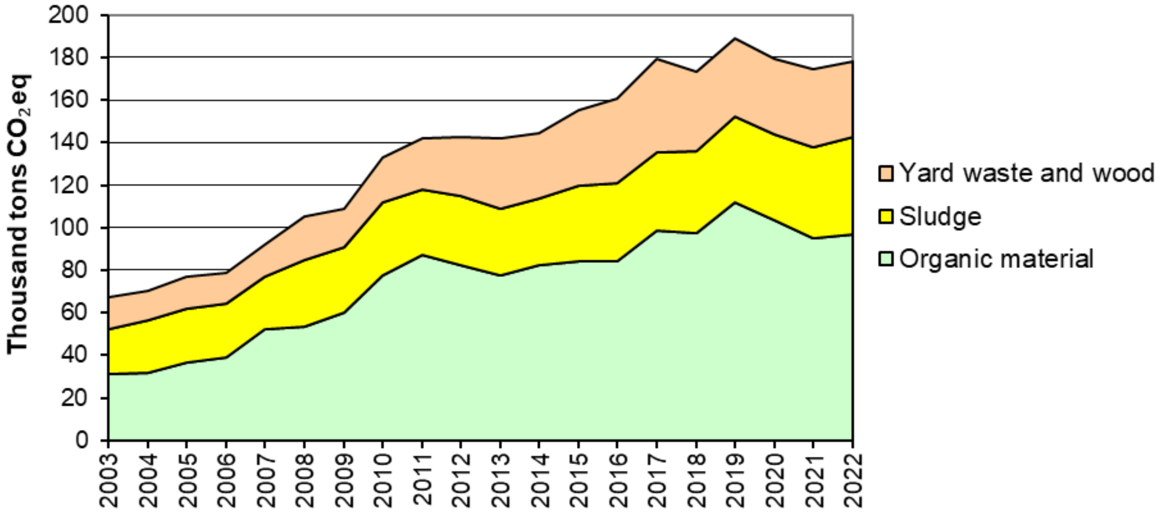


DIAGRAM 7.8B. CH_4 AND N_2O EMISSIONS FROM BIOLOGICAL TREATMENT OF WASTE 2003–2022



7.5. 5.C Waste Incineration

Controlled emissions of Refuse Derived Fuel (RDF) were included in the energy section. Uncontrolled emissions from waste incineration were not calculated, and their extent is assumed to be negligible.

7.6. 5.D Wastewater Treatment and Discharge

7.6.1 Description of Emission Sources

CH_4 and N_2O are emitted from treatment and discharge of household and industrial wastewater.

CH_4 is emitted when anaerobic processes take place, during which organic matter in wastewater decomposes. CH_4 emissions depend on the degradable organic matter in wastewater, its temperature and the method used for treating it. Large amounts of CH_4 are seldom present in wastewater, because even a little oxygen is toxic to anaerobic bacteria that produce the CH_4, although in some WTPs, anaerobic conditions develope that allow the growth of such organisms.

Emission of **N_2O** can be a direct emission in WTPs or an indirect emission from wastewater after its discharge into effluent reservoirs, streams or the sea. N_2O is emitted from the decomposition and oxidation of nitrates in wastewater. Actions to reduce the concentration of nitrogen in wastewater, the purpose of which is to improve the quality of wastewater for agricultural uses, are carried out by means of biological or chemical processes leading to nitrification and denitrification, during which the emission of N_2O also occurs.

Nitrification is an aerobic process that converts ammonia and other nitrogen compounds into nitrate (NO_3), whereas denitrification occurs under anoxic conditions (without free oxygen), and involves biological conversion of nitrate into atmospheric nitrogen (N_2). N_2O emission can be an intermediate product of both processes, and is often associated with denitrification. Direct emission from biological decomposition in WTPs is minor, and usually much less than the emission in effluents. Direct emission is only possible in advanced treatment facilities where nitrification and denitrification take place. In Israel, these processes take place in tertiary treatment facilities and in some secondary treatment facilities.

During the process of wastewater treatment, **CO_2 emissions may occur,** but according to the IPCC guidelines, they need not be reported, as they are of biogenic origin.

During the process of wastewater treatment, sludge is formed at each of the treatment stages. CH_4 from wastewater treatment is sometimes collected and incinerated and can also be used to produce energy.

In Israel, as in other developed countries, the common method of treating wastewater is by means of a central facility for the aerobic treatment of household and industrial wastewater, and in some facilities, pre-treatments are carried out to meet emission standards.

The chain of treatments in a central wastewater treatment facility includes the following steps of treatment:

- Initial treatment – initial filtering of large objects.
- Secondary treatment – a combination of aerobic and anaerobic biological treatments.
- Tertiary treatment – treatment of pathogens, pollutants, and remaining nutrients such as nitrogen and phosphorus compounds.

In Israel, there are two main types of wastewater treatment facilities: intensive treatment facilities and extensive treatment facilities. Most wastewater is treated in intensive facilities.

Intensive treatment facilities are processes in which a great deal of energy is invested and they are relatively fast. During this process, large quantities of air are pumped mechanically into aeration basins where an active bacterial population develops. During this process, the bacteria break down the organic and nitrogenous compounds found in wastewater and convert them into biomass or gas (CO_2) that is emitted into the atmosphere.

Extensive treatment facilities typically include relatively deep anaerobic stabilization pools, interspersed with shallow anaerobic pools. In these pools, algae develope that add oxygen to the water and thus help in the microbial decomposition of pollutants. In pools with a high organic load or that have a relatively small surface area, it is sometimes necessary to add mechanical ventilation to improve the oxidation processes. During these processes, CH_4 is emitted.

7.6.2 5.D.1 Emissions From Treatment of Household Wastewater

7.6.2.1 Methane (CH_4) Emissions

7.6.2.1.1 Calculation Method

The main factor in determining the emission potential of CH_4 from treatment of wastewater is the amount of degradable organic matter in it. Other factors that affect emissions are the temperature of the wastewater (the emissions increase with the increase in temperature) and the method of treating it.

Common indices used to measure the organic component in wastewater are BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand). In wastewater with a higher BOD or COD concentration, more CH_4 will usually be produced.

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen consumed by organisms that break down the organic matter in wastewater. The BOD concentration refers only to the amount of degradable organic carbon in an aerobic process and therefore, increased oxygen consumption is the result of a high organic load and many nutrients in the water. The BOD index is more suitable for estimating the level of pollution in household wastewater. The standard test for the amount of oxygen consumed is carried out under constant conditions, lasts five days, and is called BOD_5.

Chemical oxygen demand (COD) is the amount of oxygen demanded by the organic matter found in wastewater. Testing of wastewater measures the concentration of all the organic matter in it. During this process, chemical oxidation of the total amount of organic matter in the water is conducted in order to determine its concentration. The COD index is more suitable for estimating the level of pollution in industrial wastewater.

CH_4 emissions from treatment of household wastewater were calculated according to the IPCC 2006 guidelines (T1) after their adjustment to the unique conditions in Israel.

Calculation steps

In the process of calculating the emissions, the first step is to calculate the amount of degradable organic matter in wastewater. In the second step, it is necessary to calculate the CH_4 emission factor appropriate for each treatment method. Finally, it is necessary to estimate the amount of wastewater treated according to each treatment method.

Below are the steps for calculating emissions from treatment of household wastewater:

Step A – Calculation of the amount of degradable organic matter in household wastewater (TOW).

Step B – Calculation of the CH_4 emission factor for each treatment method (EF).

Step C – Calculation of CH_4 emissions according to the treatment method (using TOW and EF).

Step A – Calculation of the degradable organic matter in household wastewater (TOW)

In the first step, it is necessary to calculate the amount of degradable organic matter present in household wastewater. The calculation is based on estimating the amount of organic matter produced per capita (in terms of BOD) and multiplying it by the population.

Below is the calculation formula for estimating the degradable organic matter in household wastewater, taken from the IPCC 2006 guidelines:

$$TOW = P \times BOD \times I \times 365$$

TOW – The degradable organic matter in household wastewater, kg BOD per year.

P – Average annual population.

BOD – Grams of BOD per capita per day. The default values in the guidelines are divided according to country. Experts at the Ministry of Environmental Protection recommended a value in the range of 60–65, and therefore an average value of 62.5 was chosen.

I – Correction factor for BOD resulting from the discharge of industrial wastewater into treatment facilities of household wastewater. A default value of 1.25 was chosen according to the IPCC 2006 guidelines.

Step B – Calculation of CH_4 emission factor for each treatment method (EF)

The CH_4 emission factor (EF) varies according to the treatment method of wastewater. The factor is affected by the production capacity of CH_4 in each treatment method and serves as an indication to determine whether the system is anaerobic.

$$EF_j = Bo \times MCF_j$$

Bo – The maximum amount of CH_4 that can be extracted from a given amount of organic matter in wastewater (expressed as a ratio of BOD). The default value chosen is 0.6 kg CH_4/kg BOD.

MCF_j – Correction factor for CH_4.

The correction factor for CH_4, which expresses the part of household wastewater treated using the anaerobic method, varies for different treatment methods. The correction factor for CH_4 was calculated as follows:

For **household wastewater connected to the wastewater treatment facility**, a specific adjustment of the MCF factor was made for each wastewater treatment facility, which enabled a more accurate estimate of the weighted MCF factor.

Below are the existing treatment methods for treatment of household wastewater and the MCF factor for each of them.

Table 7.10 Correction Factor for CH_4 (MCF) for Calculating Emissions From Treatment of Household Wastewater, by Treatment Method (IPCC 2006)

Treatment method	Correction factor for CH_4 (MCF)
Activated sludge	0
Sunken basins and reservoir	0.8
Sunken, surface ventilation and reservoir	0.2
Activated sludge and biological multipliers	0
Sunken basins and oxidation	0
Rot pit and reservoir	0.5
Compact device	0.2
Sunken basins and aeration	0
Sunken + oxidation + evaporation basins	0
Reservoir	0.2
SBR biological reactor	0
Membrane + bioreactor	0
Extensive	0.8
WTP with no data	0.5

The weighted MCF factor was calculated for each year by multiplying the MCF of each facility by the percentage of the total amount of wastewater treated at the facility. The factor obtained was multiplied by the percentage of wastewater from the population connected to the wastewater treatment facility out of the total amount of wastewater produced (The figure for 2022 was estimated using the value of 2021-97.6%).

