UKNetZero

August 24, 2021

1 UK Net Zero

1.1 1. Introduction

The aim of this document is to look at the data published in the UK on the emissions of greenhouse gases. It provides an overview of what emissions are, what 'net-zero' is and talks about the data published and used in the UK.

Before delving into specifics, at a high level, the data is published on a yearly basis by the Office for National Statistics, as part of the UK National Accounts: UK National Accounts, The Blue Book: 2020. Although Environmental Accounts are "satelitte accounts" (meaning that they cover activities linked to the economy but are not part of the core UK national accounts), these do include information on atmospheric emissions, alongside others. The latest emissions dataset, titled "Atmospheric emissions: greenhouse gases by industry and gas" was published by the ONS on the 3rd of June 2021 and it includes data for the years 1990 to 2019.

At a lower level, the data is collected by and prepared by Ricardo Energy & Environment. The estimates published in the National Atmospheric Emissions Inventory (NAEI) are re-packaged and used by the ONS in its datasets.

1.1.1 How is the data created - methodology [1]

The exact methodology is complex and inaccessible for the average person: the six documents making up the methodology are over 1000 pages in length and can be found on the NAEI website: Report: UK Greenhouse Gas Inventory, 1990 to 2019: Annual Report for submission under the Framework Convention on Climate Change. Similar to the datasets themselves, these are also updated yearly to reflect any changes in the state-of-the-art employed by Ricardo EE in producing the data.

The sources used by Ricardo Energy & Environment provide data data on air emissions, which is then calculated from activity data and emissions factors, where

$Emission = Factor ; x ; Activity $

For example, a factor can be the emission factor for diesel and an activity the distance in kilometers driven by cars. Moreover, the ONS applies 'the residence principle' to the datasets - this means that for certain specific industries, emissions are not included in the datasets as they were not produced in the UK or by UK businesses.

[1] https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/environmentalaccountsonairemissionsqmi

Moreover, the "estimates for emissions made by each industry are made on the basis of which industry is the primary emitter and which industry owns the unit creating the emissions". The example given by the ONS is straightforward: " if a retailer owns a fleet of trucks that deliver stock to its stores, the emissions from those trucks would go to the retail industry. However, if the retailer hires a separate freight company to deliver its goods, the emissions would go to the road freight industry".

Confusingly, for each of these specific source, there are colour coded estimated uncertainty ratings. These relate to the allocation to industry group, are in addition to the uncertainty used by the NAEI estimates and do not include any uncertainty introduced by the residency principle mentioned above.

1.1.2 TL;dr findings

On average, for the period 1990 to 2018, there has been a reduction in CO2 emissions of ~1.01% per year. This was worked out from the yearly percentage change in CO2 and then averaged over the number of years in the dataset.

Notwithstanding other types of greenhouse gases, if the UK were to follow this descending trend for the next 16 years (2019 to 2035), we would reach our assumed target of 78% of CO2 emissions compared to the levels of 1990.

Unfortunately, this approximation does not account for the rest of the greenhouse gases which have different Global Warming Potential (GWP).

Figure 2. below shows a plot line of the year 1990 to 2035, with the last 16 years portraying a straight downwards slope for the CO2 emissions.

1.2 2. Background to technical terms

1.2.1 What are emissions? [2], [3], [4], [5], [6], [7]

Emissions refer to the the pollutans humans release in the atmosphere through their activities. These range from greenhouse gases (such as CO2, HFC or methane), air pollutants (CO, black smoke or benzene), heavy metals (arsenic, mercury or lead) or particulate matter (PM10, PM2.5, PM1 or PM0.1).

Carbon is usually the main reference to emissions in the media. That is mainly because 5 million metric tons of carbon produced by humans remains in the atmosphere each year. This raises the global average of CO2 by 2.3 part per million every year. This means that, since 1750, humans have increased the amount of CO2 in the atmosphere by 50%.

The Kyoto Protocol, which entered into force in 2005, establishes the UN Framework Convention on Climate Change for industrialised economies to limit and reduce their greenhouse gases emissions.

[2] https://www.climate.gov/news-features/climate-qa/are-humans-causing-or-contributing-global-warming#:~:text=A%20net%205%20billion%20metric,atmosphere%20by%20nearly%2050%20percent.

[3] https://naei.beis.gov.uk/data/data-selector?view=pms

[4] https://www.instituteforgovernment.org.uk/explainers/net-zero-target

[5] https://www.iea.org/reports/methane-tracker-2020

[6] https://www.ipcc.ch/report/ar6/wg1/

[7] https://grist.org/article/un-report-ipcc-methane-cows-oil/

Besides CO_2, methane (CH_4) is also worth mentioning. This is a powerful greenhouse gas and its main source (from human activity) comes from agriculture. Compared to CO_2, methane has a relatively short atmospheric lifetime (around 12 years, versus hundreds of years for CO_2), but it absorbs more energy during its lifetime.

The latest IPCC report discusses CH_4 at length and mentions that "strong, rapid and sustained reductions in CH_4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality."

While CO_2 is the main culprit behind climate change, the same IPCC study suggest that 30-50% of temperature rises are caused by CH_4. In simpler terms, while methane dissipates quite quickly from the atmosphere, it is accentuating the effects of CO_2 on climate change.

1.2.2 What is net zero? Net vs gross zero [8]

Although a broad term, this has been highly used in the public space over the past few years and more so recently. It refers to the reduction of greenhouse gas emissions combined with the removal of such gases from the atmosphere.

This is in contrast to gross zero, which refers to reducing all greenhouse gas emissions to zero. Net zero recognises this is a potentially unrealistic goal, as some industries will continue to emit such gases.

To allow net zero to be a viable route, the gases emitted by more polluting industries will need to be offset, through means such as natural carbon sinks or as artificial carbon sinks. As research into these artifical technologies is ongoing, the focus is on using natural carbon sinks to capture these gases, using, for e.g., oceans and forests.

When the carbon produced is cancelled out by the carbon removed, the UK will be a net zero emitter, which becomes easier as emissions lower further down.

1.2.3 UK's net zero targets

"The UK government will set the world's most ambitious climate change target into law to reduce emissions by 78% by 2035 compared to 1990 levels, it was announced today (Tuesday 20 April)." [9]

1.3 3. How is the data created

To understand how this data is created, we have been in touch with the data producer (Ricardo EE), followed the methodology published by the ONS ([10]) and tried to understand the Greenhouse Gas Inventory published by Ricardo. The latter is a long document aimed at professional and as such it is extremely difficult to read and understand.

A good question would be should Ricardo EE and the ONS create a simple explanation for the methodology such researchers and other interested parties can quickly and easily understand what is happening?

We have contacted the ONS to discuss a series of questions we have prepared after analysing their published dataset, but at the time this notebook was created, an interview was not agreed upon.

[8] https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
[9] https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
[10] https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/environmentalaccountsonairemissionsqmi

1.4 4. Analysis

Considering the amount of data available, the analysis consisted in trying to make sense of the dataset published by the ONS. As such, we can report that:

- the dataset is published as an Excel spreadsheet and it is updated on a yearly basis
- the spreashet is divided into eight individual sheets, the first one being an aggregate of all GHG emissions
- the analysis was done on the CO2 emissions and so the rest of the gases have not been included in the analsysis

From the 1990 to 2018 reported CO2 emissions, we have worked out that the highest increase year-on-year in emissions was from 1995 to 1996, an increase of ~4.49% and the highest year-on-year decrease was from 2008 to 2009, ~8.63%.

Working on the difference between each year and averaging the amount for the number of years, the average percentage change for the period included in the dataset is -1.01%, effectively a 1.01% reduction in CO2 emissions.

1.5 5. What have we learned

1.5.1 Aggregated CO2 emissions

[72]:
```
# Import necessary libraries
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import numpy as np
```

[73]:
```
# Create a pandas DataFrame based on the information on the sheet titled "CO2"␣
↪in the speadsheet
df_co2 = pd.read_excel("data_sources/atmos_emis_ghg.xlsx", sheet_name="CO2")
```

[74]:
```
# Remove any unnecessary columns and rows, and reset the index for easier␣
↪analsysis
temp_frame = df_co2.copy(deep=True).iloc[[2, 25]]
temp_frame.reset_index();
temp_frame.drop(columns=temp_frame.columns[:3], inplace=True)
```

[75]:
```
# Invert the columns and rows by transposing the dataframe and rename the␣
↪columns
# Update the data type of the data in the Yar column to integer to ignore any␣
↪decimal point
transposed_overview = temp_frame.transpose(copy=True)
transposed_overview.rename(columns={2: "Year", 25: "CO2e"}, inplace=True)
transposed_overview.reset_index(drop=True);
transposed_overview['Year'] = transposed_overview['Year'].astype('int')
```

