Justin Napolitano Watt Time Take Home

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Apr 18, 2022

CONTENTS

Thank You

I am grateful for the opportunity to work on something that I am passionate about. I also had a lot of fun experimenting with the data and learning some new skills along the way.

About This Document

This document is a sample of the type of work that I like to create. I used the Jupyter Book Packages Jupyter-Book to build the website and the PDF document. I like working with this suite and Sphinx because it integrates well with Python and Jupyter Notebooks. There are other options available such Gatsby, but that requires more manual tinkering than I had time to complete.

Sections

You will find code and no code blog post examples, data exploration/preperation notebooks that I kept to document my thinking, and an analysis of the University of Malaysia paper provided to me.

The scripts I used to prepare the data are found in the data exploration section

Check out my work below.

- Blog Posts
  - *Are We Undercounting Global Methane Emissions? (No Code Example)*
  - *Are We Undercounting Global Methane Emissions? (Code Example)*
- Analysis of The University of Malaysia Paper
  - *Replicating the University of Malysia Paper.*
  - *Hypothesis Testing the University of Malaysia Paper*
- Data Exploration
  - *Emissions Estimation Data: A Comparison between FAOSTAT and University of Malysia Estimates*
  - *Merging TRACE and FAOSTAT Data with Geographic Data for Mapping*

Discussion

Limiting myself to 300 - 500 words.

I found it difficult to not write a thesis paper. The data exploration notebooks document my journey through the data. My intention was to recreate the Climate Trace article provided to me, test the claims, and review the emissions conversion rates methodology. That work is preserved in the analysis and data exploration sections.

The final post that I prepared feels short, despite not having delved into the depths of the analysis. Nonetheless, I enjoyed the challenge.

Things I would have Done Differently

I would have begun this process by clearly identifying my audience. Without that in mind, I struggled to formulate an argument.

I would also like to have read the literature to a greater extent in order to cite statements in my post that I felt were under researched.

Things left to Do

Data Pipeline

With unlimited time, I would have like to compile my data manipulation processes into a data pipeline program to automate the process without the jupyter overhead. It would better facilitate distributing the repository via github for other researchers to explore.

Bibliography

Including a bibliography is a feature supported by Jupyter Book. Unfortunately, it can be finicky. I would have liked to include a references section that links to the cited documents.

20 and 100 Year Warming Potentials

I would have liked to make an argument supporiting including co2equiv in the 20 and 100 year warming potentials measure, but I did not feel authorized to do so. I worried about making an argument that was inaccurate due a lack of exposure to the literature. A full literature review would have been necessary in my opinion to make a valid argument. Unfortunately, I did not have the time nor the space to do so.

Publish the Website

I chose not to publish the site publicaly at the request of the instructions. I've prepared methane.jnapolitano.io for deployment to publish this site when permitted to do so.

Part I

Blog Posts

CHAPTER

ONE

ARE WE UNDERCOUNTING GLOBAL METHANE EMISSIONS? (NO CODE EXAMPLE)

According to the United Nations Environment Program "methane is the primary contributor to the formation of ground-level ozone." Over 20 years, "it is 80 times more potent at warming than carbon dioxide." (UNEP). In fact, one kilogram of CH4 produced is equivalent to 25 kilograms of CO2 (Econometra).

The agricultural industry is the primary producer of methane emissions globally. While the cattle industry is a well known culprit, paddy rice cultivation accounts for another 8 per cent of human linked emissions (UNEP).

1.1 How are Rice Paddy Emissions Measured?

Methane estimates are calcuated by multipling the hecatares of rice paddy in cultivation by a conversion factor.

The Food and Agricultural Organization of the United Nations (FAOSTAT) is the most trusted provider of methane emission estimates. The accuracy of their data however, can be questioned as the organization relies upon official government sources which may be manipulated.

Climate TRACE (Climate TRACE) on the other hand estimates emission levels by calculating the area of cultivated paddies with satellite imaging. While this method may undercount small fields and cultivation at higher altitudes, the metric does not rely upon possibly manipulated sources. This should result in more accurate predictions.

Note: It is important to note that FAOSTAT and TRACE estimate emissions with different conversion factors.

1.2 Differences between FAOSTAT and TRACE Estimates.

1.2.1 Data Review

We will be reviewing the data provided by FAOSTAT and TRACE. The dataframe imported was prepared for this post. You may review the documentation *here*.