Experts in the field stated that 50% of the organic matter becomes sludge and that the CH_4 emitted from the sludge is incinerated and used in part to produce energy. Because of this, the factor was multiplied by 0.5 to deduct the organic matter that turns into sludge.

Below is the calculation formula:

$$MCF_{Connected} = 0.5 \times \ PercentWasteWaterconnected \times \sum_{i}^{N} MCF_i \times \frac{WasteWater_i}{TotalWasteWater}$$

PercentWasteWaterconnected – The percentage of the population connected to the wastewater treatment facility.

WasteWater$_i$ – The amount of household wastewater treated in the *i*th WTP

MCF$_j$ – Correction factor for CH_4 in the *i*th WTP

TotalWasteWater – The total amount of household wastewater treated in the WTPs

For wastewater from a population **that is not connected to the wastewater treatment facility**, MCF factors were chosen for each treatment method.

Treatment method	MCF correction factor (IPCC)	Percentage of the population not connected to the wastewater treatment facility (2022, in percentages), imputed from 2021
Self-treatment	0.1	1.65
No treatment	0.5	0.77

$$MCF_{notConnected} = \sum_{i}^{N} MCF_i \times \ PercentWasteWater_i$$

PercentWasteWater$_i$ – The percentage of the population according to the *i*th treatment method.

MCF$_j$ – Correction factor for CH_4 according to the *i*th treatment method.

Finally, a weighted factor was obtained by adding the two factors together:

$$MCF_{Total} = MCF_{notConnected} + MCF_{Connected}$$

and the emission factor for CH_4 is

$$EF = MCF_{Total} \times BO$$

Step C – Calculation of CH_4 emissions according to treatment method (using TOW and EF)

The emissions are calculated based on results of the preceding steps. From the total amount of organic matter (TOW) produced, the wastewater sludge that has been removed, is subtracted – S. This value is multiplied by the relative part of each wastewater source or type of treatment, and from this value, the methane that has been collected is subtracted – R.

As explained above, based on consultation with experts in the field, methane emitted from the sludge is incinerated, part of which is used to produce energy and therefore, it is not included in emissions from the treatment of wastewater.

$$Emissions = EF \times TOW - R$$

7.6.2.1.2 Information Sources

The table below shows the distribution of the population connected to the wastewater treatment facility according to the level of household wastewater treatment. In 2022, about 98% of the population were connected to the wastewater treatment facility, compared with about 91% in 2003.

Table 7.11 Population Connected to Wastewater Treatment Facility, According to Level of Wastewater Treatment, 2003–2022

Percentages

Year	Connected to the wastewater treatment facility				**Not connected** to the wastewater treatment facility	
	Primary treatment	**Secondary treatment**	**Tertiary treatment**	**Undefined treatment**	**No treatment**	**Self-treatment**
2003	10.20	43.70	34.80	2.00	5.30	3.10
2004	9.80	45.20	35.10	2.00	4.40	2.60
2005	8.90	42.90	39.10	2.00	4.10	2.10
2006	8.00	40.40	43.20	1.90	3.80	1.80
2007	6.90	37.90	47.50	1.80	3.50	1.50
2008	6.50	38.40	47.90	1.70	3.20	1.40
2009	6.20	38.90	48.20	1.70	3.00	1.30
2010	5.90	39.10	48.80	1.70	2.60	1.20
2011	5.70	39.30	49.40	1.60	2.20	1.20
2012	5.50	39.00	50.20	1.60	2.20	1.10
2013	5.30	38.60	51.10	1.60	2.20	1.10
2014	5.10	38.20	51.90	1.50	2.20	1.00
2015	5.00	37.60	52.70	1.50	2.20	0.90
2016	4.90	37.00	53.40	1.50	2.20	0.90
2017	4.80	37.10	53.40	1.40	2.30	0.90
2018	4.60	36.80	53.90	1.50	2.30	0.90
2019	4.40	36.60	54.50	1.40	2.30	0.80
2020	4.42	35.57	55.67	1.38	2.16	0.79
2021	3.13	33.74	59.32	1.38	0.77	1.65
2022 (imputed from 2021)	3.13	33.74	59.32	1.38	0.77	1.65

Table 7.12 Household Wastewater Treated in WTPs (Wastewater Treatment Facilities), by Treatment Method, 2022

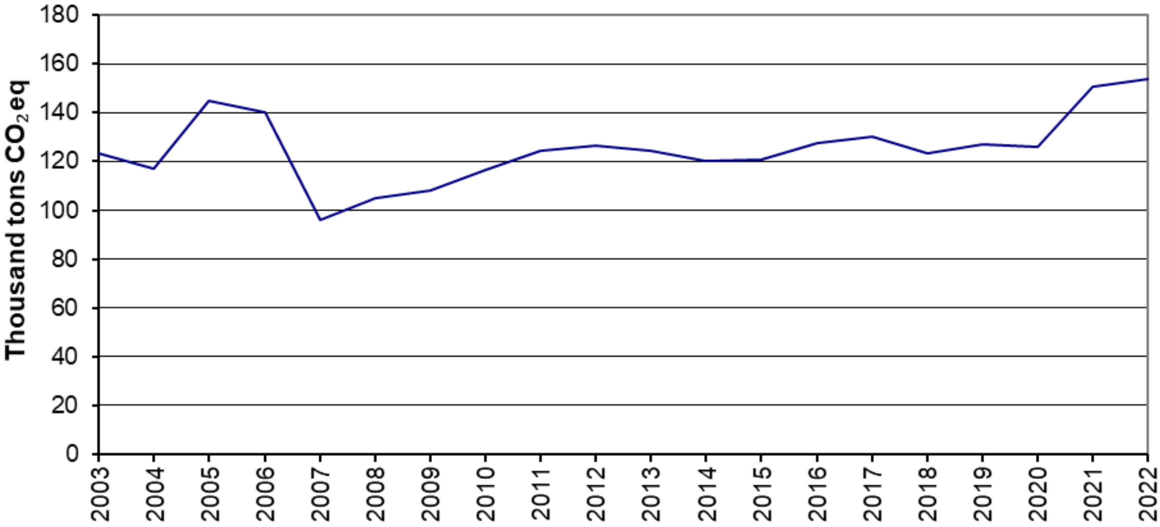
Million cubic meters

MCF factor	Treatment method	Household wastewater treated
	Total	538
0	Activated sludge	491
	Activated sludge and multiplexes	0
	SBR biological reactor	19
	Biological multiplexes	5
	Sunken and oxidation basins	0
	Membrane + bioreactor	1
	Aeration basins	10
	Sunken and aerated basins	0
0.2	Sunken surface ventilation and reservoir	0
	Reservoir	
0.8	Extensive	0
	Sunken basins and reservoir	13
	Sunken basins	0

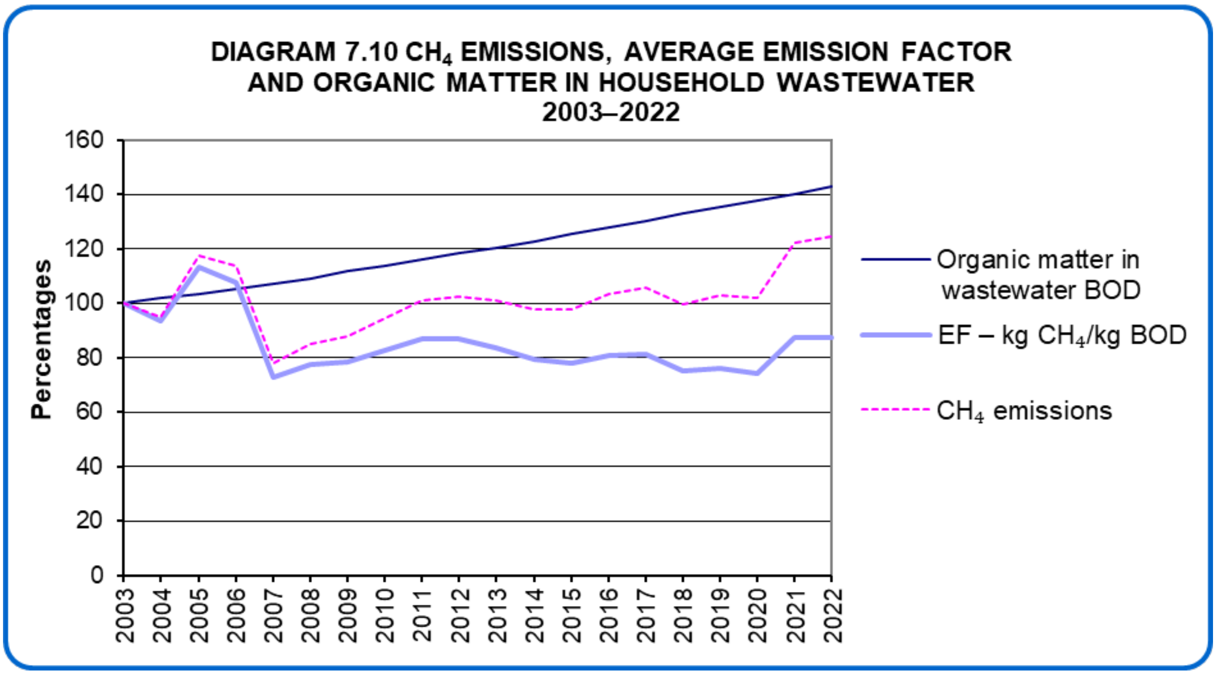
7.6.2.1.3 Emissions

In 2022, CH_4 emissions from treatment and discharge of household wastewater amounted to 153,900 tons of CO_2eq, which accounted for about 1.7% of the total amount of emissions from waste and wastewater. Between the years 2007 and 2022, emissions increased by 59.7%.

DIAGRAM 7.9 CH_4 EMISSIONS
FROM TREATMENT AND DISCHARGE OF HOUSEHOLD WASTEWATER
2003–2022



As mentioned, CH_4 emissions from treatment of household wastewater are affected by the amount of organic matter in the wastewater and the methods used to treat it. On the one hand, the emissions increase with the increase in the amount of organic matter in the wastewater (which increases due to population growth) and on the other hand, the treatment method changes over the years, and more wastewater is treated using tertiary treatment and in intensive facilities (where less CH_4 is emitted). In the diagram, it is possible to see that the total amount of organic matter in the wastewater has increased continuously over the years (with the increase in population), but the average emission factor is stable and has even decreased in some years due to changes in the distribution of wastewater treatment. The rate of emissions is moderated by these changes.