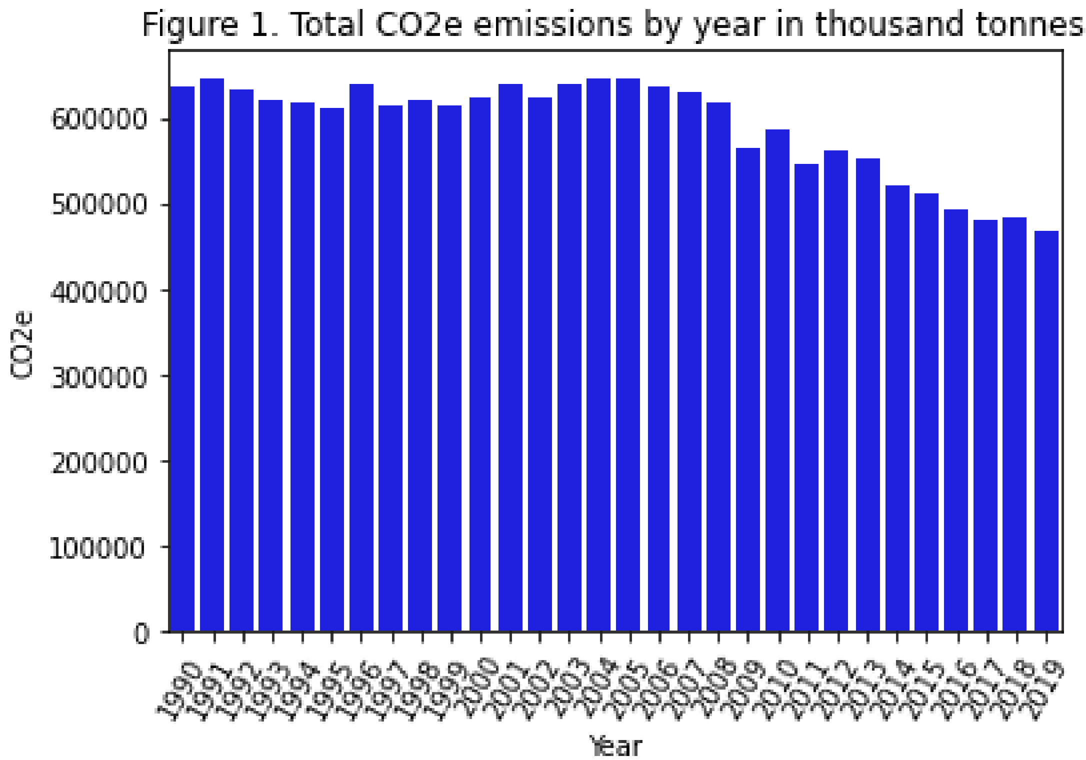
[76]:
```
# Print the created frame
transposed_overview
```

[76]:

	Year	CO2e
Unnamed: 3	1990	637165.2
Unnamed: 4	1991	646096.2
Unnamed: 5	1992	631454.6
Unnamed: 6	1993	618872.8
Unnamed: 7	1994	616015.1
Unnamed: 8	1995	610099.7
Unnamed: 9	1996	637549.4
Unnamed: 10	1997	612855.6
Unnamed: 11	1998	621289.2
Unnamed: 12	1999	615051.9
Unnamed: 13	2000	624562.6
Unnamed: 14	2001	637723.5
Unnamed: 15	2002	622978.1
Unnamed: 16	2003	637966.1
Unnamed: 17	2004	645473.9
Unnamed: 18	2005	646493.3
Unnamed: 19	2006	637063.9
Unnamed: 20	2007	629524.0
Unnamed: 21	2008	617366.8
Unnamed: 22	2009	564075.8
Unnamed: 23	2010	585192.7
Unnamed: 24	2011	546679.7
Unnamed: 25	2012	561419.3
Unnamed: 26	2013	552928.7
Unnamed: 27	2014	521135.1
Unnamed: 28	2015	512455.3
Unnamed: 29	2016	491955.4
Unnamed: 30	2017	478424.0
Unnamed: 31	2018	484541.8
Back to contents	2019	468276

[77]:
```
# Generate a bar graph for the information in the dataset
graph = sns.barplot(
    x="Year",
    y="CO2e",
    data=transposed_overview,
    color='blue'
)

graph.set_xticklabels(graph.get_xticklabels(), rotation=60);
graph.set_title("Figure 1. Total CO2e emissions by year in thousand tonnes");
```



[78]:
```
# Calculate the percentage change between each year in the frame
transposed_overview['pct_change'] = transposed_overview.CO2e.pct_change()
```

[79]:
```
# Find the largest positive percentage change in the dataset and output it
max_diff_positive_row_name = transposed_overview['pct_change'].idxmax()
max_diff_positive_row = transposed_overview.loc[max_diff_positive_row_name,:]
max_diff_positive_row
```

[79]:
```
Year              1996
CO2e          637549.4
pct_change    0.044992
Name: Unnamed: 9, dtype: object
```

[80]:
```
# Find the largest negative percentage change in the dataset and output it
max_diff_negative_row_name = transposed_overview['pct_change'].idxmin()
max_diff_negative_row = transposed_overview.loc[max_diff_negative_row_name,:]
max_diff_negative_row
```

[80]:
```
Year              2009
CO2e          564075.8
pct_change    -0.08632
Name: Unnamed: 22, dtype: object
```

[81]:
```
# Calculate the mean of all year-on-year percentage changes and output the␣
↪result
transposed_overview['pct_change'].mean()
```

[81]: -0.010104327184030001

Figure 1 above shows the quantity of CO2e emitted in the UK every year from 1990 to 2019.

For the period 1990 to 2019, the CO2 emissions in the UK fell, on average, 1.01% year-on-year.

The largest increase YoY in CO2 emissions was recorded in 1996, namely a 4.49% increase on 1995 levels.

The largest decrease YoY in CO2 emissions was recorded in 2009, where the levels of carbon dioxide emissions decreased by 8.63% compared to 2008 levels.

UK's Net Zero strategy requires a reduction of emissions to 78% of 1990 levels by 2035. Following the average of 1.01% YoY reduction in emissions (and thereby assuming nothing will change and thus everything remains as it is), we can work out the emissions the UK is due to produce over the next 14 years.

[82]:
```
# Based on the average change, create values for the next 16 years and add them␣
↪to a list
last_value_in_emissions = transposed_overview.at['Back to contents', 'CO2e']
next_sixteen_yrs_emissions = []
for i in range(16):
    last_value_in_emissions = last_value_in_emissions +␣
↪transposed_overview['pct_change'].mean() * last_value_in_emissions
    next_sixteen_yrs_emissions.append(last_value_in_emissions)
```

[83]:
```
# Print out the next 16 yrs of CO2 emissions
next_sixteen_yrs_emissions
```

[83]:
```
[463544.3860835712,
 458860.5819422625,
 454224.10449046345,
 449634.47552381875,
 445091.22166990634,
 440593.874339414,
 436141.96967780916,
 431735.04851749726,
 427372.6563304634,
 423054.3431813924,
 418779.6636812627,
 414548.1769414092,
 410359.44652805,
 406213.0404172731,
 402108.5309504774,
```

```
 398045.4947902641]
```

[84]:
```
# Create a new DataFrame for the period 2020 to 2036 and the emissions␣
 ↪previously calculated
next_sixteen_yrs_df = pd.DataFrame(data={"Year": list(range(2020, 2036)),␣
 ↪"CO2e": next_sixteen_yrs_emissions})
```

[85]:
```
# Round the emissions to one decimal point
next_sixteen_yrs_df = next_sixteen_yrs_df.round(decimals=1)
```

[86]:
```
next_sixteen_yrs_df
```

[86]:

	Year	CO2e
0	2020	463544.4
1	2021	458860.6
2	2022	454224.1
3	2023	449634.5
4	2024	445091.2
5	2025	440593.9
6	2026	436142.0
7	2027	431735.0
8	2028	427372.7
9	2029	423054.3
10	2030	418779.7
11	2031	414548.2
12	2032	410359.4
13	2033	406213.0
14	2034	402108.5
15	2035	398045.5

[87]:
```
# Get 1990's emissions in CO2
# 1990's emissions: 637165.2 Thousand Tonnes
transposed_overview.reset_index().at[0, "CO2e"]

# Calculate 78% of 1990 levels as required by the Net Zero targets the UK has␣
 ↪set
# 78% of 637165.2
78/100 * 637165.2
```

[87]:
```
496988.85599999997
```

From the above approximation, based on a year-on-year reduction in emissions of ~1.01%, the UK should be able to reach its Net Zero goals (78% of 1990's emissions levels) by 2035.

It is important to point out this approximation is incomplete and it is not accounting for different changes in the UK. As the next section will show, there are industries where the CO2 emissions have steadily increasing for the past few years. Moreover, these figures are dependant on many factors, for example, population numbers.

[88]:
```
# Create a concatenated frame for the entire period 1990 to 2035
entire_period_df = pd.concat([transposed_overview, next_sixteen_yrs_df])
```

[89]:
```
# Reconstruct the dataframe to ignore any unecessary information
# and so focus just on the year and the emissions quantity
reconstructed_entire_period_df = pd.DataFrame(data={"Year":␣
↪list(entire_period_df.Year), "CO2e": list(entire_period_df.CO2e)})
```

[90]:
```
reconstructed_entire_period_df
```

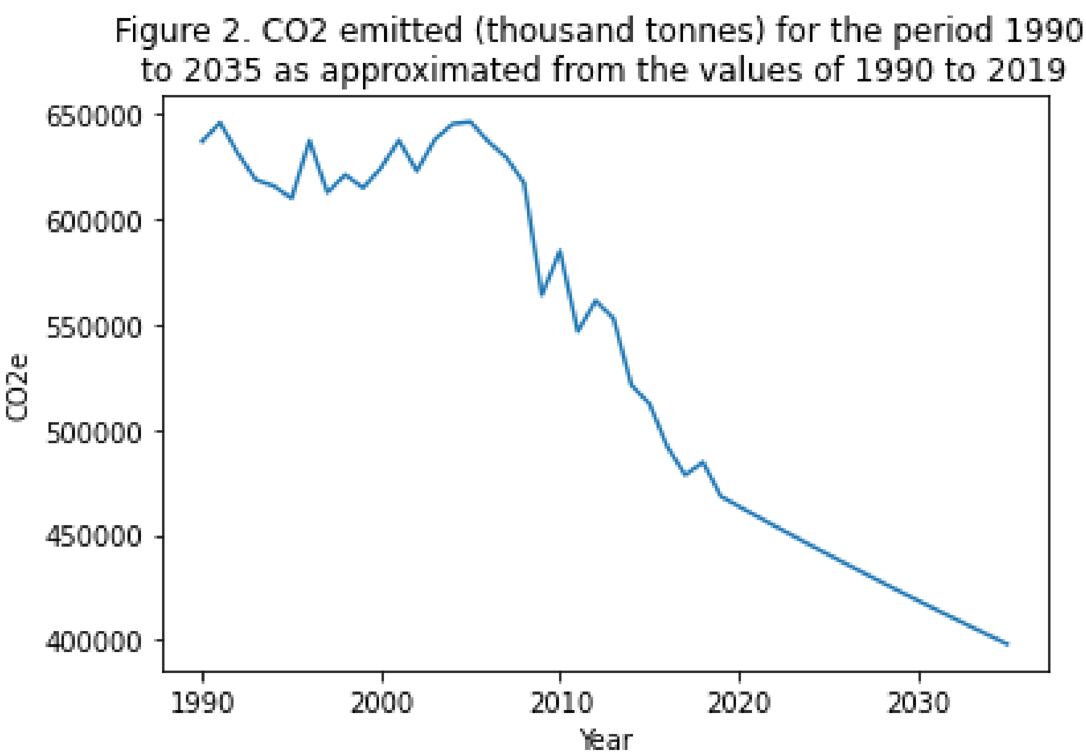
[90]:

	Year	CO2e
0	1990	637165.2
1	1991	646096.2
2	1992	631454.6
3	1993	618872.8
4	1994	616015.1
5	1995	610099.7
6	1996	637549.4
7	1997	612855.6
8	1998	621289.2
9	1999	615051.9
10	2000	624562.6
11	2001	637723.5
12	2002	622978.1
13	2003	637966.1
14	2004	645473.9
15	2005	646493.3
16	2006	637063.9
17	2007	629524.0
18	2008	617366.8
19	2009	564075.8
20	2010	585192.7
21	2011	546679.7
22	2012	561419.3
23	2013	552928.7
24	2014	521135.1
25	2015	512455.3
26	2016	491955.4
27	2017	478424.0
28	2018	484541.8
29	2019	468276.0
30	2020	463544.4
31	2021	458860.6
32	2022	454224.1
33	2023	449634.5
34	2024	445091.2
35	2025	440593.9

```
36  2026  436142.0
37  2027  431735.0
38  2028  427372.7
39  2029  423054.3
40  2030  418779.7
41  2031  414548.2
42  2032  410359.4
43  2033  406213.0
44  2034  402108.5
45  2035  398045.5
```

[92]:
```python
# Create a bar graph of the entire 45 year period
graph = sns.lineplot(
    x="Year",
    y="CO2e",
    data=reconstructed_entire_period_df,
)

# graph.set_xticklabels(graph.get_xticklabels(), rotation=60);
graph.set_title("Figure 2. CO2 emitted (thousand tonnes) for the period 1990␣
↪\nto 2035 as approximated from the values of 1990 to 2019");
```



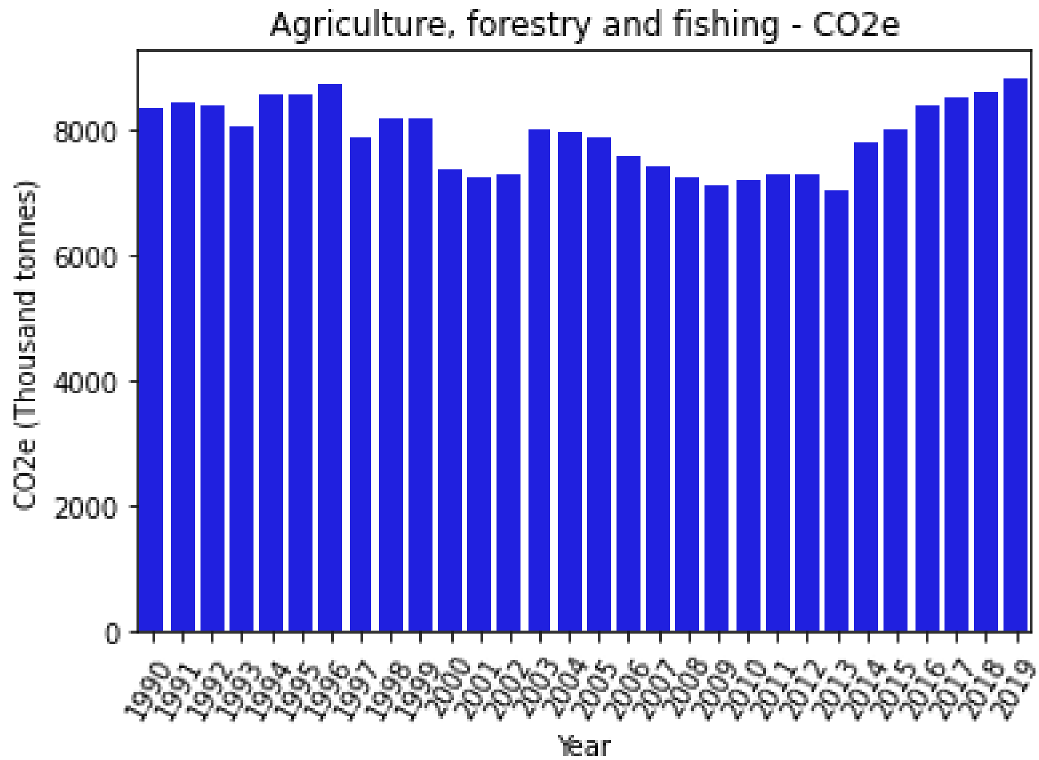
1.5.2 By industry

[93]:
```
industries = df_co2.copy(deep=True).iloc[list(range(2,24))]
industries.reset_index();
industries.drop(columns=industries.columns[:2], inplace=True)
industries = industries.transpose(copy=True)
industries.columns = industries.iloc[0]
industries.drop(industries.index[0], inplace=True)
industries.rename(columns={np.nan: "Year"}, inplace=True)
industries.reset_index(drop=True);
industries['Year'] = industries['Year'].astype('int')
```

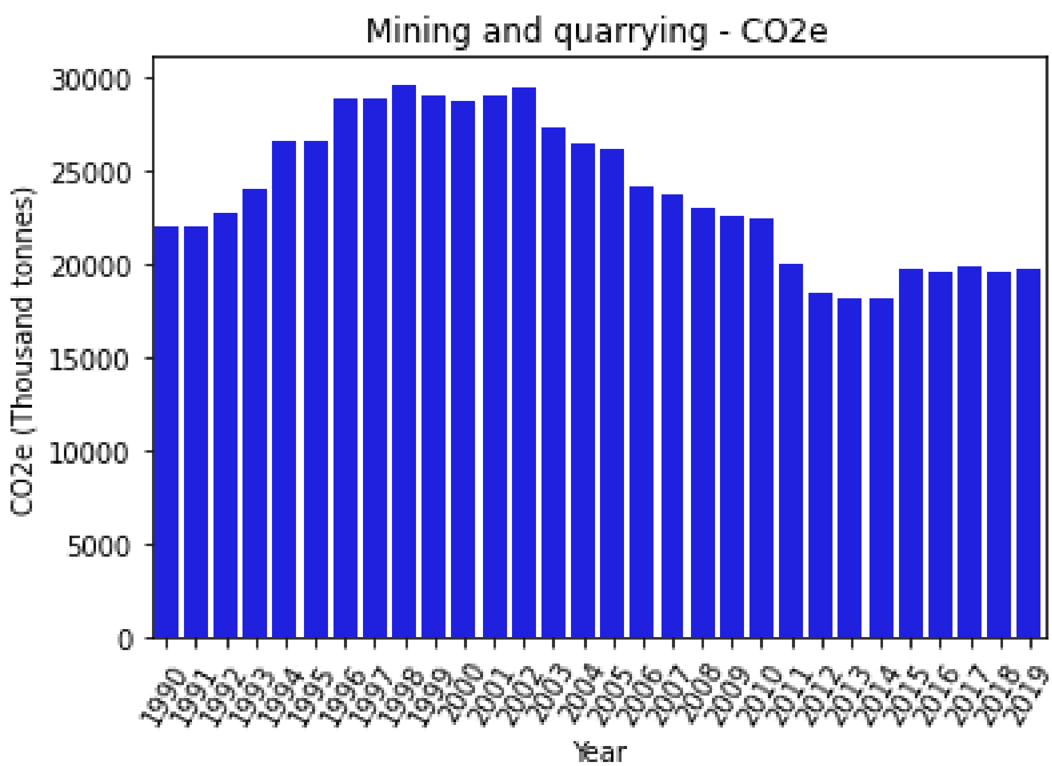
[94]:
```
labels = list(industries.columns)[1:]
```

[95]:
```
for label in labels:
    plt.figure()
    graph = sns.barplot(
    x="Year",
    y=label,
    data=industries,
    color='blue'
)
    graph.set_title(f"{label} - CO2e")
    graph.set_ylabel("CO2e (Thousand tonnes)")
    graph.set_xticklabels(graph.get_xticklabels(), rotation=60);
```