1.2.2 Methane Emissions Data 2015 - 2019

```
                         country_name_FAOSTAT      continent  \
0                                  Bangladesh           Asia
1                                      Brazil  South America
2                                       China           Asia
3                                       Spain         Europe
4                                   Indonesia           Asia
5                                       India           Asia
6                   Iran (Islamic Republic of)           Asia
7                                       Italy         Europe
8                                       Japan           Asia
9                                    Cambodia           Asia
10                     Korea (the Republic of)           Asia
11      Lao People's Democratic Republic (the)           Asia
12                                   Sri Lanka           Asia
13                                     Myanmar           Asia
14                                    Malaysia           Asia
15                                       Nepal           Asia
16                                    Pakistan           Asia
17                           Philippines (the)           Asia
18  Korea (the Democratic People's Republic of)           Asia
19                                    Thailand           Asia
20                 Taiwan (Province of China)           Asia
21              United States of America (the)  North America
22                                    Viet Nam           Asia
23                                        mean           None
24                                       total           None

    CH4_abs_percent_diff_totals  CH4_relative_percent_diff_totals  \
0                     63.425917                         -92.881337
1                     93.222402                        -174.610414
2                      9.421813                          -9.887609
3                    124.705066                          76.811284
4                     70.153790                          51.936188
5                     32.086209                         -38.217479
6                     13.260902                          12.436318
7                     80.187551                          57.238482
8                     36.874729                          31.134372
9                     14.304565                         -15.406481
10                    15.813819                          14.655057
11                   145.627378                          84.268427
12                    27.569003                          24.229137
13                    14.697380                         -15.863111
14                    13.043224                          12.244674
15                    50.437328                          40.279401
16                    31.154530                         -36.903009
17                   121.748165                          75.679166
18                    17.492669                         -19.169278
19                    22.551331                          20.266184
20                    52.458032                         -71.109302
21                    78.850049                          56.553728
22                     0.902428                          -0.906518
23                    49.129925                           3.599038
24                  1129.988279                          82.777881

    CH4_diff_totals        2015     tCH4_2015          2016     tCH4_2016  \
```

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```
0     -5.265110e+06   1131293.4  2.344420e+06  1.093480e+06  2.278158e+06
1     -1.096923e+06    138910.3  3.410233e+05  1.262782e+05  3.104189e+05
2     -2.642293e+06   5406593.9  6.133647e+06  5.399920e+06  5.859531e+06
3      2.069382e+05     55082.2  1.141464e+04  5.507310e+04  1.334803e+04
4      6.172158e+06   2407953.5  1.283649e+06  2.387656e+06  1.023129e+06
5     -8.806357e+06   4580248.4  6.219887e+06  4.559136e+06  5.309413e+06
6      6.526191e+04    116486.7  8.774407e+04  1.310085e+05  9.180121e+04
7      3.267972e+05    114574.8  4.995968e+04  1.180030e+05  4.937785e+04
8      5.053990e+05    330353.1  2.305465e+05  3.264030e+05  2.284133e+05
9     -3.570168e+05    436826.0  4.954698e+05  4.590031e+05  5.731698e+05
10     1.169559e+05    167862.2  1.451878e+05  1.635341e+05  1.274597e+05
11     3.747725e+05     94826.8  1.661169e+04  9.563000e+04  1.696441e+04
12     1.337589e+05    132640.0  8.305626e+04  1.217563e+05  1.011743e+05
13    -8.567154e+05   1059409.6  1.132082e+06  1.052288e+06  1.290806e+06
14     7.536891e+04    121942.6  1.057399e+05  1.232328e+05  1.110049e+05
15     3.080032e+05    149262.2  1.007479e+05  1.427237e+05  6.667161e+04
16    -7.340502e+05    383529.3  4.852431e+05  3.813618e+05  5.945922e+05
17     5.944023e+06   1557810.6  3.432021e+05  1.524292e+06  4.073554e+05
18    -8.007815e+04     82823.3  1.143217e+05  8.344230e+04  9.177653e+04
19     1.667678e+06   1554254.0  1.393798e+06  1.703328e+06  1.780993e+06
20    -1.736733e+05     45838.7  7.866956e+04  4.983830e+04  8.089149e+04
21     1.075629e+06    364728.0  1.611324e+05  4.386620e+05  1.618576e+05
22    -6.129998e+04   1381744.4  1.346013e+06  1.365174e+06  1.483777e+06
23    -1.348162e+05    948478.0  9.871116e+05  9.522272e+05  9.587863e+05
24    -3.100772e+06  21814994.0  2.270357e+07  2.190123e+07  2.205208e+07