7.6.2.1.4 Data Limitations

The estimate of the degradable organic matter in household wastewater was based on an average value of one BOD (gram per capita per day) throughout all the years.

Calculation of the CH_4 emission factor was based on the default factors recommended in the IPCC guidelines after adjusting them to the various wastewater treatments in Israel. This adjustment is general, so there may be differences between the wastewater treatment facilities.

7.6.2.2. Nitrous Oxide (N_2O) Emissions

7.6.2.2.1 Calculation Method

N_2O emissions from treatment and discharge of household wastewater were calculated according to the IPCC 2006 guidelines after adjusting them to the unique conditions in Israel.

Calculation steps

N_2O emissions from the treatment and discharge of household wastewater are generated in WTPs where the treatment level is high (tertiary treatment), and in wastewater discharged into nature.

When calculating the emissions from wastewater discharged into nature, it is necessary to estimate the amount of nitrogen in the wastewater. The IPCC guidelines present a formula for calculating the amount of nitrogen in wastewater based on the consumption of protein per capita and multiplying it by the population. Up to 2017, the calculation in Israel was carried out in this way, but after better sources of information were found in Israel to estimate the nitrogen in wastewater – information on amounts of wastewater and the concentration of nitrogen in it – the calculation method was updated for all years of the calculation.

Below is a general description of the calculation of emissions in each source:

The first source of N_2O emissions is the tertiary treatment facilities, and emissions from them were calculated based on the extent of treatment in these facilities and multiplying that by the emission factor presented in the IPCC 2006 guidelines.

The second source of N_2O emissions is the nitrogen generated in wastewater discharged into nature (into the sea and into streams). The emission calculation is based on an estimate of the amount of nitrogen available in the discharged wastewater and the nitrogen concentrations in it. There are two types of wastewater discharged into nature which contain nitrogen: effluents and untreated wastewater.

Effluents are raw wastewater that has been treated to reduce its organic load. In 2022 About 82% of the effluents in Israel are used for irrigation. The nitrogen in these effluents is a source of fertilizer and is included in N_2O emissions from organic fertilizers in Chapter 5 – Agriculture. About 10% of the effluents are discharged into nature, and N_2O is emitted from them in the Wastewater category.

All untreated wastewater is discharged into nature.

After calculating the estimate of the nitrogen discharged into nature (in effluents and untreated wastewater), N_2O emissions were calculated.

The total amount of N_2O emissions includes emissions in the tertiary treatment facilities (the first source) and emissions from the discharge of wastewater into nature (the second source).

The first source – Calculation of N_2O emissions generated in tertiary treatment facilities

The first source of N_2O emissions is the tertiary treatment facilities, and emissions from them were calculated based on the share of wastewater treatment of that type, the annual population and an emission factor per capita.

N_2O_{PLANTS} – Total amount of N_2O emissions from the treatment facilities (kg).

P – Annual population.

T_{PLANT} – The share of wastewater treated in the tertiary treatment facilities. The figure was obtained from the Ministry of Environmental Protection.

$F_{IND-COM}$ – Protein correction factor from industry and commerce. A default value of 1.25 was recommended.

EF_{PLANT} – N_2O emission factor – 3.2 grams per capita per year.

44/28 – Conversion factor from nitrogen to N_2O (according to the molar ratio between the oxygen and the nitrogen).

The second source – Calculation of N_2O emissions from nitrogen in wastewater discharged into nature (into the sea and into streams)

The amounts of nitrogen in the wastewater are estimated by multiplying the concentration of nitrogen in the wastewater by the amount of wastewater.

Data on the concentration of nitrogen in wastewater and the amount of wastewater and effluents were obtained from national surveys that the Water Authority conducts every few years on the collection and treatment of wastewater and the utilization of effluents, for example, Collection and treatment of wastewater and the utilization of effluents for agricultural irrigation: National survey 2018 (Hebrew only). In these surveys, there is information on the nitrogen concentrations at the exit of the WTP and on the amounts of wastewater and effluents, according to purpose. There are such surveys for the years 2006–2007, 2010, 2012, 2014, 2016 and 2018. For missing years, the results of the nearest survey were used.

The total amount of nitrogen available in wastewater is multiplied by an emission factor and converted into N_2O values according to the molar ratio.

$$N_2O\ Emissions = N_{EFFLUENT} \times EF_{EFFLUENT} \times 44/28$$

N_2O emissions – Total amount of N_2O emissions from discharge of wastewater (kg per year).

$N_{EFFLUENT}$ – The amount of nitrogen available in wastewater (kg per year), estimated by multiplying the concentration of nitrogen in wastewater by the amounts of wastewater.

$EF_{EFFLUENT}$ – Emission factor – kg of N_2O per kg of nitrogen available in wastewater. A default value of 0.005 was recommended.

44/28 – Conversion factor from nitrogen into N_2O (according to the molar ratio between the oxygen and nitrogen).

7.6.2.2.2 Information Sources

Table 7.13 shows the data on wastewater treated using tertiary treatment each year, which are used to calculate N_2O emissions from WTPs.

Table 7.13 The Proportion of Wastewater Treated Using Tertiary Treatment and N_2O Emissions From WTPs (Wastewater Treatment Plants), 2003–2022

Year	Proportion of wastewater treated in tertiary facilities (in percentages)	Nitrous oxide emissions from WTPs (in tons)
2003	34.80	9,312
2004	35.10	9,560
2005	39.10	10,839
2006	43.20	12,189
2007	47.50	13,642
2008	47.90	14,004
2009	48.20	14,432
2010	48.80	14,881
2011	49.40	15,345
2012	50.20	15,884
2013	51.10	16,473
2014	51.90	17,055
2015	52.70	17,665
2016	53.40	18,254
2017	53.40	18,612
2018	53.90	19,151
2019	54.50	19,738
2020	55.67	20,520
2021	59.32	22,237
2022 (imputed from 2021)	59.32	22,679

Table 7.14 shows the amounts of nitrogen available in wastewater for each year, obtained by multiplying the nitrogen concentrations by the amounts of wastewater. As mentioned, the data are not published every year, and for missing years, data were estimated or imputed.

The amounts of effluents and wastewater discharged into nature and the amounts of effluents used for agriculture were obtained from the "Collection and treatment of wastewater and utilization of effluents" surveys of the Water Authority during the years in which the surveys were conducted. In the missing years, the data on the amounts of effluents used for agriculture were obtained from the Water Authority, and based on these amounts, the total amount of effluents was estimated.

The concentrations of nitrogen in effluents and wastewater were obtained from "Collection and treatment of wastewater and utilization of effluents" surveys during the years in which the surveys were conducted. In the missing years, the nitrogen concentrations in the effluents were taken from surveys of neighbouring years, and the nitrogen concentrations in untreated wastewater were estimated based on a multi-year average of 77 mg/l (milligrams per liter).

Table 7.14 Estimate of the Nitrogen Available in Wastewater and in Effluents Discharged Into Nature, 2003–2022

Million cubic meters (Mcm)

Year	Source	Effluents used for agriculture, Mcm	Effluents discharged into nature, Mcm	Effluents – total Mcm	Untreated wastewater, Mcm	Concentration of nitrogen in effluents, mg per litre	Concentration of nitro gen in untreated wastewater, mg per litre	Calculation of nitrogen in effluents discharged into nature, (tons)	Calculation of nitrogen in effluents used for agriculture, (tons)	Calculation of nitrogen in untreated wastewater discharged into nature (tons)
		A	B		C	α	β	= B*α	= A*α	= C *β
2003	estimate	288.00	106.80	394.80	41.600	29.90	77	3,193	8,611	3,203
2004	estimate	312.00	115.70	427.70	41.600	29.90	77	3,459	9,329	3,203
2005	estimate	335.00	124.23	459.23	41.600	29.90	77	3,714	10,017	3,203
2006	estimate	359.00	133.13	492.13	41.600	29.90	77	3,981	10,734	3,203
2007	estimate	357.70	114.30	472.00	44.401	29.90	77	3,418	10,695	3,419
2008	estimate	404.00	129.09	533.09	44.401	29.90	77	3,860	12,080	3,419
2009	estimate	388.00	123.98	511.98	44.401	29.90	77	3,707	11,601	3,419
2010	estimate	384.20	56.50	440.70	42.600	29.90	77	1,689	11,488	3,280
2011	estimate	421.00	61.91	482.91	42.600	29.90	77	1,851	12,588	3,280
2012	survey	400.80	53.56	454.36	39.370	29.60	78	1,585	11,864	3,071
2013	estimate	463.00	61.87	524.87	39.370	29.60	75	1,831	13,705	2,953
2014	survey	418.75	46.30	465.05	33.400	30.20	80	1,398	12,646	2,672
2015	estimate	476.00	52.63	528.63	33.400	30.20	75	1,589	14,375	2,505
2016	survey	444.40	59.93	504.33	33.180	28.52	78	1,709	12,674	2,588
2017	estimate	520.00	70.13	590.13	33.180	28.52	76	2,000	14,830	2,522
2018	survey	472.95	70.73	543.68	35.410	23.80	75	1,683	11,256	2,656
2019	estimate	545.00	81.51	626.51	35.410	23.80	77	1,940	12,971	2,727
2020	estimate	471.03	103.20	574.23	28.530	26.00	77	2,683	14,930	2,197
2021	estimate	557.00	122.04	679.04	28.530	26.00	77	3,173	17,655	2,197
2022	estimate	591.00	129.48	720.48	28.530	26.00	77	3,367	18,733	2,197

7.6.2.2.3 Emissions

In 2022, N_2O emissions from treatment and discharge of household wastewater amounted to approximately 17,600 tons of CO_2eq, which accounted for about 0.2% of the total amount of emissions from waste and wastewater.

Between 2003 and 2022, the total amount of N_2O emissions from treatment and discharge of household wastewater increased by 11.5%. Between 2003 and 2014, the emissions decreased by 17.7% due to a decrease in the amount of effluents discharged into nature and a decrease in nitrogen concentrations in these effluents. Between 2015 and 2022, emissions increased by 33.2% due to an increase in the amount of wastewater and, in some years, an increase in nitrogen concentrations in effluents.

Emissions from WTPs increased by 143.5% between 2003 and 2022, mainly because of the increase in the amounts of wastewater treated using tertiary treatment (about 35% in 2003 compared with about 59% in 2022).