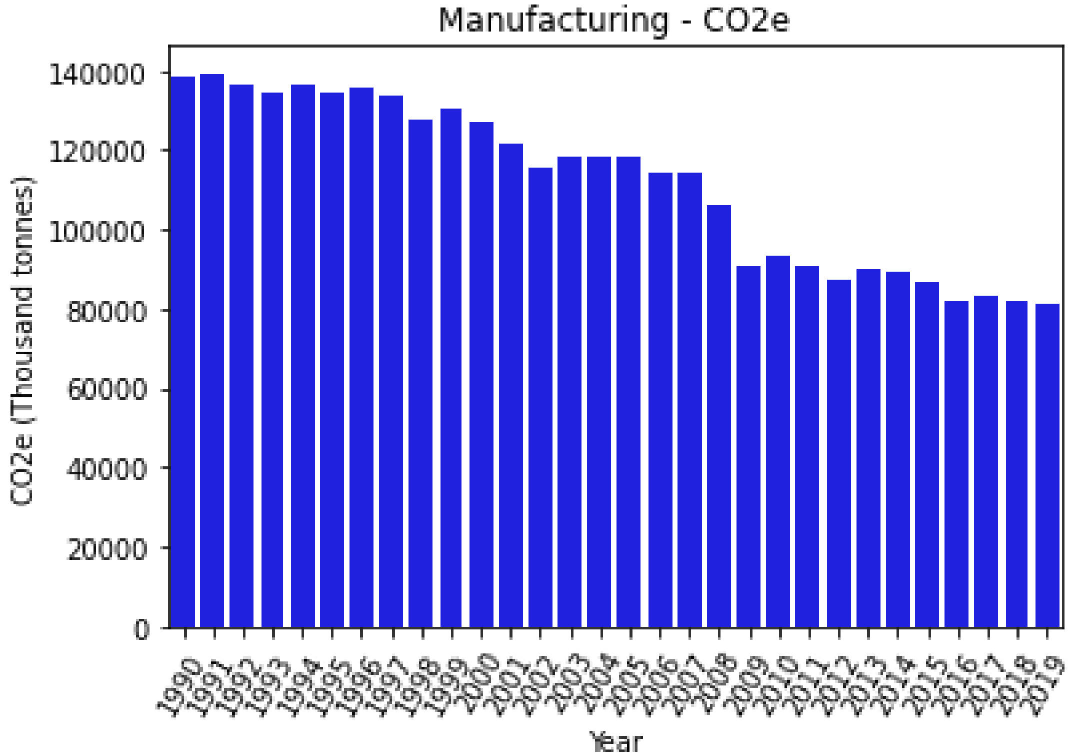
```
/var/folders/fq/p9v5h3gd76d1vkj5rhzqhyjw0000gn/T/ipykernel_79776/2756036491.py:2
: RuntimeWarning: More than 20 figures have been opened. Figures created through
the pyplot interface (`matplotlib.pyplot.figure`) are retained until explicitly
closed and may consume too much memory. (To control this warning, see the
rcParam `figure.max_open_warning`).
  plt.figure()
```



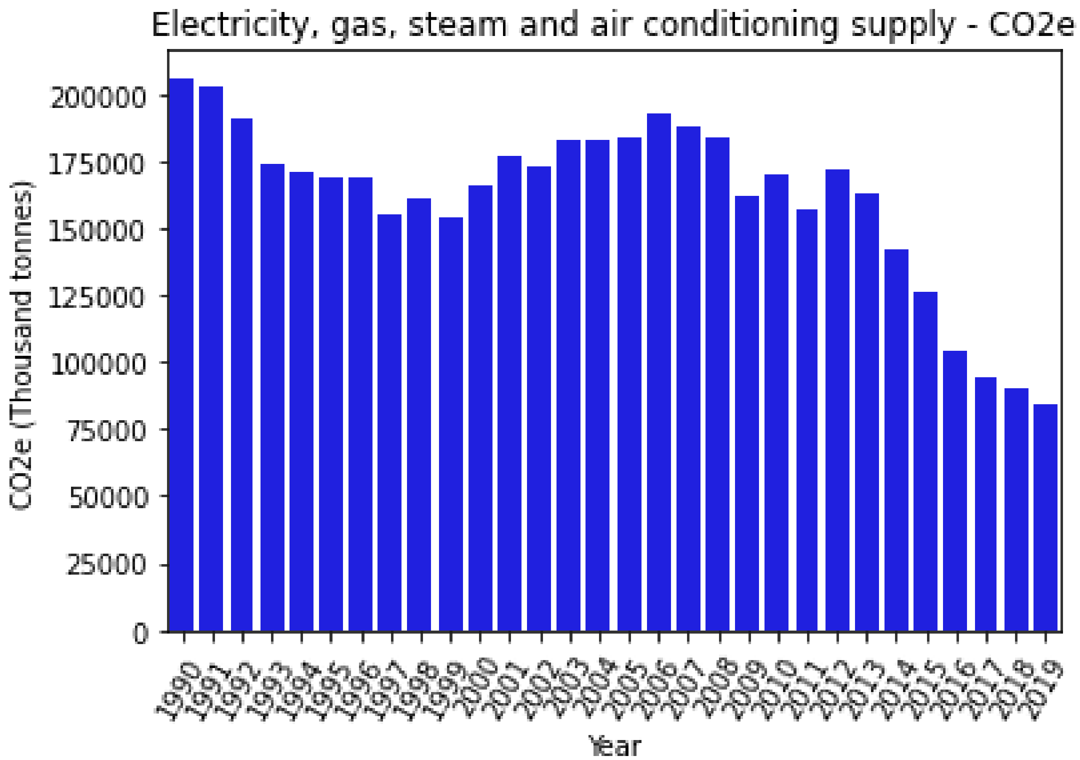
Agriculture, forestry and fishing - CO2e
CO2e (Thousand tonnes)
0
2000
4000
6000
8000
Year



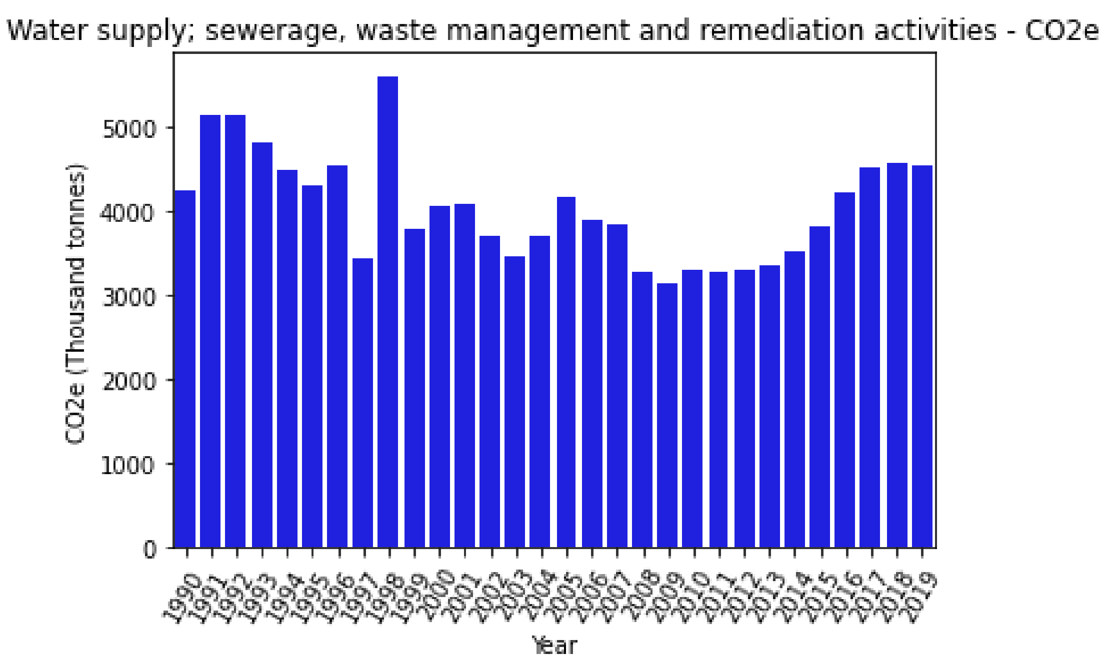
Mining and quarrying - CO2e
CO2e (Thousand tonnes)
0
5000
10000
15000
20000
25000
30000
Year



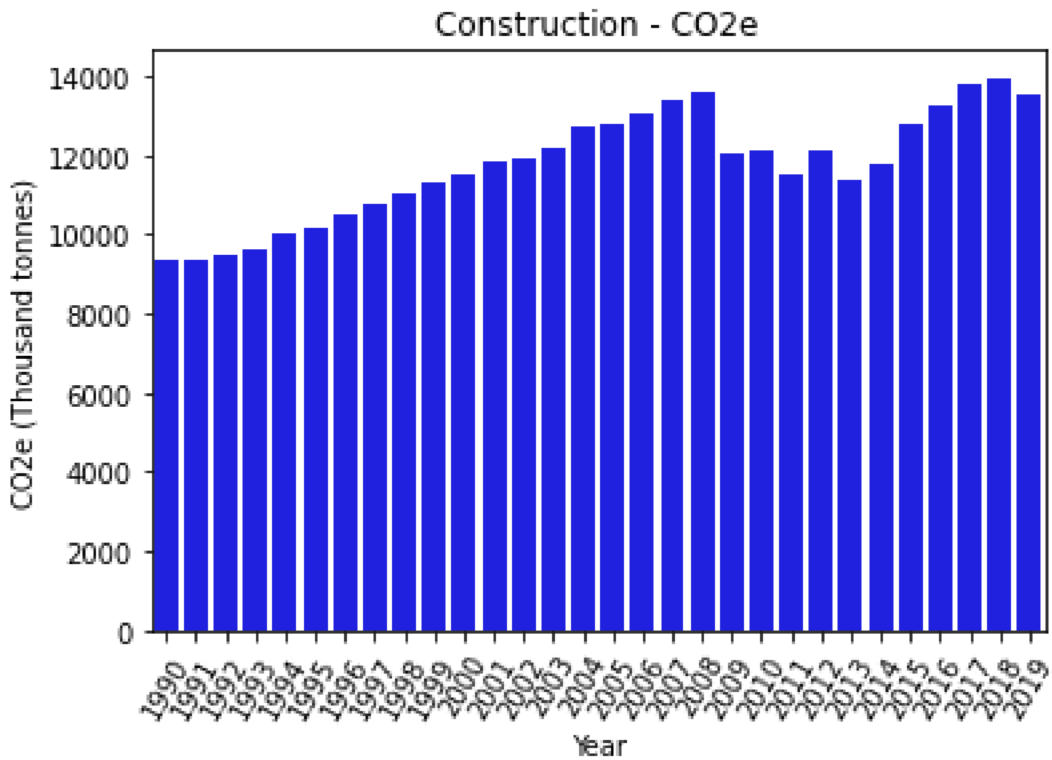
Manufacturing - CO2e
CO2e (Thousand tonnes)
140000
120000
100000
80000
60000
40000
20000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