            2017     tCH4_2017          2017     tCH4_2017          2018  \
0   1.154531e+06  2.098958e+06  1.154531e+06  2.098958e+06  1.144591e+06
1   1.303229e+05  3.725173e+05  1.303229e+05  3.725173e+05  1.216152e+05
2   5.400129e+06  6.355071e+06  5.400129e+06  6.355071e+06  5.302173e+06
3   5.423240e+04  1.217299e+04  5.423240e+04  1.217299e+04  5.292500e+04
4   2.425291e+06  9.615327e+05  2.425291e+06  9.615327e+05  2.405614e+06
5   4.620791e+06  6.228451e+06  4.620791e+06  6.228451e+06  4.661155e+06
6   8.723360e+04  9.620217e+04  8.723360e+04  9.620217e+04  9.393660e+04
7   1.180030e+05  5.443679e+04  1.180030e+05  5.443679e+04  1.094638e+05
8   3.237003e+05  2.708935e+05  3.237003e+05  2.708935e+05  3.222450e+05
9   4.737453e+05  4.517045e+05  4.737453e+05  4.517045e+05  4.793627e+05
10  1.584897e+05  1.463222e+05  1.584897e+05  1.463222e+05  1.549113e+05
11  9.394070e+04  1.168063e+04  9.394070e+04  1.168063e+04  8.333360e+04
12  8.445630e+04  5.911841e+04  8.445630e+04  5.911841e+04  1.110490e+05
13  1.087030e+06  1.205169e+06  1.087030e+06  1.205169e+06  1.118850e+06
14  1.226563e+05  1.111291e+05  1.226563e+05  1.111291e+05  1.252385e+05
15  1.625746e+05  8.081300e+04  1.625746e+05  8.081300e+04  1.538908e+05
16  4.060833e+05  5.372641e+05  4.060833e+05  5.372641e+05  3.934042e+05
17  1.609862e+06  3.836830e+05  1.609862e+06  3.836830e+05  1.606048e+06
18  8.459620e+04  1.085457e+05  8.459620e+04  1.085457e+05  8.394330e+04
19  1.714466e+06  1.164699e+06  1.714466e+06  1.164699e+06  1.702989e+06
20  4.999120e+04  8.705634e+04  4.999120e+04  8.705634e+04  4.941410e+04
21  3.362555e+05  1.684799e+05  3.362555e+05  1.684799e+05  4.121775e+05
22  1.360552e+06  1.406437e+06  1.360552e+06  1.406437e+06  1.336231e+06
23  9.590840e+05  9.727103e+05  9.590840e+05  9.727103e+05  9.575896e+05
24  2.205893e+07  2.237234e+07  2.205893e+07  2.237234e+07  2.202456e+07