The trend of the emissions over the years is mixed and is impacted by fluctuations in the amounts of effluents and wastewater discharged into nature, and by concentrations of nitrogen in wastewater, as shown in the diagram.

DIAGRAM 7.11 N_2O EMISSIONS FROM TREATMENT AND DISCHARGE OF HOUSEHOLD WASTEWATER, BY SOURCE 2003–2022

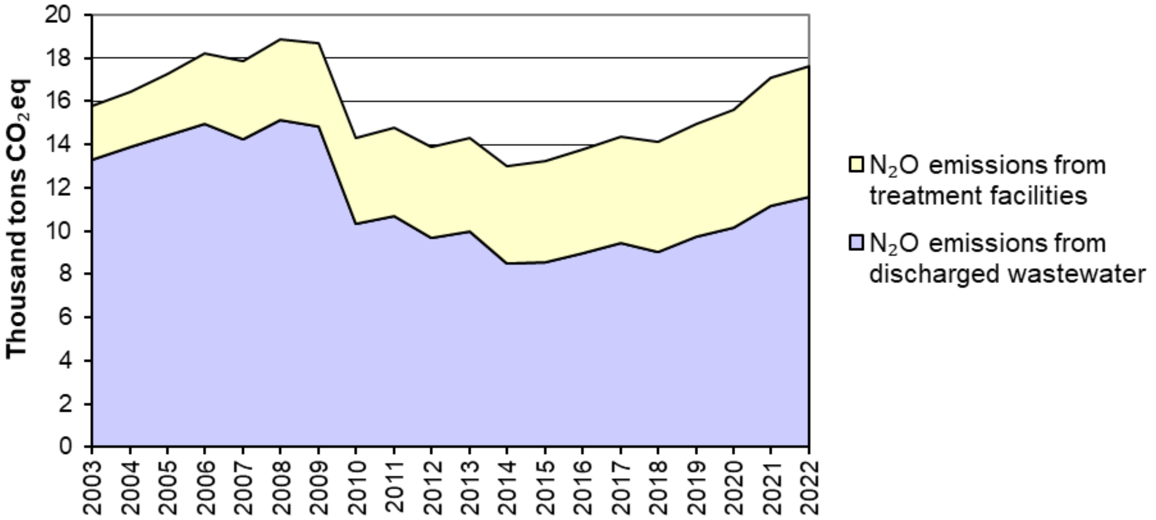
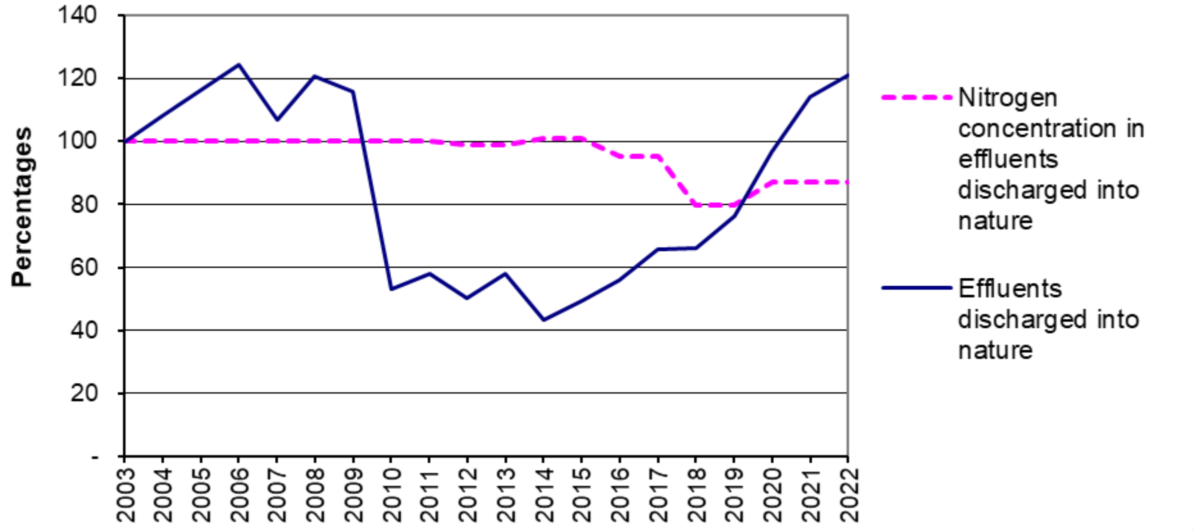


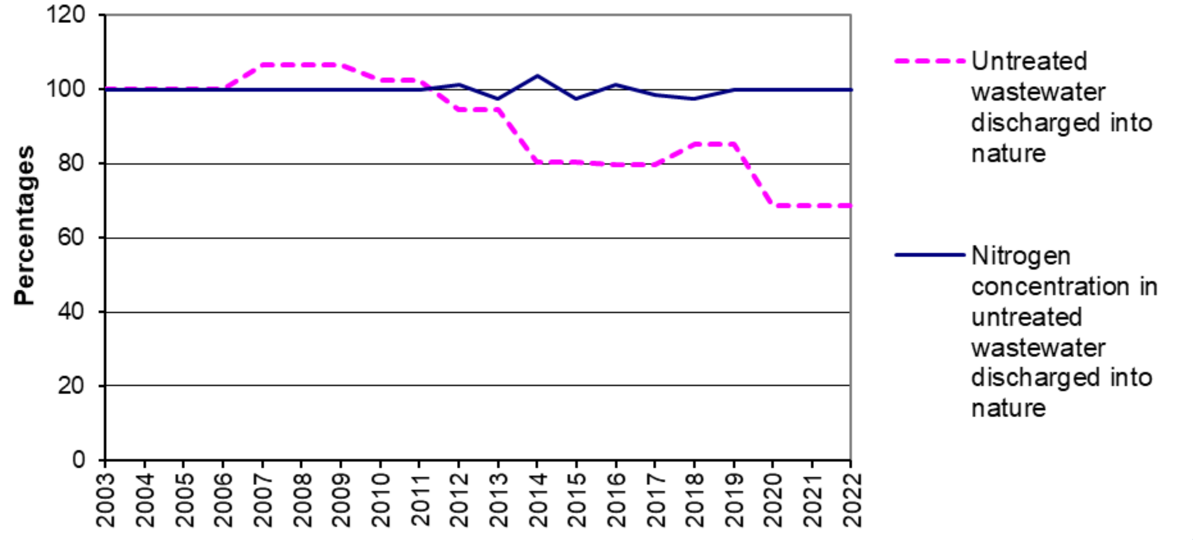
DIAGRAM 7.12 INDICES OF THE AMOUNT OF EFFLUENTS DISCHARGED INTO NATURE AND THEIR NITROGEN CONCENTRATIONS 2003–2022



Index of the amount of effluents 106.8 Mcm = 100% (2003)

Index of the concentration of nitrogen in effluents 29.9 mgl = 100% (2003)

DIAGRAM 7.13 INDICES OF THE AMOUNT OF UNTREATED WASTEWATER DISCHARGED INTO NATURE AND NITROGEN CONCENTRATIONS IN IT 2003–2022



Index of untreated wastewater 41.6 Mcm = 100% (2003)

Index of nitrogen concentration in untreated wastewater 77 mgl = 100% (2003)

7.6.2.2.4 Data Limitations

The amounts of nitrogen in wastewater and in effluents are estimated by multiplying the concentration of nitrogen in wastewater and in effluents by the amounts of wastewater and effluents. The nitrogen concentrations in wastewater and effluents were obtained from the Water Authority reports for the years in which the Collection and Treatment of Wastewater and Utilization of Effluents for Agricultural Irrigation surveys were conducted. For missing years, the concentrations were estimated based on the nearest survey.

7.6.3 5.D.2 Emissions From Treatment of Industrial Wastewater

7.6.3.1 Methane (CH_4) Emissions

7.6.3.1.1 Calculation Method

Industrial wastewater can be treated in the central wastewater facility (which treats household wastewater) or in treatment facilities in the industrial plants. Emissions from discharge into the central wastewater facility were calculated in the category of emissions from treatment of household wastewater. This section deals with CH_4 emissions from treatment of industrial wastewater in industrial plants.

CH_4 is emitted from treatment of industrial wastewater with a high organic load and under anaerobic conditions. The production industries with a high organic load in wastewater are paper, food, dairy products, soft drinks, beer, wine, vegetable oils, meat and fish, as well as processed vegetables and fruits and juices.

CH_4 emissions from treatment of industrial wastewater were calculated according to the IPCC 2006 guidelines (T1).

Calculation steps

Below are the steps for calculating emissions from treatment of industrial wastewater:

Step A – Calculation of the degradable organic matter in industrial wastewater (TOW).

Step B – Calculation of the CH_4 emission factor according to treatment method (EF).

Step C – Calculation of CH_4 emissions according to the treatment method (using TOW and EF).

Step A – Calculation of degradable organic matter in industrial wastewater (TOW)

The amount of degradable organic matter in industrial wastewater was calculated based on factors of the amounts of wastewater produced in each production industry per ton of production and based on COD factors per cubic meter of wastewater produced.

Below is the calculation formula for estimating the degradable organic matter in industrial wastewater:

$$TOW = \sum P_i \times W_i \times COD_i$$

TOW – The degradable organic matter in industrial wastewater, kg COD per year.

P_i – The industrial output in each production industry, tons per year.

W_i – The amount of wastewater produced in each manufacturing industry, cubic meters of wastewater produced per ton of production. The default values used are those in the IPCC guidelines, by production industry.

COD_i – gram of COD per cubic meter of wastewater produced in each production industry. The default values used are those in the IPCC guidelines, by production industry.

Below are the factors chosen for calculation according to the IPCC 2006 guidelines:

Table 7.15 Emission Factors From Treatment of Industrial Wastewater, by Production Industry (IPCC 2006)

Manufacturing industry	Cubic meter of wastewater per ton of production	Kg of COD per cubic meter of wastewater produced
Paper	162.00	9.00
Processed vegetables and fruits and juices	20.00	5.00
Dairy products	2.70	7.00
Soft drinks	2.00	2.00
Beer	6.30	2.90
Wine	23.00	1.50
Vegetable oils	3.10	0.30

Step B – Calculation of CH_4 emission factor according to treatment method (EF)

The CH_4 emission factor (EF) varies according to the wastewater treatment method. The factor is affected by the production capacity of CH_4 (in every treatment method) and serves as an indicator to determine whether the facility is anaerobic.

$$EFj = Bo \bullet MCF_j$$

Bo – The maximum amount of CH_4 that can be extracted from a given amount of organic matter in wastewater (expressed as a ratio of COD). The default value was chosen from the IPCC guidelines: CH_4/kg 0.25kg COD.