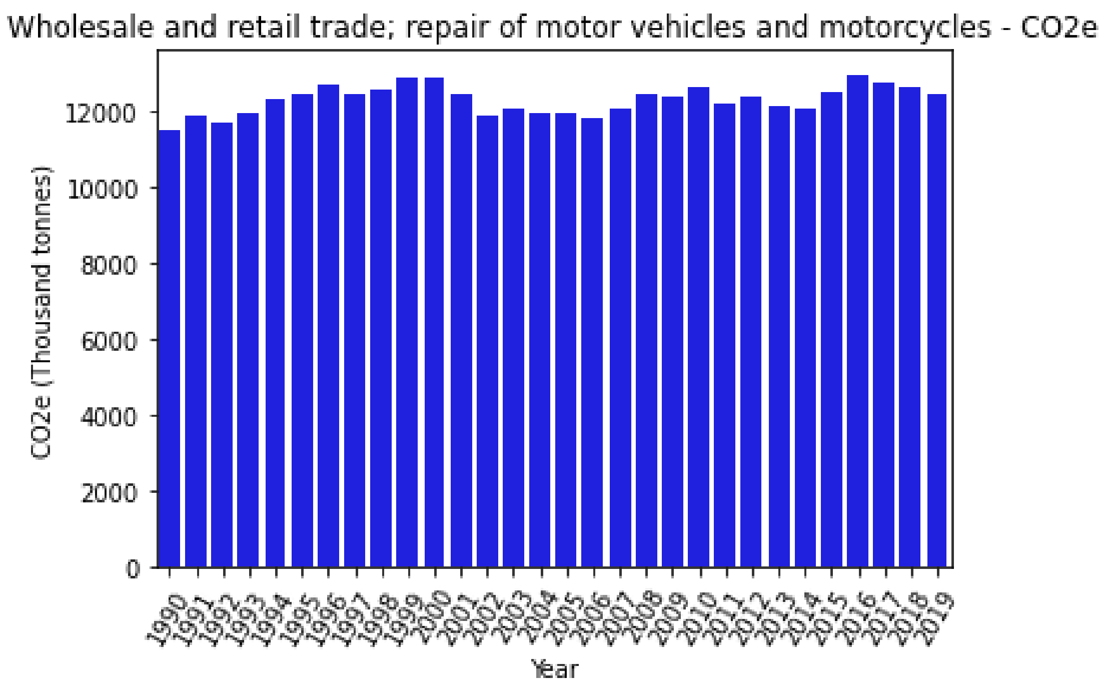


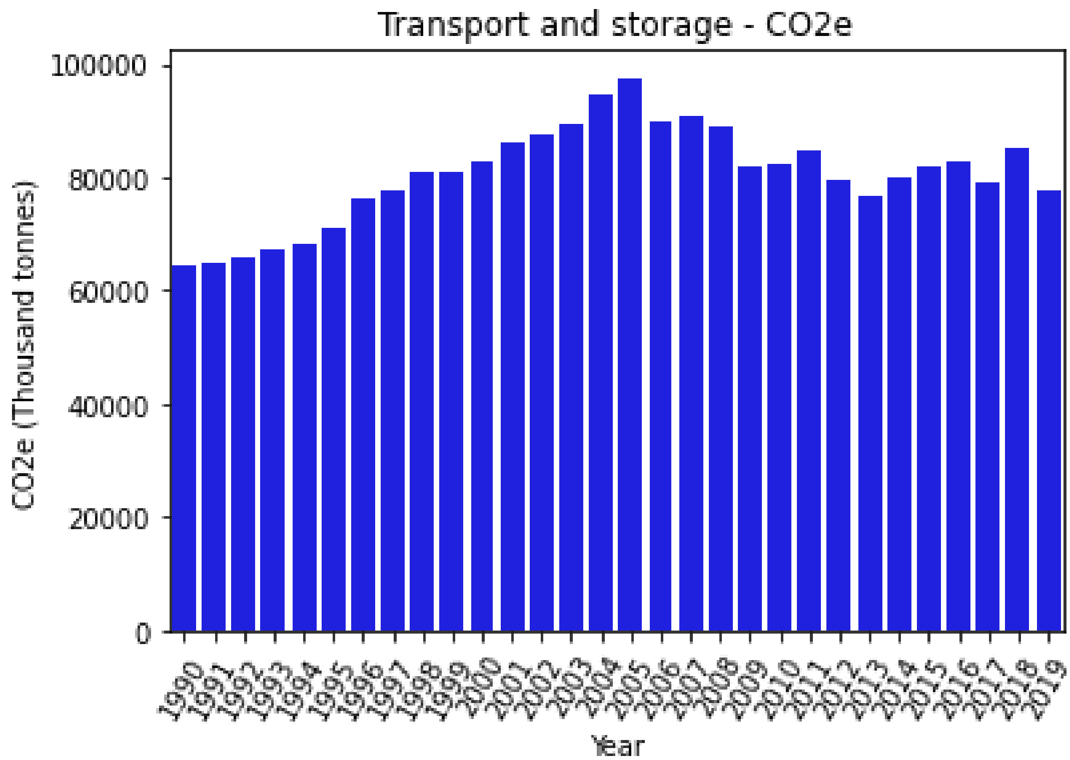
Electricity, gas, steam and air conditioning supply - CO2e
CO2e (Thousand tonnes)
0
25000
50000
75000
100000
125000
150000
175000
200000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

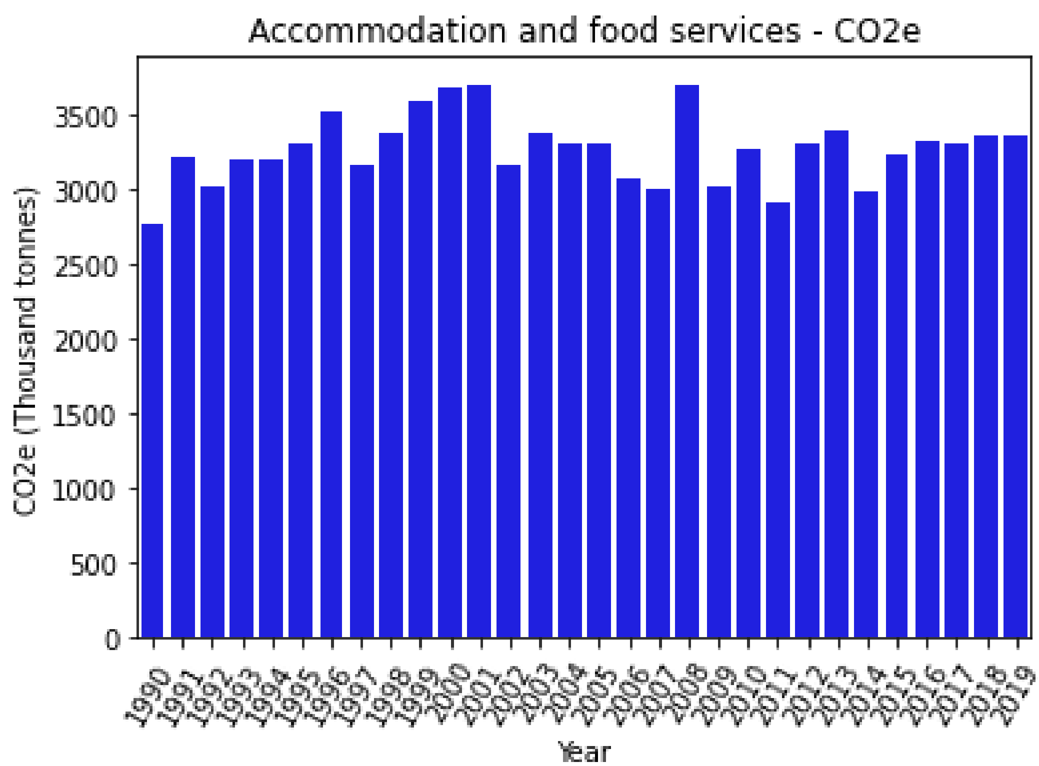


Water supply; sewerage, waste management and remediation activities - CO2e
CO2e (Thousand tonnes)
0
1000
2000
3000
4000
5000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year


Construction - CO2e
CO2e (Thousand tonnes)
0
2000
4000
6000
8000
10000
12000
14000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year


Wholesale and retail trade; repair of motor vehicles and motorcycles - CO2e
CO2e (Thousand tonnes)
0
2000
4000
6000
8000
10000
12000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year


Transport and storage - CO2e
CO2e (Thousand tonnes)
0
20000
40000
60000
80000
100000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year


Accommodation and food services - CO2e
CO2e (Thousand tonnes)
0
500
1000
1500
2000
2500
3000
3500
1990
1991
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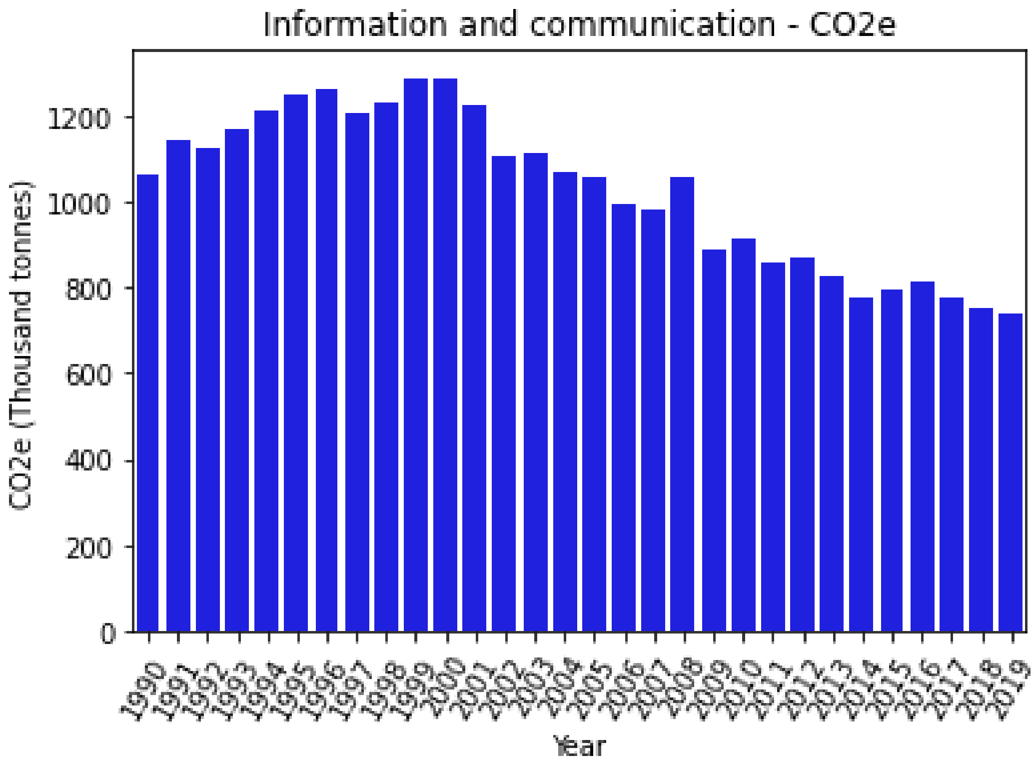
Year