       tCH4_2018          2019     tCH4_2019
0   2.141231e+06  1.144745e+06  2.070985e+06
1   3.717030e+05  1.110848e+05  3.294713e+05
```

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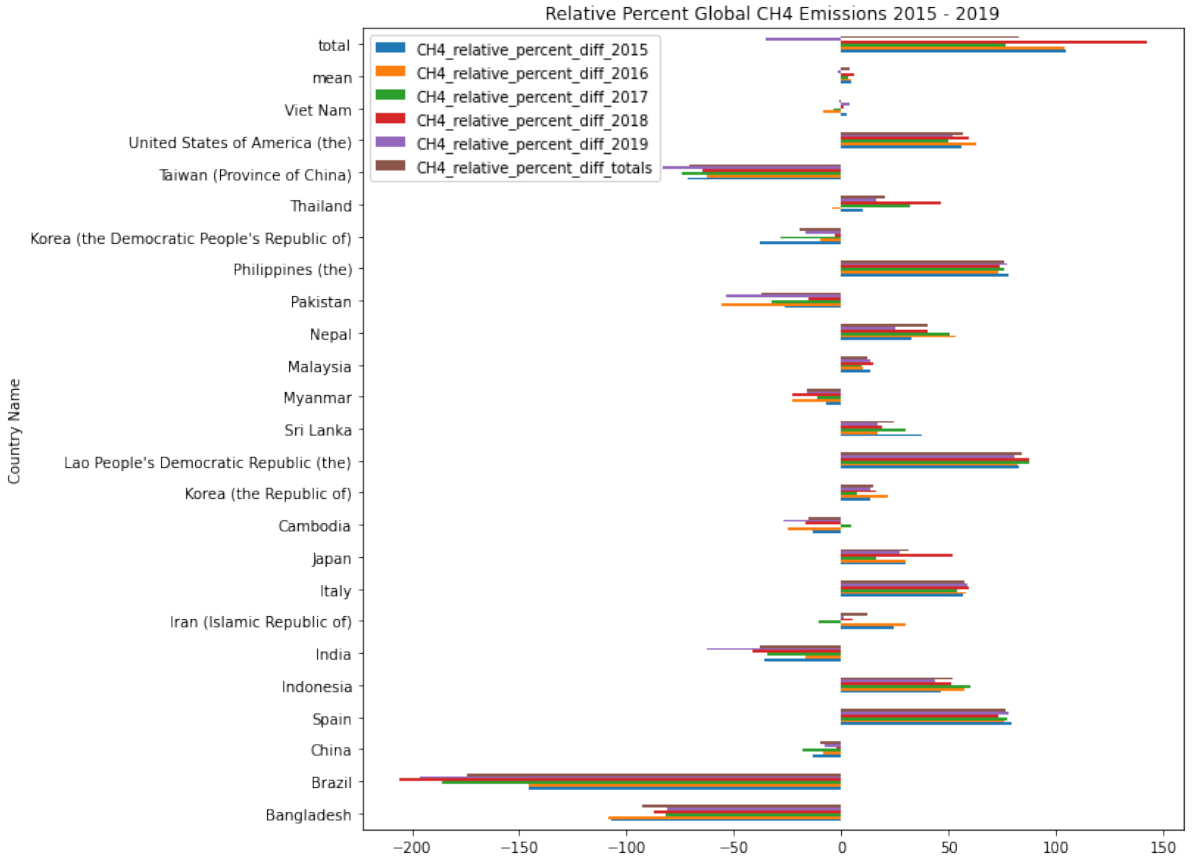
```
2   5.413962e+06  5.214455e+06  5.603352e+06
3   1.405410e+04  5.209850e+04  1.148324e+04
4   1.176982e+06  2.257604e+06  1.266668e+06
5   6.589798e+06  4.621417e+06  7.501556e+06
6   8.875744e+04  9.610340e+04  9.500199e+04
7   4.469902e+04  1.108951e+05  4.566914e+04
8   1.548252e+05  3.205818e+05  2.332056e+05
9   5.592610e+05  4.683789e+05  5.947277e+05
10  1.293543e+05  1.532609e+05  1.327782e+05
11  1.009675e+04  7.700550e+04  1.461058e+04
12  9.018914e+04  1.021563e+05  8.476088e+04
13  1.372447e+06  1.083100e+06  1.256888e+06
14  1.066525e+05  1.224538e+05  1.056287e+05
15  9.200752e+04  1.562154e+05  1.164235e+05
16  4.532297e+05  4.247551e+05  6.528548e+05
17  4.175210e+05  1.556226e+06  3.584550e+05
18  8.662578e+04  8.293700e+04  9.655062e+04
19  9.166575e+05  1.553836e+06  1.305046e+06
20  8.138151e+04  4.915200e+04  8.990870e+04
21  1.657254e+05  3.501365e+05  1.691351e+05
22  1.317455e+06  1.318431e+06  1.269751e+06
23  9.475920e+05  9.316100e+05  1.017605e+06
24  2.179462e+07  2.142703e+07  2.340491e+07
```

Methane Emissions Insights

- FAOSTAT underestimated by about 2.8 percent in comparison to TRACE.
- FAOSTAT undestimated a total of 3,100,772 tonnes of methane over a 5 year period.

Let's review the bar chart below to better understand the data.

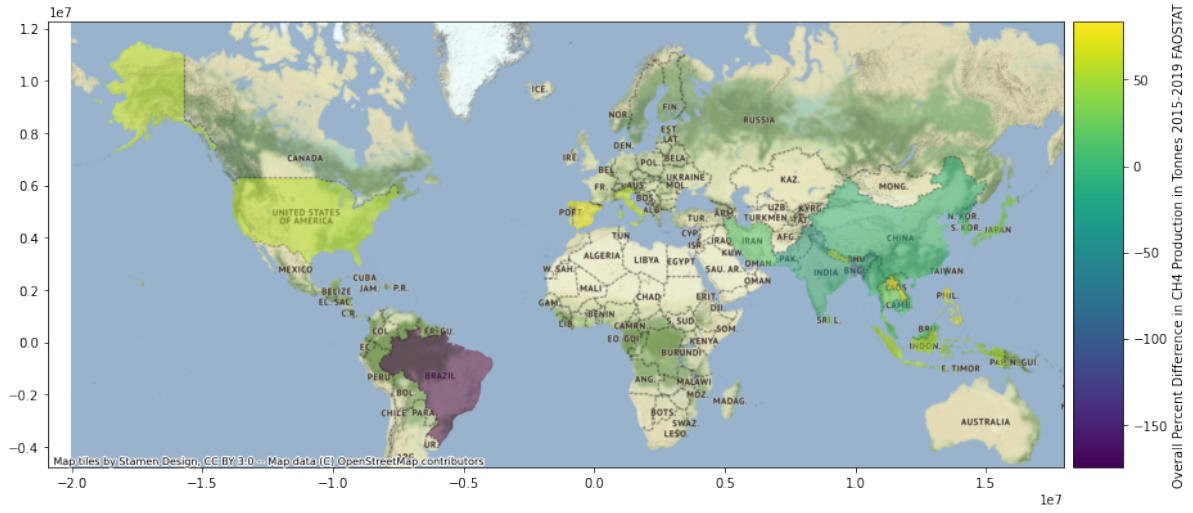
```
<AxesSubplot:title={'center':'Relative Percent Global CH4 Emissions 2015 - 2019'},␣
↪ylabel='Country Name'>
```



1.2.3 Major Differences Between FAOSTAT and TRACE for Certain Countries

FaoSTAT methods underestimate nearly as often as they overestimate; however, large producer such as Brazil, Bangladesh, China, and India generate large amounts of emissions not considered by FAOSTAT.

The following map illustrates these differences well.



1.2.4 FAOSTAT Under Estimation in Brazil China, India, and Bangledesh.

Brazil's emissions are greatly undercounted over the 5 year period. A factor greater than the difference in emission conversion factors would predict. Rice Paddies in cultivation may be hidden from satellites by tree cover or altitude. China, India, and Bangladesh too differ, but at a smaller scale. It is likely that the TRACE data are nearly equivalent to the FAOSTAT data for these contries.

1.3 The Case for Climate Trace Estimates

The TRACE and the FAOSTAT methods could both erroneously estimate methane emissions. Climate Trace's advantage is that hecatares of cultivation are estimated from satellite imaging as opposed to government reports. The result of which is a falsifiable report supported by empirical evidence. When calculating the CO2 equivalency of CH4 emissions it is safer to use the TRACE data because the data collection methodology is rigorous.

1.4 Estimating CO2 Equivalency

CH4 can be converted to CO2 equivalent by multiplying the 1 kilogram of CH4 by 25 (Econometra). The dataframe below has been precalculated view the documentation *here*.

Note: All differences are recorded as FAOSTAT - TRACE.

1.4.1 Tonnes C02 2015 - 2019 TRACE Estimations

	country_name_TRACE	CO2_abs_percent_diff_totals
0	Bangladesh	63.425917
1	Brazil	93.222402
2	China	9.421813
3	Spain	124.705066
4	Indonesia	70.153790
5	India	32.086209
6	Iran (Islamic Republic of)	13.260902
7	Italy	80.187551
8	Japan	36.874729
9	Cambodia	14.304565
10	Korea (the Republic of)	15.813819
11	Lao People's Democratic Republic (the)	145.627378
12	Sri Lanka	27.569003
13	Myanmar	14.697380
14	Malaysia	13.043224
15	Nepal	50.437328
16	Pakistan	31.154530
17	Philippines (the)	121.748165
18	Korea (the Democratic People's Republic of)	17.492669
19	Thailand	22.551331
20	Taiwan (Province of China)	52.458032