MCF_j – CH_4 correction factor. On the recommendation of experts in Israel, a value of 0.15 was chosen, as in secondary treatment, which is appropriate for Israel.

Step C – Calculation of CH_4 emissions according to treatment method (using TOW and EF)

Emissions are calculated based on the results of the preceding steps. From the total amount of organic matter produced (TOW), the wastewater sludge removed must be subtracted (S). This value is multiplied by the relative part of each wastewater source or treatment method, and from this value, the methane collected must be subtracted (R).

In the calculation, the sludge in the preliminary treatments in industry was not subtracted, nor was an estimate calculated for the amount of CH_4 that was collected (R) during those treatments.

$$(TOW - S) \times EF - R$$

EF – Emission factor for CH_4.

TOW – The amount of degradable organic matter in wastewater.

S – The amount of sludge removed.

R – The amount of CH_4 collected.

7.6.3.1.2 Information Sources

Data on amounts of wastewater produced in the production industries in Manufacturing were obtained from the Senior Sector of Agriculture, Environment and Energy and the Business and Manufacturing Indices Sector at the Central Bureau of Statistics, Israel.

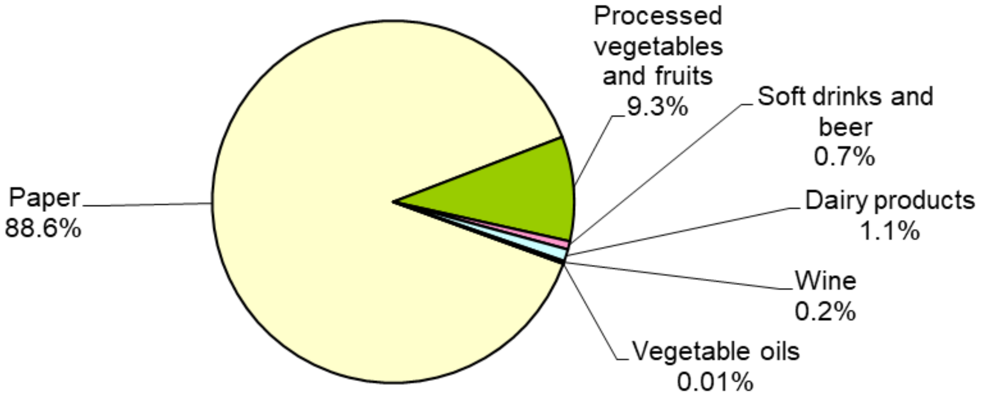
Emissions were calculated based on produce in the paper, dairy, beer, wine, juices and vegetable oil industries.

There was no information on the amount of production of the industries that use vegetables and fruits, and the input data on production using vegetables and fruits were used on the assumption that they correspond with the quantity of production.

7.6.3.1.3 Emissions

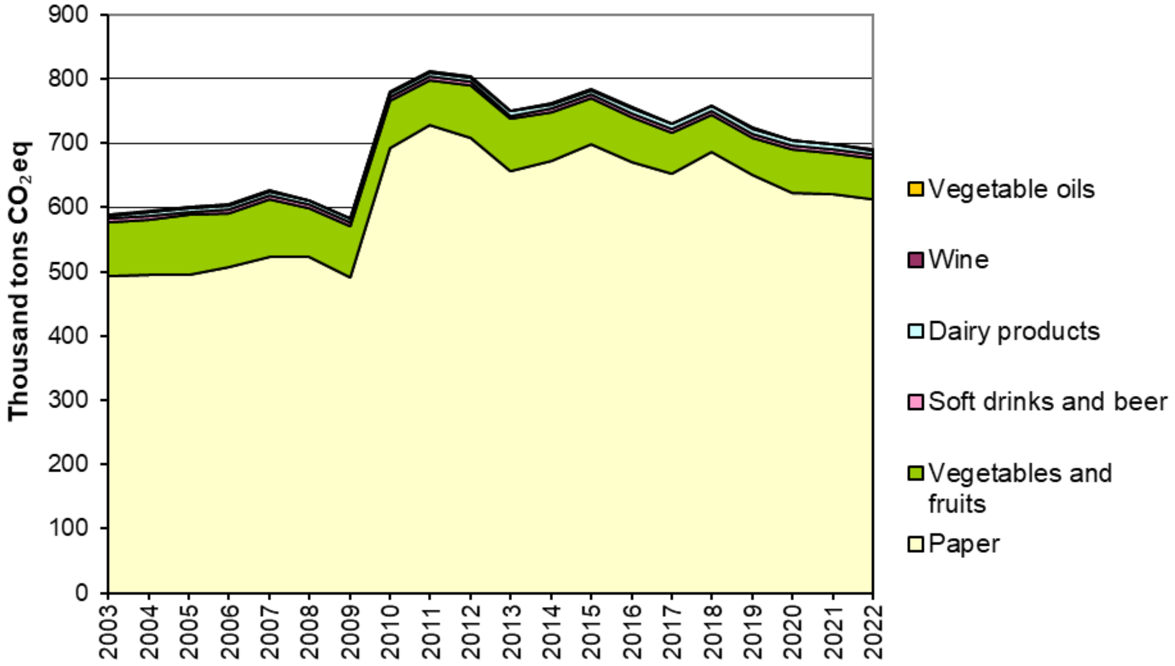
In 2022, CH_4 emissions from the treatment of industrial wastewater amounted to 690,700 tons of CO_2eq, which accounted for about 7.6% of the total amount of emissions from waste and wastewater. Between the years 2003 and 2022, the emissions increased by 17.3% and between the years 2021 and 2022, they decreased by 1.2%. Most of the emissions from treatment of industrial wastewater (about 88%) were from paper production.

DIAGRAM 7.14A. CH_4 EMISSIONS FROM TREATMENT OF INDUSTRIAL WASTEWATER, BY PRODUCTION INDUSTRY 2022



Total
0.69 thousand tons CO_2eq

DIAGRAM 7.14B. CH_4 EMISSIONS FROM TREATMENT OF INDUSTRIAL WASTEWATER, BY PRODUCTION INDUSTRY 2003–2022



7.6.3.1.4 Data Limitations

The estimate of emissions is based on production quantities in industries that produce wastewater with organic content. For some of these industries, there was no information on the amount of production, and their input data was used on the assumption that they correspond with the amount of production. In some industries, the amount of production does not include the total amount of production in the economy.

Emissions from industries that process meat and fish and from organic chemical production were not included.

Emissions resulting from sludge treatment in the preliminary treatments in industry were not calculated, nor was an estimate calculated for the amount of CH_4 collected during those treatments.

8. Updates and Recalculations of the Inventory

8.1. General

The inventory of GHG emissions is calculated yearly according to the information available at the time of calculation. An update of the inventory calculation may stem from an update to the data used for the calculation. For example, an update of the quantities of fuels consumed, an update of the amount of methane (CH_4) collected in landfills, or an update of the volume of imports of gases containing fluorine, all lead to updates in the calculation.

Another reason for updates is improvement of the calculation method, for example a switch from calculating emissions based on default coefficients to calculations based on detailed information specific to Israel (such as data from the report to the Ministry of Environmental Protection's Pollutant Release and Transfer Register [PRTR]).

In addition, there are updates due to errors in calculations and in reports from the data sources.

Information in detail on updates in the calculation is documented from 2018 onwards, and the updates for the years 2008 and 2011 – years when a change in the calculation method has had an effect on the feasibility of comparing the data between the years – are also presented.

8.2. Updates Conducted

8.2.1. 2008 Inventory

The calculation of emissions from the use of substitutes for ozone-depleting substances began with the 2008 inventory.

8.2.2. 2011 Inventory

The calculation of emissions from agriculture was updated from the 2011 inventory onwards, and it was conducted based on the IPCC 2006 calculation guidelines, in contrast to previous inventories, that were calculated according to the IPCC 1996 guidelines. Furthermore, in the 2011 inventory and those following, the emission factors from enteric fermentation and the distribution of manure management were updated, and emissions from the use of additional organic fertilisers (compost, sewage sludge, and effluents) and nitrogen emissions from land use change were included.

8.2.3. 2018 Inventory

Emissions from refinery gases – Until the 2018 inventory, the default coefficient of the energy value of refinery gases, as stated in the IPCC guidelines, was used. Starting from the 2018 inventory, the calculation method has been updated, and the energy value is calculated as the difference between the energy value of the inputs and the energy value of the outputs in the refineries, according to the energy balance. For previous years, the energy value was estimated.

Emissions from oil shale – Until the 2018 inventory, the default coefficients from the IPCC were used for emissions from oil shale regarding the pollutants SO_X, NO_X, and CO. Since the 2018 inventory, the emissions data have been obtained from the reports to the PRTR for the year 2012 and onwards. For the years 2000–2011, emissions were estimated based on the reports to the PRTR from the year 2012. Emissions from oil shale were attributed in the past to electricity generation, however, starting from the 2018 inventory, they have been attributed to manufacturing, since most of the oil shale is consumed in manufacturing. (The data were updated for all the calculation years.)

Emissions from waste incineration – Emissions from incineration of refuse-derived fuel (RDF), which started in 2012 in small quantities, but from 2016 increased considerably, were added to the calculation. (The data were updated for all the calculation years.)

8.2.4. 2019 Inventory

Emissions from biological treatment of waste – Emissions of CH_4 and N_2O from biological treatment of sludge and organic matter were added (for the year 2003 and onwards).

8.2.5. 2020 Inventory

Emissions from fuels – The data on emissions of the pollutants NO_X and SO_2 from combustion of refinery gases for the years 2012–2020 were updated. Previously, the estimate of refinery gases from the energy balance was used, and this was multiplied by international emission factors. Since the 2020 inventory, data on emission of pollutants have been estimated according to the reports of the refineries to the PRTR.

Emissions from waste and wastewater – The calculation of N_2O from wastewater treatment and disposal was updated for the years 2003–2019, and accordingly, the estimates of nitrogen in wastewater were corrected and the quantities of nitrogen transferred to agricultural irrigation were deducted and were included in the calculation of emissions in agriculture The data are based on a survey of effluents conducted by the Water Authority.