Information and communication - CO2e
CO2e (Thousand tonnes)
0
200
400
600
800
1000
1200
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
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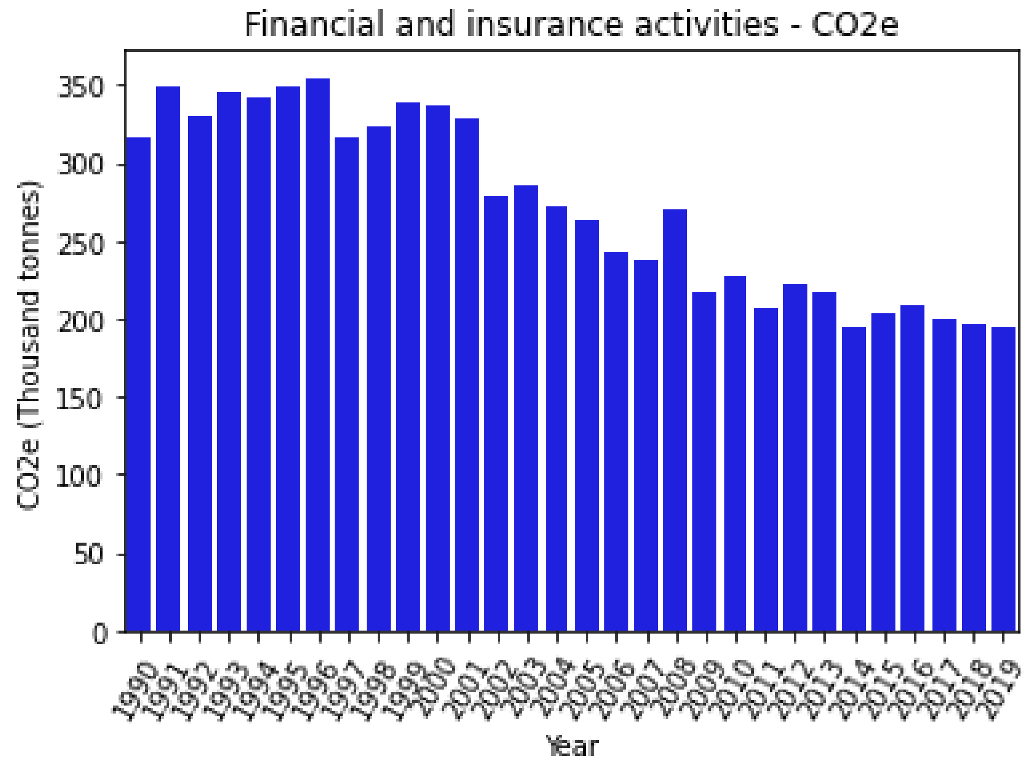
2018
2019
Year



Financial and insurance activities - CO2e
CO2e (Thousand tonnes)
0
50
100
150
200
250
300
350
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
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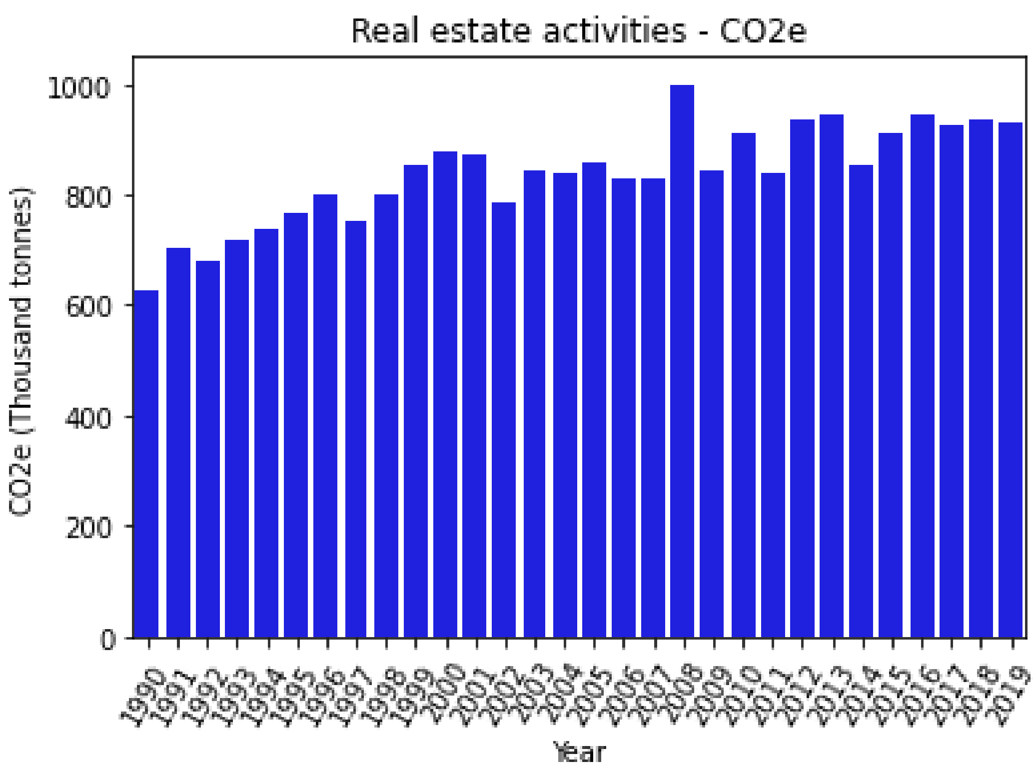
2018
2019
Year



Real estate activities - CO2e
CO2e (Thousand tonnes)
0
200
400
600
800
1000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
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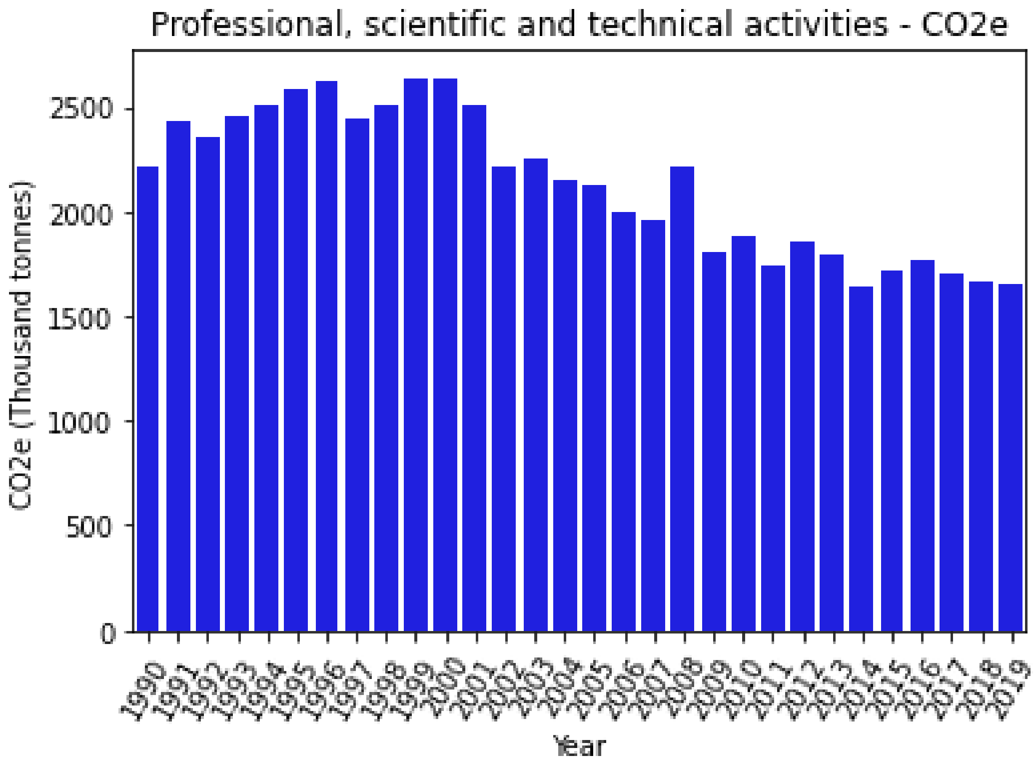
2018
2019
Year