21	United States of America (the)	78.850049
22	Viet Nam	0.902428
23	mean	49.129925
24	total	1129.988279

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```
    CO2_relative_percent_diff_totals  CO2_diff_totals  tCO2_2015_TRACE  \
0                          -92.881337    -1.316277e+08     5.861049e+07
1                         -174.610414    -2.742306e+07     8.525583e+06
2                           -9.887609    -6.605732e+07     1.533412e+08
3                           76.811284     5.173455e+06     2.853661e+05
4                           51.936188     1.543040e+08     3.209122e+07
5                          -38.217479    -2.201589e+08     1.554972e+08
6                           12.436318     1.631548e+06     2.193602e+06
7                           57.238482     8.169930e+06     1.248992e+06
8                           31.134372     1.263498e+07     5.763662e+06
9                          -15.406481    -8.925421e+06     1.238675e+07
10                          14.655057     2.923897e+06     3.629695e+06
11                          84.268427     9.369313e+06     4.152924e+05
12                          24.229137     3.343972e+06     2.076407e+06
13                         -15.863111    -2.141788e+07     2.830206e+07
14                          12.244674     1.884223e+06     2.643498e+06
15                          40.279401     7.700079e+06     2.518697e+06
16                         -36.903009    -1.835125e+07     1.213108e+07
17                          75.679166     1.486006e+08     8.580052e+06
18                         -19.169278    -2.001954e+06     2.858041e+06
19                          20.266184     4.169196e+07     3.484495e+07
20                         -71.109302    -4.341833e+06     1.966739e+06
21                          56.553728     2.689073e+07     4.028310e+06
22                          -0.906518    -1.532499e+06     3.365033e+07
23                           3.599038    -3.370404e+06     2.467779e+07
24                          82.777881    -7.751930e+07     5.675891e+08

    tCO2_2016_TRACE  tCO2_2017_TRACE  tCO2_2018_TRACE  tCO2_2019_TRACE  \
0      5.695395e+07     5.247394e+07     5.353076e+07     5.177463e+07
1      7.760473e+06     9.312934e+06     9.292575e+06     8.236783e+06
2      1.464883e+08     1.588768e+08     1.353491e+08     1.400838e+08
3      3.337007e+05     3.043248e+05     3.513524e+05     2.870810e+05
4      2.557824e+07     2.403832e+07     2.942454e+07     3.166670e+07
5      1.327353e+08     1.557113e+08     1.647450e+08     1.875389e+08
6      2.295030e+06     2.405054e+06     2.218936e+06     2.375050e+06
7      1.234446e+06     1.360920e+06     1.117475e+06     1.141729e+06
8      5.710333e+06     6.772337e+06     3.870631e+06     5.830141e+06
9      1.432925e+07     1.129261e+07     1.398153e+07     1.486819e+07
10     3.186493e+06     3.658056e+06     3.233858e+06     3.319455e+06
11     4.241102e+05     2.920158e+05     2.524186e+05     3.652645e+05
12     2.529358e+06     1.477960e+06     2.254728e+06     2.119022e+06
13     3.227014e+07     3.012923e+07     3.431117e+07     3.142221e+07
14     2.775123e+06     2.778227e+06     2.666313e+06     2.640717e+06
15     1.666790e+06     2.020325e+06     2.300188e+06     2.910588e+06
16     1.486480e+07     1.343160e+07     1.133074e+07     1.632137e+07
17     1.018389e+07     9.592074e+06     1.043803e+07     8.961374e+06
18     2.294413e+06     2.713641e+06     2.165645e+06     2.413765e+06
19     4.452483e+07     2.911748e+07     2.291644e+07     3.262615e+07
20     2.022287e+06     2.176408e+06     2.034538e+06     2.247717e+06
21     4.046440e+06     4.211999e+06     4.143136e+06     4.228377e+06
22     3.709441e+07     3.516092e+07     3.293637e+07     3.174377e+07
23     2.396966e+07     2.431776e+07     2.368980e+07     2.544012e+07
24     5.513021e+08     5.593084e+08     5.448654e+08     5.851228e+08

           Means        Totals
```