The calculation of CH_4 emissions from household wastewater was updated, and a CH_4 emission factor was calculated in accordance with the methods of wastewater treatment used in Israel. The update was carried out from the 2003 inventory onwards.

Emissions from agriculture – The quantities of organic matter actually recycled were updated (using up-to-date information obtained from the companies on the actual recycling of organic matter), and accordingly, data on emissions of N_2O from the use of organic fertilisers for the years 2012–2019 were corrected.

The number of camels and horses was updated, and accordingly, data on emissions of N_2O and CH_4 from enteric fermentation and manure management for the years 2011–2019 were corrected.

The quantities of nitrogen from effluents that were used for irrigation and previously were included in emissions from wastewater, were added, and accordingly, data on emissions of N_2O from the use of organic fertilisers for the years 2011–2019 were corrected.

Emissions from industrial processes and product use – In the past, not all sources of emissions from glass production were included, only emissions from the use of soda ash. In the 2020 inventory, emissions from all sources in glass production were added, including from the use of soda ash. Therefore, in the calculation of emissions from the entire economy's use of soda ash, emissions from the use of soda ash for glass production were deducted, in order to avoid double counting. Accordingly, the data on CO_2 emissions from the year 2003 onwards were corrected, including emissions from glass production.

The classification of the use of gases in industrial processes and product use was updated, and accordingly, the data on emissions from the use of hydrofluorocarbons (HFCs) for the years 2017–2019 were corrected.

In the past, emissions of N_2O and NO_X from nitric acid production were calculated using international emission factors, whereas from 2020 onwards, the emissions data are obtained from the companies' reports to the PRTR. Due to this change, the emissions data for these gases for the years 2003–2019 were corrected.

8.2.6. 2022 Inventory

The Global Warming Potential (GWP) coefficients were updated to the latest values in accordance with the IPCC Fifth Assessment Report (AR5).
The latest coefficients are presented in Appendix A, Global Warming Potential Coefficients.

Emissions from fuels – Emission calculations for CO and NO_X from motor vehicles for 2020 were updated to include LPG-powered and hybrid vehicles. Fuel oil consumption in the industrial sector for 2013–2020 was revised following the receipt of updated data from the Fuel Administration. The distribution of Diesel oil consumption for 2019–2020 was updated based on new information.

Emissions from waste and wastewater – Recycling quantities of organic material from 2016 to 2020 were updated, and methane (CH_4) and nitrous oxide (N_2O) emissions from waste treatment during these years were recalculated accordingly. Nitrogen estimates in wastewater were updated, leading to corrections in nitrous oxide (N_2O) emissions from wastewater for 2020.

Emissions from agriculture – Synthetic fertiliser usage quantities were updated, resulting in corrections to nitrous oxide (N_2O) emissions from fertilisers for 2019–2020. Nitrogen quantities from wastewater effluent used for irrigation were revised, and nitrous oxide (N_2O) emissions from effluents' fertilisation for 2020 were corrected accordingly. Recycling quantities of organic material and pruning residues used as compost from 2016 to 2020 were updated, leading to adjustments in nitrous oxide (N_2O) emissions during these years.

9. Glossary

Carbon dioxide (CO_2)

A greenhouse gas originating from the combustion of material that contains carbon.

Carbon dioxide equivalent (CO_2eq)

A unit of measure used to compare emissions of different greenhouse gases based on their global warming potential (GWP) by converting them to the equivalent amount of carbon dioxide.

Carbon monoxide (CO)

A colourless, odourless and poisonous gas produced by incomplete fossil fuel combustion. Carbon monoxide is a greenhouse gas precursor.

Gases containing fluorides

Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulfur hexafluoride (SF_6).

Global Warming Potential (GWP)

An index that represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation. This index represents the effect of greenhouse gases on global warming relative to carbon dioxide (the GWP of CO_2 is defined as 1). The index is calculated according to the time horizon of the gas's effect in the atmosphere, and in international comparisons, it is customary to use the index calculated according to a time horizon of 100 years.

Greenhouse effect

A process in which greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. The infrared radiation turns into heat, which causes the warming of the atmosphere.

Greenhouse gas (GHG)

A gas occurring naturally and resulting from human activities, and contributing to the greenhouse effect and the global warming. Including Carbon dioxide (CO_2), Nitrous oxide (N_2O), Methane (CH_4), Ozone (O_3), Sulfur hexafluoride (SF_6), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and other gases.

Hydrofluorocarbons (HFCs)

A group of organic gas compounds composed of carbon, hydrogen and fluoride atoms. These compounds are emitted mainly from cooling and air-conditioning systems

Methane (CH_4)

A colourless, non-poisonous and flammable hydrocarbon greenhouse gas created by anaerobic decomposition of organic compounds. Methane is produced from animal digestion processes, mainly from chewing cud, and from anaerobic decomposition of animal secretions. Methane is also produced from other sources such as organic waste and plant

Nitrogen oxides (NO_X)

Acidic gases emitted primarily by power stations, manufacturing plants, and motor vehicles (mainly from diesel engines).

Nitrous oxide (N_2O)

A greenhouse gas produced from fuel combustion and microbial processes in soil and water, which are caused by the use of fertilizers that contain nitrogen.

Perfluorocarbons (PFCs)

A group of organic gas compounds composed of carbon and fluoride atoms. These compounds are emitted mainly from the electronics industry and semi-conductors.

Sulfur dioxide (SO_2)

A heavy, pungent, colourless gas formed primarily by the combustion of fossil fuels. It is harmful to human beings, animals and vegetation, and contributes to the acidity in precipitation.

Sulfur hexafluoride (SF_6)

A non-organic gas compound, emitted mainly by production processes and magnesium casting, as well as its use as an isolating medium in switchgear and circuit breaker systems.

10. Appendices

10.1 Appendix A – Global Warming Potential Coefficients

Below are the Global Warming Potential (GWP) coefficients for the various gases. The coefficients were taken from the he Fifth Assessment Report (AR5) of the IPCC based on a 100-year time horizon. For gases that did not have coefficients listed in the report, coefficients were taken from publications by the gas manufacturers based on the specifications of these gases.

Table 10.1 Global Warming Potential Coefficients

Gas	Until 2022 inventory	From 2022 inventory
CO_2	1	1
CH_4	21	28
N_2O	310	265
R-410	1,725	1,924
DYR5	1,120	1,120
HFC-125	2,800	3,170
HFC-134a	1,300	1,300
HFC-152a	140	138
HFC-227ea	2,900	3,350
HFC-23	11,700	12,400
HFC-236fa	6,300	8,060
HFC-32	650	677
HFC-41	150	116
HFO-1233zd	1	1
HFO-1234	1	1
MO89	3,698	3,527
PFC-116	9,200	11,100
PFC-14	6,500	6,630
PFC-218	7,000	8,900
PFC-318c	8,700	9,540
R-1336MZ	2	2
R-245FA	1,030	858
R-404	3,260	3,943
R-407	1,770	1,923
R-407c	1,526	1,624
R-417	2,346	2,127
R-422D	2,729	2,473
R-426A	1,508	1,371
R-427A	2,138	2,024
R-437A	1,805	1,639
R-438	2,265	2,059
R449a	1,397	1,282
R-452A	2,141	1,945
R-507	3,300	2,235
R-508	10,350	10,350
R-508b	10,350	11,698
R513a	631	573
R514a	2	8
SF_6	23,900	23,500
YH222a	2,465	1,606

10.2 Appendix B – Analysis of Key Category Sources

To focus on the key category sources, the IPCC provides methods to examine and quantify the relative contribution of the emission sources. In the IPCC guidelines, some of the sources are defined as "key source category". This is the IPCC definition: "A key source category is an emission source that has a significant impact on the total greenhouse gas emissions in the country or on the trend of emissions over time. Analyzing key source categories makes it possible to identify where the best opportunities to reduce emissions are."

The key source categories can be analyzed at different levels of detail. The key source categories as defined by the IPCC are Energy, Industrial processes and product use, Agriculture, Land use change and forestry, and Waste and wastewater. For the purpose of analyzing the key source categories in Israel, the key sources were divided into secondary sources:

Table 10.2 Emission Sources of GHG in Israel, by Type of Source, 2022

Level 1	Level 2	Level 3	Level 4
1. Energy	A. Fuel combustion activities	1. Energy industries	a. Electricity and heat production
1. Energy	A. Fuel combustion activities	1. Energy industries	b. Petroleum refining
1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	
1. Energy	A. Fuel combustion activities	3. Transport	a. Domestic aviation
1. Energy	A. Fuel combustion activities	3. Transport	b. Road transportation
1. Energy	A. Fuel combustion activities	3. Transport	c. Railways
1. Energy	A. Fuel combustion activities	3. Transport	d. Domestic water-borne navigation
1. Energy	A. Fuel combustion activities	4. Other sectors	a. Commercial, institutional
1. Energy	A. Fuel combustion activities	4. Other sectors	b. Residential
1. Energy	A. Fuel combustion activities	4. Other sectors	c. Agriculture, forestry, fishing
2. Industrial processes and product use	A. Mineral industry	1. Cement production	
2. Industrial processes and product use	A. Mineral industry	2. Lime production	
2. Industrial processes and product use	A. Mineral industry	3. Glass production	
2. Industrial processes and product use	A. Mineral industry	4. Other process use of carbonates	
2. Industrial processes and product use	B. Chemical industry	1. Ammonia production	
2. Industrial processes and product use	B. Chemical industry	2. Nitric acid production	
2. Industrial processes and product use	B. Chemical industry	8. Petrochemical and carbon black production	
2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances	1. Refrigeration and air conditioning	

Level 1	Level 2	Level 3	Level 4
2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances	3. Fire protection	
2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances	4. Aerosols	
2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances	5. Solvents	
2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances	6. Semiconductor Manufacture	
2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances	7.Electrical Equipment (Manufacture and Use of Transformer and Switching Systems)	
2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances	8. Other Applications	
3. Agriculture	A. Enteric fermentation		
3. Agriculture	B. Manure management		
3. Agriculture	D. Agricultural soils	According to the various sources (fertilizers, crop residues in the field, etc.)	
4. land-use change and forestry	A. Forest land		
4. land-use change and forestry	G. Harvested wood products		
4. land-use change and forestry	H. Other (cultivation of organic soils)		
5. Waste and wastewater	A. Solid waste disposal		
5. Waste and wastewater	B. Biological treatment of solid waste		
5. Waste and wastewater	D. Wastewater treatment and discharge	1. Domestic wastewater	
5. Waste and wastewater	D. Wastewater treatment and discharge	2. Industrial wastewater	

Analysis and identification of key source categories is done in two ways:

1. Analysis of the relative contribution of an emission source to the total absolute emissions.
2. Analysis of the impact of an emission source on the emission trend over the years.