Professional, scientific and technical activities - CO2e
CO2e (Thousand tonnes)
0
500
1000
1500
2000
2500
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
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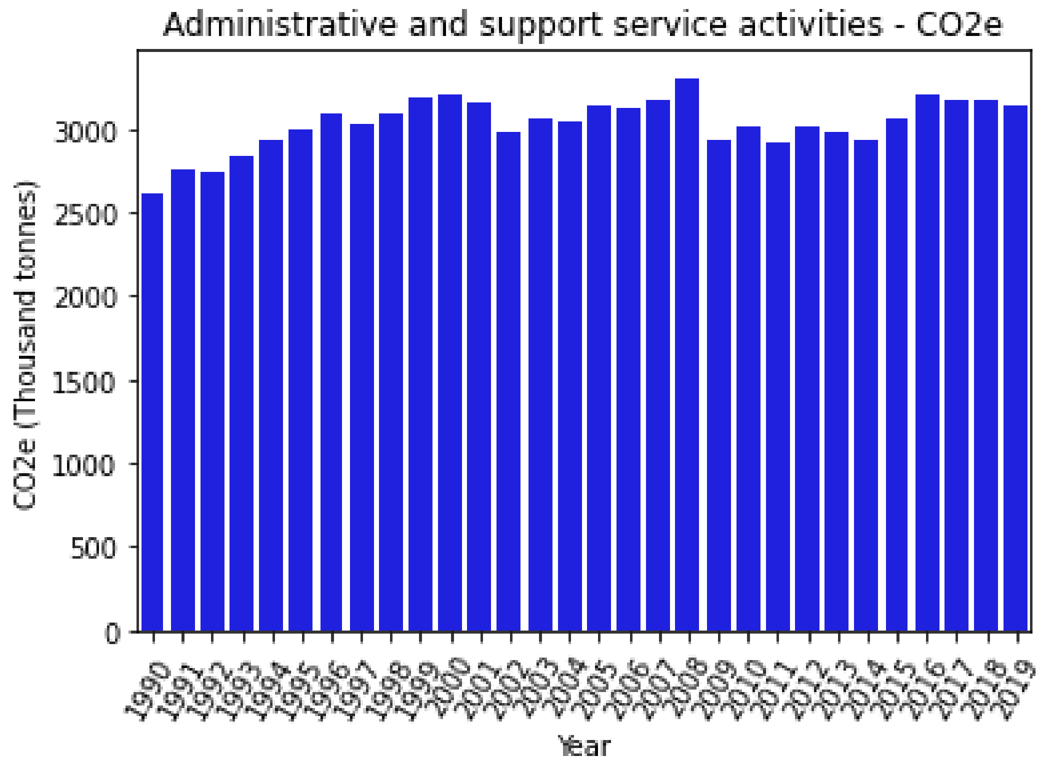
2019
Year


Administrative and support service activities - CO2e
CO2e (Thousand tonnes)
0
500
1000
1500
2000
2500
3000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
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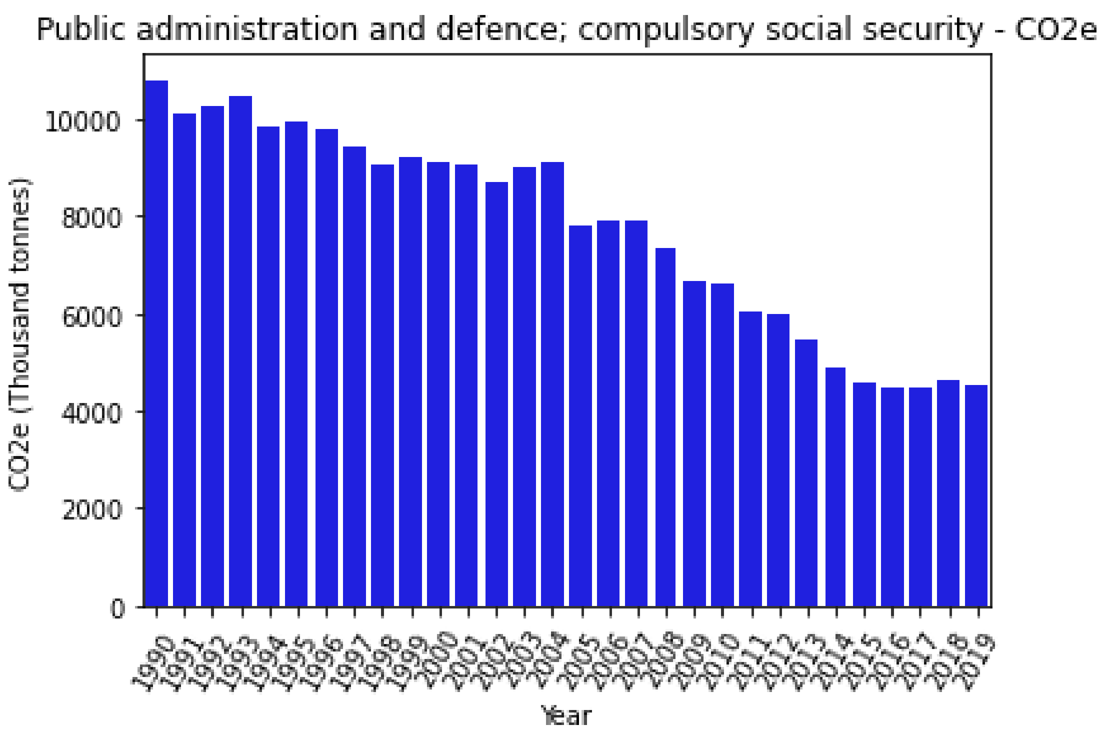
2019
Year


Public administration and defence; compulsory social security - CO2e
CO2e (Thousand tonnes)
0
2000
4000
6000
8000
10000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
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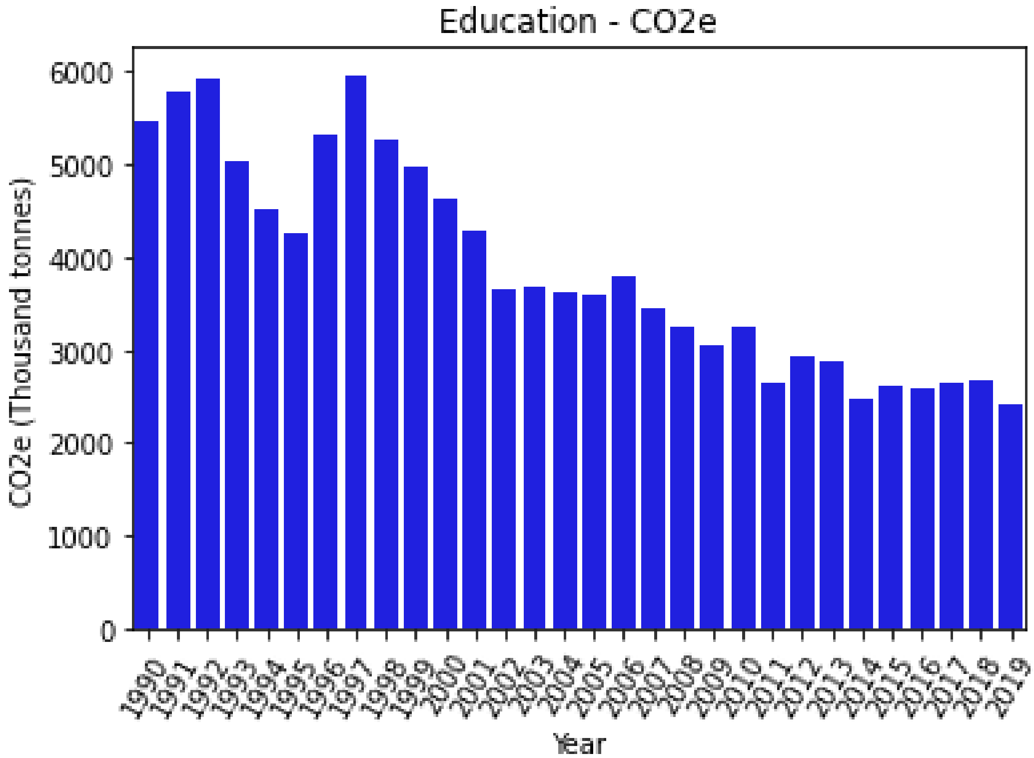
2019
Year