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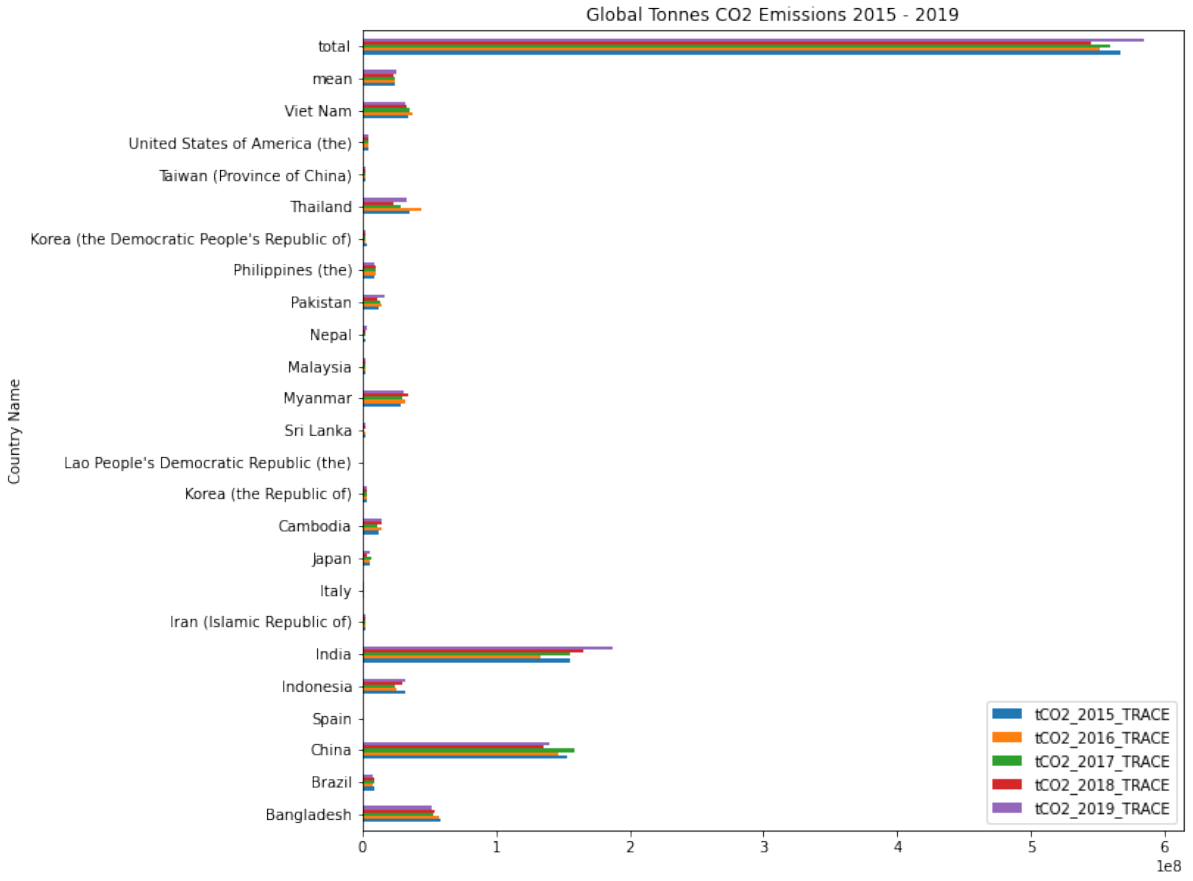
```
0   1.771450e+07  2.733438e+08
1   1.963150e+06  4.312835e+07
2   8.351022e+07  7.341391e+08
3   8.419352e+05  1.561825e+06
4   3.713789e+07  1.427990e+08
5   7.200858e+07  7.962276e+08
6   1.639906e+06  1.148767e+07
7   1.784204e+06  6.103562e+06
8   5.072769e+06  2.794710e+07
9   7.241612e+06  6.685832e+07
10  2.493936e+06  1.702756e+07
11  1.389831e+06  1.749102e+06
12  1.725187e+06  1.045748e+07
13  1.687712e+07  1.564348e+08
14  1.923516e+06  1.350388e+07
15  2.389595e+06  1.141659e+07
16  6.216042e+06  6.807960e+07
17  2.454452e+07  4.775541e+07
18  1.305444e+06  1.244551e+07
19  2.571523e+07  1.640298e+08
20  7.632299e+05  1.044769e+07
21  5.943640e+06  2.065826e+07
22  2.113166e+07  1.705858e+08
23  1.484060e+07  1.220951e+08
24  3.413337e+08  2.808188e+09
```