Below is a detailed explanation of these analyses.

10.2.1 Analysis of the Relative Contribution of Each Emission Source to the Total Absolute Emissions

This analysis examines how each emission source impacts the total emissions in a specific year.

Below is the calculation process for analysing the relative contribution of each emission source to the total absolute emissions:

We will define these variables:

$L_{\mathrm{x,t}}$ – The partial contribution of source x to the total emissions in year t.

$|E_{\mathrm{x,t}}|$ – The total emissions (in absolute values) from source x in year t.

$\sum_y |E_{\mathrm{y,t}}|$ – The total emissions from all sources in year t.

The calculation is performed as follows:

- Calculate the emissions (in absolute values) of each source x in year t and convert it to CO_2eq – $|E_{\mathrm{x,t}}|$
- Calculate the total emissions from all sources in year t – $\sum_y |E_{\mathrm{y,t}}|$
- Calculate the relative part of each source out of the total emissions in year t – $L_{\mathrm{x,t}}$

$$L_{\mathrm{x,t}} = |E_{\mathrm{x,t}}| \, / \, \sum_y |E_{\mathrm{y,t}}|$$

- Arrange the emission sources in descending order according to their relative part from the total emissions in year t: A source with a higher relative part from the total emissions will be placed before an emission source with a lower relative part.
- Summary of all emission sources that are cumulatively 95% of all emission sources.
- According to IPCC guidelines, a key source category will be one that contributes 95% of the total emissions.

Below are the results of the analysis of the relative contribution to the total absolute emissions in selected years. The results were arranged by the size of the contribution in the most recent calculation year – 2022.

Note the changes made in the calculations over the years:

- In 2008, emissions from the use of substitutes for ozone-depleting substances were added to the calculation.
- In 2011, the calculation method for emissions from agriculture was updated.

Table 10.3 GHG Emissions as a Percentage of Total Emissions, by Source, for Selected Years

	Level 1	Sub-levels	2005	2010	2015	2020	2021	$L_{x,}$ 2022 ,in descending order	$L_{x,t}$ 2022, aggregated sum
1	1. Energy	A. Fuel combustion activities 1. Energy industries a. Electricity and heat production	52.13	50.10	46.00	42.82	42.02	41.46	41.46
2	1. Energy	A. Fuel combustion activities 3. Transport b. Road transportation	18.22	19.43	20.35	19.93	21.51	22.41	63.87
3	5. Waste and wastewater	A .Solid waste disposal	7.29	8.45	8.89	9.39	9.84	9.83	73.70
4	1. Energy	A. Fuel combustion activities 2. Manufacturing industries and construction	8.43	6.99	6.53	7.55	7.61	7.14	80.84
5	2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances 1. Refrigeration and air conditioning	-	1.54	3.85	6.32	5.12	5.31	86.15
6	1. Energy	A. Fuel combustion activities b. Petroleum refining	1.88	1.94	3.35	3.71	3.37	3.18	89.33
7	2. Industrial processes and product use	A. Mineral industry 1. Cement production	2.98	2.59	2.74	2.14	2.10	2.21	91.54
8	3. Agriculture	A. Enteric fermentation	1.25	1.24	1.30	1.39	1.44	1.45	92.99

	Level 1	Sub-levels	2005	2010	2015	2020	2021	L_{x}, 2022 ,in descending order	$L_{x,t}$ 2022, aggregated sum
9	1. Energy	A. Fuel combustion activities 3. Transport a. Domestic aviation	1.22	1.26	0.97	0.82	0.85	0.87	93.86
10	5. Waste and wastewater	D. Wastewater treatment and discharge 2. Industrial wastewater	0.83	1.00	0.96	0.88	0.88	0.84	94.71
11	1. Energy	A. Fuel combustion activities 4. Other sectors b. Residential	0.77	0.48	0.45	0.59	0.60	0.59	95.30

From this analysis in 2022, the key category sources were electricity generation (41.5%), road transportation (vehicles) (22.4%), solid waste disposal (9.8%), fuel combustion in manufacturing and construction industries (7.1%), emissions of gases used for air conditioning and refrigeration (HFCs) (5.3%), petroleum refining (3.2%), cement production (2.2%) and enteric fermentation of animals (1.4%).

Over the years, electricity generation has been the main source of emissions, although its share of total emissions has decreased: in 2003, it was 53.1%, and by 2022, it was 41.5%. The share of emissions from transport and the manufacturing and construction industries has remained approximately 20% and 8%, respectively, over the years. The share of emissions of gases used for air conditioning and refrigeration (HFCs) has increased significantly over the years: in 2008, it stood at 0.7%, and by 2022, it reached 5.3%. The share of emissions from cement production has ranged between 2% and 3% over the years.

10.2.2 Analysis of the Relative Contribution of Each Emission Source to the Emission Trend

In addition to the relative impact of a specific emission source on the total absolute emissions, it may have a significant impact on the emission trend. The purpose of the calculation in this part is to identify emission sources that significantly affect the emission trend over the years.

There may be an emission source whose trend differs significantly from the general trend, but its absolute contribution is small, and therefore its impact on the general trend is minor. Conversely, there may be a source that differs slightly in its trend from the general trend, but its overall contribution is large, and therefore its impact on the general trend is significant.

Below is the calculation formula for analyzing the contribution of each emission source to the emission trend.

We will define these variables:

- $T_{x,t}$ – The contribution of emission source x to the emission trend in year t.
- $\Sigma E_{,t}$ – Total emissions in year t.
- $E_{x,0}$ – Emissions from source x in the base year.
- $E_{x,t}$ – Emissions source x in year t.

$$T_{x,t} = \frac{|E_{x,o}|}{\sum_y |E_{y,o}|} \times \left| \left(\frac{(E_{x,t} - E_{x,o})}{|E_{x,o}|} \right) - \frac{\left(\sum_y E_{y,t} - \sum_y E_{y,o}\right)}{|\sum_y E_{y,o}|} \right|$$

Key source categories are calculated as follows:

- Calculate the total emissions from each source in year t and convert them to CO_2eq – $E_{x,t.}$
- Calculate the total emissions from all sources in year t – E_t.
- Calculate the trend of each emission source relative to the base year – calculate the increase or decrease in emissions of the emission source relative to its emissions from that source in the base year – $(E_{x,t} - E_{x,0})/ |E_{x,0}|$.
- Calculate the trend of all emissions – calculate the increase or decrease in total emissions relative to the base year – $(\Sigma E_t - \Sigma E_0)/|\Sigma E_0|$.
- Calculate the gap between the trend of the emission source and the trend of all emissions. The gap is calculated in absolute values to isolate the effect of an increase or decrease.
- Calculate the contribution of emission source x to the emission trend – multiply the obtained gap by the relative part of each emission source in the base year from the total emissions in the base year.
- Calculate the share of each source from the overall trend $T_{x,t}/ \Sigma x\ T_{x,t}$ and sort the relative parts by size.
- Summarise all emission sources that are 95% of all emission sources.
- According to IPCC guidelines, a key source category is one that accounts for 95% of the total emissions.

Table 10.4 GHG Emissions as a Percentage of the Impact on the Emission Trend, by Source, for Selected Years

	Level 1	Sub-levels	2015	2020	2021	$T_{x,t}$ 2022	$T_{x,t}$/ $\Sigma x\ T_{x,t}$ 2022, in descending order	2022, aggregate sum
1	1. Energy	A. Fuel combustion activities 1. Energy industries a. Electricity and heat production	4.05	7.16	7.85	8.69	42.15	42.15
2	1. Energy	A. Fuel combustion activities 3. Transport b. Road transportation	1.65	1.20	2.74	3.75	18.19	60.34
3	2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances 1. Refrigeration and air conditioning	1.74	4.18	2.93	3.23	15.66	76.00
4	5. Waste and wastewater	A. Solid waste disposal	0.45	0.95	1.37	1.41	6.86	82.85
5	1. Energy	A. Fuel combustion activities b. Petroleum refining	0.98	1.32	0.97	0.80	3.89	86.75
6	2. Industrial processes and product use	A. Mineral industry 1. Cement production	0.06	0.65	0.68	0.59	2.85	89.60
7	1. Energy	A. Fuel combustion activities 3. Transport a. Domestic aviation	0.21	0.36	0.32	0.31	1.50	91.10

	Level 1	**Sub-levels**	**2015**	**2020**	**2021**	**$T_{x,t}$ 2022**	**$T_{x,t}$/ $\Sigma x\ T_{x,t}$ 2022, in descending order**	**2022, aggregate sum**
8	3. Agriculture	A. Enteric fermentation	0.08	0.17	0.22	0.23	1.11	92.20
9	2. Industrial processes and product use	F. Product Uses as Substitutes for Ozone-Depleting Substances 6. Semiconductor Manufacture	0.02	0.10	0.14	0.17	0.83	93.04
10	5. Waste and wastewater	D. Wastewater treatment and discharge 2. Industrial wastewater	0.05	0.13	0.12	0.17	0.81	93.85
11	4. land-use change and forestry	A. Forest land	0.17	0.14	0.12	0.15	0.73	94.59

To isolate other effects on the trend analysis in Israel, the base year 2011 was chosen. From 2011, emissions were calculated in a similar manner. From this analysis, it is possible to learn which key source categories influenced the emission trend in 2022.

The key source categories influencing the emissions trend are electricity generation (42.2%), road transportation (vehicles) (18.2%) and emissions of gases used for air conditioning and refrigeration (HFCs) (15.7%). Electricity generation has a significant impact on the trend due to their large share of emissions, while road transportation emissions of gases used for air conditioning and refrigeration (HFCs) have a significant impact due to the substantial change in emissions from this source over the years.

These sources of emissions also influence the trend, but their impact is relatively smaller: solid waste disposal (6.9%), petroleum refining (3.9%) and cement production (2.9%).