Education - CO2e
CO2e (Thousand tonnes)
0
1000
2000
3000
4000
5000
6000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
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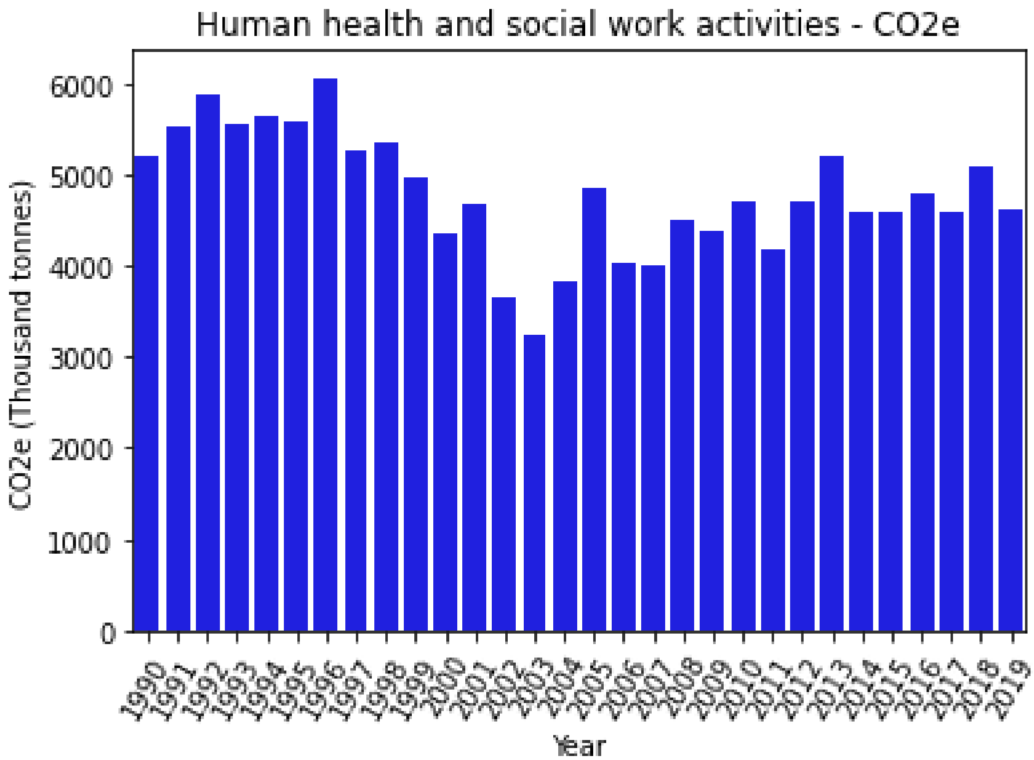
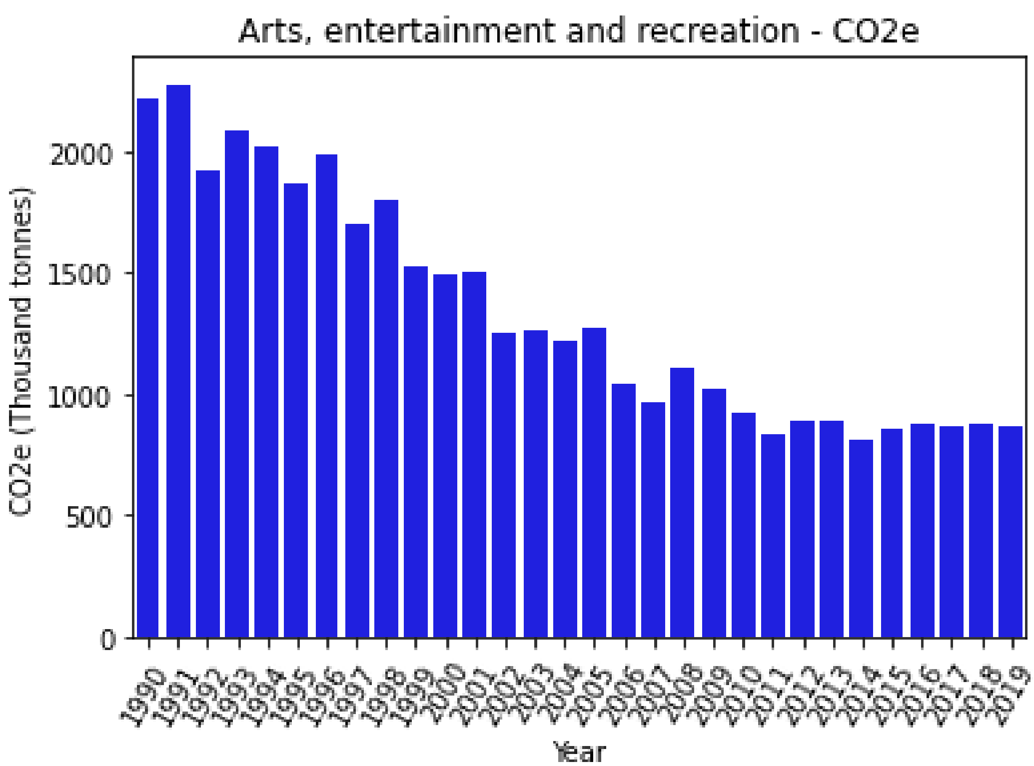
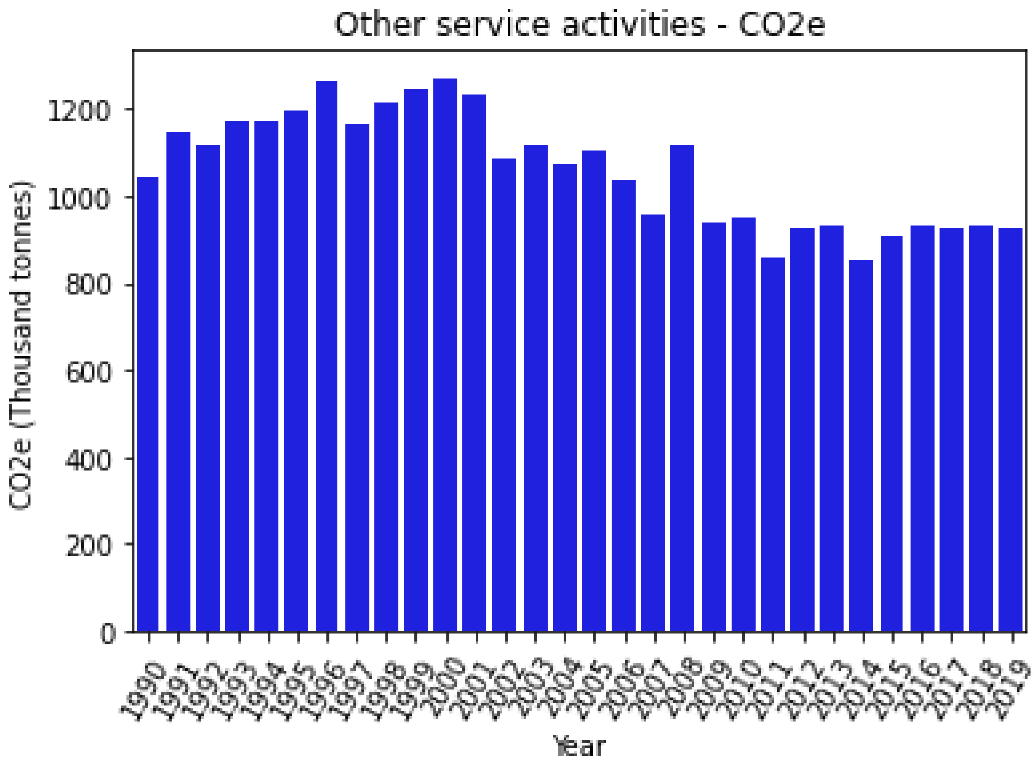
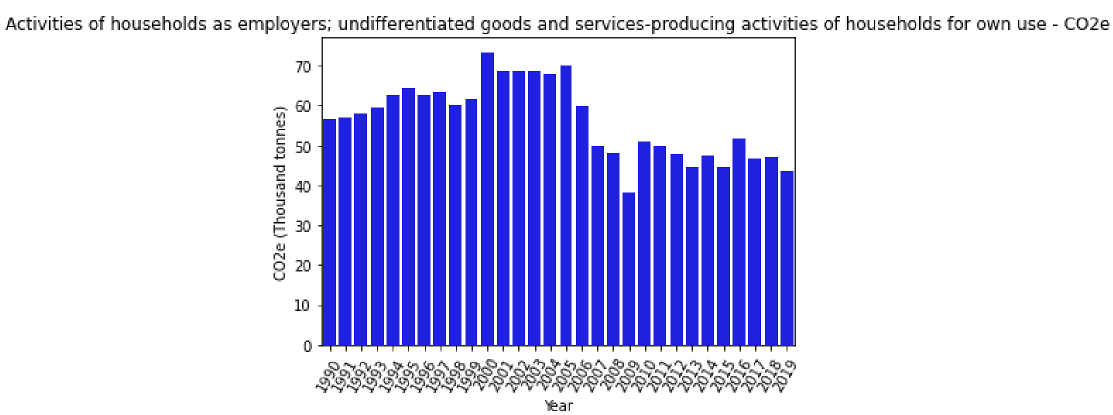
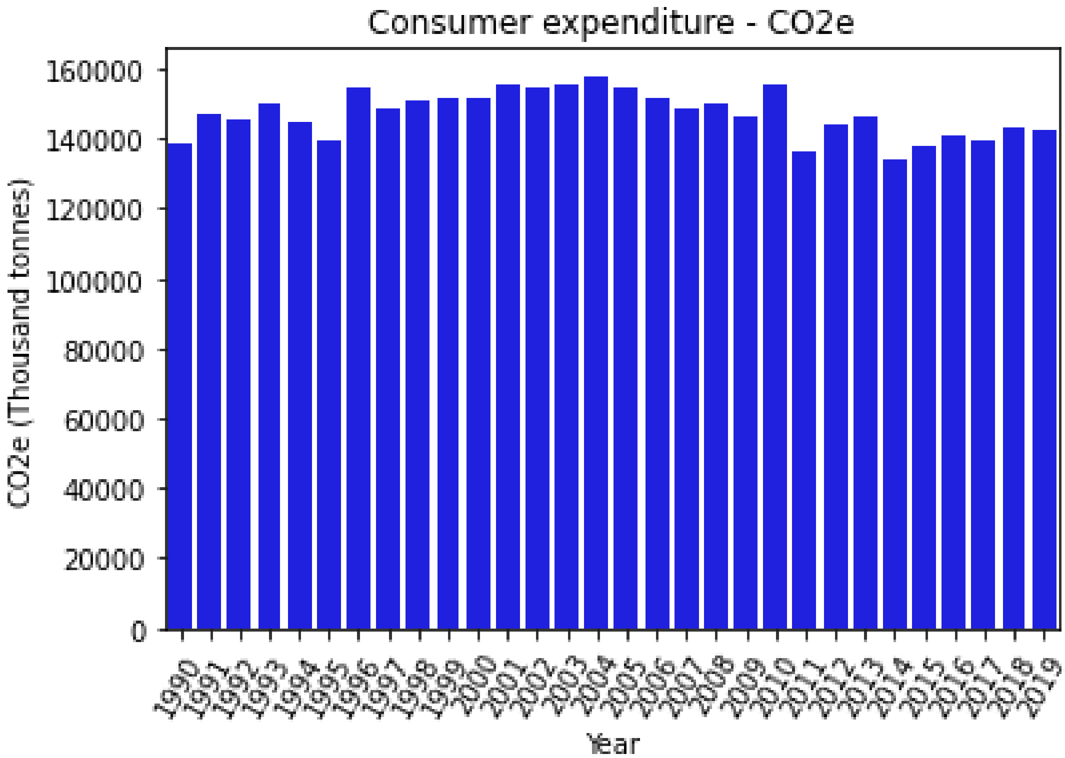
Year


Human health and social work activities - CO2e
CO2e (Thousand tonnes)
Year


Arts, entertainment and recreation - CO2e
CO2e (Thousand tonnes)
Year


Other service activities - CO2e
CO2e (Thousand tonnes)
Year


Activities of households as employers; undifferentiated goods and services-producing activities of households for own use - CO2e
CO2e (Thousand tonnes)
Year


Consumer expenditure - CO2e
CO2e (Thousand tonnes)
0
20000
40000
60000
80000
100000
120000
140000
160000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
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2004
2005
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Year