Note: Note a mean of 561,637,600 tonnes CO2equiv produced between annualy 2015 - 2019.

CO2 Data Insights

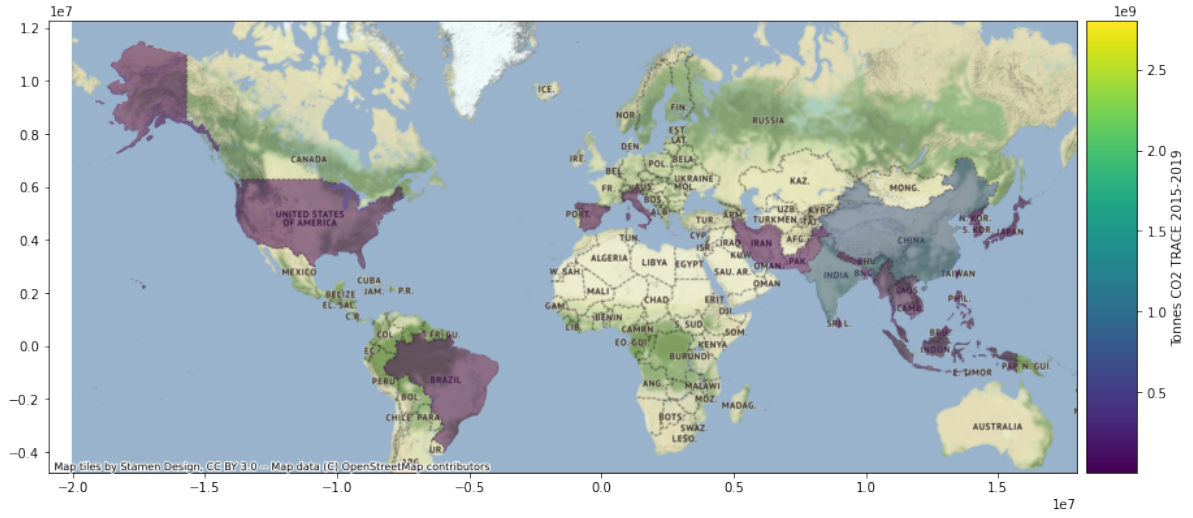
- Total difference in 3,370,404 tonnes of CO2equiv between the FAOSTAT and TRACE data.
- TRACE reports 2,808,188,000 Tonnes of CO2equiv produced between 2015 to 2019.
- There is a relative percent difference of -2.8 percent.

```
<AxesSubplot:title={'center':'Global Tonnes CO2 Emissions 2015 - 2019'}, ylabel=
↪'Country Name'>
```



The Worst Offenders are the Most Dependent on Rice Cultivation

The worst offenders are China, India, and Bangladesh. These states struggle with feeding their massive populations. Including CO2equiv in carbon goals may harm the people of these countries.



Note: Values in billions.

1.5 Conclusions

1.5.1 FAOSTAT Likely Undercounts Emissions

The TRACE data set on average reports about 2.8 percent more methane emissions than the FAOSTAT data set. This equates to a total methane emmissions estimates difference of 3,100,772 tonnes over a 5 year period. The CO2equiv over that same period is 77,519,300 tonnes. Neither value is negligible.

1.5.2 Countries Should Attempt to Reduce Methane Emssions

The 20 and 100 year warming potentials for methane emsission are 84 and 28 [(WG1AR5_Chapter08, Pg 73)]. These factors will impact our climate if nothing is done. Unfortunately, the countries that produce the most methane from rice cultivation are also those most dependent on the grain. To make the change, realistic solutions must be provided to feed people culturally and geographically dependent on rice cultivation.

CHAPTER

TWO

ARE WE UNDERCOUNTING GLOBAL METHANE EMISSIONS? (CODE EXAMPLE)

According to the United Nations Environment Program "methane is the primary contributor to the formation of ground-level ozone." Over 20 years, "it is 80 times more potent at warming than carbon dioxide." (UNEP). In fact, one kilogram of CH4 produced is equivalent to 25 kilograms of CO2 (Econometra).

The agricultural industry is the primary producer of methane emissions globally. While the cattle industry is a well known culprit, paddy rice cultivation accounts for another 8 per cent of human linked emissions (UNEP).

2.1 How are Rice Paddy Emissions Measured?

Methane estimates are calcuated by multipling the hecatares of rice paddy in cultivation by a conversion factor.

The Food and Agricultural Organization of the United Nations (FAOSTAT) is the most trusted provider of methane emission estimates. The accuracy of their data however, can be questioned as the organization relies upon official government sources which may be manipulated.

Climate TRACE (Climate TRACE) on the other hand estimates emission levels by calculating the area of cultivated paddies with satellite imaging. While this method may undercount small fields and cultivation at higher altitudes, the metric does not rely upon possibly manipulated sources. This should result in more accurate predictions.

Note: It is important to note that FAOSTAT and TRACE estimate emissions with different conversion factors.