10.3 Appendix C – Parameters and Emission Factors for Calculating CO_2 Emissions from Fuel Combustion

10.3.1 Emission Factors

The carbon content in fuels, the oxidation factor, and the fraction of carbon stored in products were taken from the IPCC 1996 guidelines (except for waste, which was calculated based on the characteristics of waste in Israel).

Table 10.5 Carbon Content in Fuels, Oxidation Factor, and Fraction of Carbon Stored in Products, IPCC

Fuel	Carbon Content (ton C/TJ)	Oxidation Factor	Fraction of Carbon Stored in Products
Gas/Diesel oil	20.20	0.99	-
Gasoline	18.90	0.99	-
Jet kerosene	19.50	0.99	-
LPG	17.20	0.99	-
Naphtha	20.00	0.99	0.80
Natural gas	15.30	0.995	-
Oil shale	29.10	0.99	-
Coal	25.80	0.98	-
Other gas (petrochemistry)	17.20	0.99	0.80
Kerosene	19.60	0.99	-
Petroleum coke	27.50	0.99	-
Refinery gas	15.70	0.99	
Residual fuel oil	21.10	0.99	-
Waste	[1]20.65	0.99	-
Crude oil	20.0	0.99	-
Feedstock for refining and additives	20.0	0.99	-
Bitumen (asphalt)	22.0	0.99	1

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[1] The carbon content is calculated based on emission reports from companies that use waste to produce energy. This is an average value of the waste by type, and it varies over the years according to the components of the waste.

10.3.2 Energy Values

The energy values of the fuels were selected based on need and data availability.

Energy values of **primary fuels** (fuels derived from natural sources such as coal, natural gas, waste, and oil shale) were obtained from information specific to Israel. Some values change annually, and for some, a fixed value was chosen. The energy value of coal is received annually from "The National Coal Supply Corporation Ltd.", for natural gas from "Israel Natural Gas Lines Ltd.", and for oil shale and waste from the companies active in the field.

Energy values for **secondary fuels** (fuels produced from primary fuels – gasoline, diesel oil, residual fuel oil, etc.) were taken from default values in the IPCC guidelines, as these are fuel products that must meet a uniform standard.

The energy value and quantities of refinery gases were estimated based on the difference between inputs and outputs at refineries using data from Israel's energy balance.

Table 10.6 Energy Values, by Fuel, 2022

Fuel	Energy Value (TJ/1000 ton)	Data Source
Gas/Diesel oil	43.33	IPCC 1996
Gasoline	44.80	IPCC 1996
Jet kerosene	44.59	IPCC 1996
LPG	47.31	IPCC 1996
Naphtha	45.01	IPCC 1996
Natural gas	49.72	Israel, fixed value
Oil shale	3.97	Israel, fixed value
Coal	24.72	IPCC 1996
Other gas (petrochemistry)	47.31	IPCC 1996
Kerosene	44.75	IPCC 1996
Petroleum coke	35.17	IPCC 1996
Refinery gas	27.42	Israel, varies each year
Residual fuel oil	40.19	IPCC 1996
Waste	17.96	Israel, varies each year
Crude oil	20.00	IPCC 1996
Feedstock for refining and additives	20.00	IPCC 1996
Bitumen (asphalt)	22.00	IPCC 1996

10.4 Appendix D – Calculation of Emissions Using the Reference Approach

10.4.1 Introduction

The Reference Approach is a method for calculating CO_2 emissions from fuel combustion, based on the "top-down" calculation principle, which uses the country's energy supply data.

The Reference Approach is straightforward and can be implemented using relatively easily available statistical data on energy supply. It also allows for comparisons in emission calculations according to the Sectoral Approach and the identification of differences that may indicate potential issues in raw data, energy values, carbon content, etc.

In the Reference Approach, it is assumed that carbon is conserved throughout its transfer. For example, the carbon content in crude oil is equal to the total carbon content of the products derived from it. The Reference Approach does not differentiate between emission sources in the energy sector and only estimates the total CO_2 emissions from fuel use. Emissions arise both from fuel combustion in the energy sector, where the fuel serves as an energy source for fuel refining or the production of secondary energy (such as electricity), and from the final consumption of fuels in industry, commerce, residential use, etc.

10.4.2 Calculation Formula

Calculating emissions using the Reference Approach is based on the observed energy consumption in the country and the carbon content in the energy sources.

It is necessary to differentiate in the calculation between primary fuels (such as crude oil, coal, and natural gas) and secondary fuels (such as gasoline, residual fuel oil, and diesel oil). To prevent double counting, carbon from secondary fuels is not included in the calculation, as they are derived from primary fuels (for example, the carbon stored in gasoline and diesel oil is already included in the crude oil used for refining).

Initially, the carbon in all fuels is calculated, and then the carbon that is not burned but remains in products or is used as raw material is subtracted. The resulting carbon amount is multiplied by a combustion correction factor and the molar ratio between carbon and carbon dioxide.

The calculation formula is as follows:

$$\begin{aligned} &\text{CO2 Emissions} \\ &\quad = \sum_{all\ fuels} \big((\text{Apparent Consumption} \times \text{Conversion Factor} \times \text{CC}\,) \times 10^{-3} \\ &\quad - \text{Excluded Carbon}\big) \times \text{COF} \ \times \frac{44}{21} \end{aligned}$$

- **CO_2 Emissions** – Carbon dioxide emissions (thousands of tons).
- **Apparent Consumption** - Production + Import – Export – International Bunkers – Stock changes (thousands of tons).
- **Conversion Factor** – Energy value of the fuel (TJ/1000 tons).
- **CC** - Carbon content of the fuel (ton C/TJ).
- **Excluded Carbon** – Carbon that is not burned but remains in products or is used as raw material (1000 tons C).
- **Carbon Oxidation Factor (COF)** – The fraction of carbon that oxidizes.
- **44/12** – The molar weight ratio between C and CO_2.

10.4.3 Information Sources and Factors

Sources of Information – The calculation of emissions using the Reference Approach mostly relied on energy balance data, except for waste combustion (which requires more detail than is presented in the balance) and the consumption of various gases in industry.

Estimation of Carbon Content – Data on the carbon content in fuels were taken from the IPCC 1996 guidelines, as with the values used in the calculations of emissions by source.

Carbon Not to Include – Some of the carbon is not burned but remains stored in products or is used as raw material. The estimate of carbon stored in products is based on the estimates in the Sectoral Approach calculation method (according to the coefficients of the fraction of carbon stored in the product from the IPCC 1996 guidelines). Carbon that is not burned and is stored in products is found in naphtha and gases in the petrochemical industry, and carbon that is not burned and used as raw material is found in the use of asphalt and natural gas.

Energy Values – The conversion of fuels to energy values was based on Israel's energy balance, published in toe (ton of oil equivalent) units. The energy values of the fuels were selected based on the availability of data (see Appendix C).

Oxidation Factor – Oxidation factors were taken from the IPCC 1996 guidelines (see Appendix C).

10.4.4 Calculation of Emissions Using the Reference Approach

Below are the emission calculation tables according to the Reference Approach.

Table 10.7 Calculation of GHG Emissions
According to the Reference Approach, by Fuel, 2022

Fuel	TJ	Carbon Content Factor (t C/TJ)	Oxidation Factor	Emission (Gg CO_2)
Coal	159,529	25.80	0.98	14,790
Oil shale	1,010	29.10	0.99	107
Crude oil	517,348	20.00	0.99	37,559
Feedstock for refining and additives	61,641	20.00	0.99	4,475
Refinery gas	-	15.70	0.99	0
Other petroleum products	-	-	0.99	0
Other gases (petrochemistry)	-	17.20	0.99	0
Petroleum coke	9,324	27.50	0.99	931
Bitumen (asphalt)	-141	22.00	0.99	-11
Liquefied petroleum gas	3,202	7.20	0.99	84
Gasoline	20,333	18.90	0.99	1,395
Kerosene and jet fuel	-39,354	19.60	0.99	-2,800
Diesel oil	-106,403	20.20	0.99	-7,802
Residual fuel oil	-82,966	21.10	0.99	-6,355
Naphtha	-18,906	20.00	0.99	-1,373
Natural gas	437,122	15.30	0.99	24,277
Waste(1)	3,508	-	0	293

(1) Emissions from waste are calculated using the Sectoral Approach.

Table 10.8 Components of the Calculation of Carbon Remaining in Products or Used as Raw Material, by Fuel, 2022

Fuel	Note	TJ	Carbon Content Factor (t C/TJ)	Fraction of Carbon Stored in Products	Oxidation Factor	Emission (Gg CO_2)
Bitumen (asphalt)	Used as raw material	12,310	22.00	1	0.99	-983
Other gases (petrochemistry)	Stored in products	9,784	17.20	0.8	0.99	-489
Natural gas	Used as raw material	5,113	17.20	1	0.99	-319
Naphtha	Stored in products	35,097	20.00	0.8	0.99	-2,038

10.4.5 Comparison Between Calculation Methods

In 2022, emissions from fuel combustion according to the Sectoral Approach and the Reference Approach stood at 62.9 and 61.7 million toe (tons of oil equivalent), respectively. The difference between the methods was about 1.8%.

As mentioned, the Reference Approach provides estimates of CO_2 emissions for comparison with the emission estimates according to the Sectoral Approach. The results of the calculations using the Reference Approach and the Sectoral Approach differ because the calculation principle in the Reference Approach is "top-down," using the country's energy supply data without detailing fuel consumption in various sectors, whereas the Sectoral Approach’s calculation principle is "bottom-up," using detailed information about fuel consumption in each sector. Typically, the gap between the two approaches should be relatively small (up to 5%).

The differences between the approaches can be due to the following reasons:

- Statistical discrepancies between energy supply and energy consumption. Statistical discrepancies arise from data collection from different sources, and when the discrepancies are large, they should be examined to determine the cause.
- Significant imbalance between refinery inputs – the difference between the amount of crude oil and other feedstocks used for the refining process, and the outputs – the quantity of petroleum products produced. In calculations in Israel, this imbalance does not exist, as the estimate of refinery gas combustion is calculated based on the difference between refinery inputs and outputs.
- High distribution losses (for example, in gas), because of which the Reference Approach may be higher than the Sectoral Approach.
- Undocumented fuel consumption, which may lead to an underestimate by the Sectoral Approach.
- Changes in the classification of energy products, which can cause differences between the methods due to the use of different energy values and emission factors for each classification.

10.5 Appendix E – List of Tables and Diagrams

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