2.2 Differences between FAOSTAT and TRACE Estimates.

```
import pandas as pd
import matplotlib.pyplot as plt
import geopandas as gpd
import contextily as cx
import numpy as np
from mpl_toolkits.axes_grid1 import make_axes_locatable
```

2.2.1 Data Review

We will be reviewing the data provided by FAOSTAT and TRACE. The dataframe imported was prepared for this post. You may review the documentation *here*.

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/MERGE_DATA_GEO.geojson"

merge_geo_df = gpd.read_file(filepath)

## Convert to 3857 for easier plotting and spatial math if necessary
merge_geo_df = merge_geo_df.to_crs(epsg=3857)
```

2.2.2 Methane Emissions Data 2015 - 2019

```
ch4_data = merge_geo_df[['country_name_FAOSTAT', 'continent','CH4_abs_percent_diff_
↪totals', 'CH4_relative_percent_diff_totals', 'CH4_diff_totals','2015', 'tCH4_2015',
↪'2016', 'tCH4_2016','2017', 'tCH4_2017','2017', 'tCH4_2017','2018', 'tCH4_2018',
↪'2019', 'tCH4_2019']].copy()
ch4_data
```

```
                          country_name_FAOSTAT      continent  \
0                                   Bangladesh           Asia
1                                       Brazil  South America
2                                        China           Asia
3                                        Spain         Europe
4                                    Indonesia           Asia
5                                        India           Asia
6                  Iran (Islamic Republic of)           Asia
7                                        Italy         Europe
8                                        Japan           Asia
9                                     Cambodia           Asia
10                   Korea (the Republic of)           Asia
11      Lao People's Democratic Republic (the)           Asia
12                                   Sri Lanka           Asia
13                                     Myanmar           Asia
14                                    Malaysia           Asia
15                                       Nepal           Asia
16                                    Pakistan           Asia
17                           Philippines (the)           Asia
18  Korea (the Democratic People's Republic of)           Asia
19                                    Thailand           Asia
20                 Taiwan (Province of China)           Asia
21              United States of America (the)  North America
22                                    Viet Nam           Asia
23                                        mean           None
24                                       total           None

    CH4_abs_percent_diff_totals  CH4_relative_percent_diff_totals  \
0                     63.425917                         -92.881337
1                     93.222402                        -174.610414
2                      9.421813                          -9.887609
3                    124.705066                          76.811284
4                     70.153790                          51.936188
5                     32.086209                         -38.217479
```

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```
6                    13.260902                          12.436318
7                    80.187551                          57.238482
8                    36.874729                          31.134372
9                    14.304565                         -15.406481
10                   15.813819                          14.655057
11                  145.627378                          84.268427
12                   27.569003                          24.229137
13                   14.697380                         -15.863111
14                   13.043224                          12.244674
15                   50.437328                          40.279401
16                   31.154530                         -36.903009
17                  121.748165                          75.679166
18                   17.492669                         -19.169278
19                   22.551331                          20.266184
20                   52.458032                         -71.109302
21                   78.850049                          56.553728
22                    0.902428                          -0.906518
23                   49.129925                           3.599038
24                 1129.988279                          82.777881

    CH4_diff_totals        2015     tCH4_2015          2016     tCH4_2016  \
0     -5.265110e+06   1131293.4  2.344420e+06  1.093480e+06  2.278158e+06
1     -1.096923e+06    138910.3  3.410233e+05  1.262782e+05  3.104189e+05
2     -2.642293e+06   5406593.9  6.133647e+06  5.399920e+06  5.859531e+06
3      2.069382e+05     55082.2  1.141464e+04  5.507310e+04  1.334803e+04
4      6.172158e+06   2407953.5  1.283649e+06  2.387656e+06  1.023129e+06
5     -8.806357e+06   4580248.4  6.219887e+06  4.559136e+06  5.309413e+06
6      6.526191e+04    116486.7  8.774407e+04  1.310085e+05  9.180121e+04
7      3.267972e+05    114574.8  4.995968e+04  1.180030e+05  4.937785e+04
8      5.053990e+05    330353.1  2.305465e+05  3.264030e+05  2.284133e+05
9     -3.570168e+05    436826.0  4.954698e+05  4.590031e+05  5.731698e+05
10     1.169559e+05    167862.2  1.451878e+05  1.635341e+05  1.274597e+05
11     3.747725e+05     94826.8  1.661169e+04  9.563000e+04  1.696441e+04
12     1.337589e+05    132640.0  8.305626e+04  1.217563e+05  1.011743e+05
13    -8.567154e+05   1059409.6  1.132082e+06  1.052288e+06  1.290806e+06
14     7.536891e+04    121942.6  1.057399e+05  1.232328e+05  1.110049e+05
15     3.080032e+05    149262.2  1.007479e+05  1.427237e+05  6.667161e+04
16    -7.340502e+05    383529.3  4.852431e+05  3.813618e+05  5.945922e+05
17     5.944023e+06   1557810.6  3.432021e+05  1.524292e+06  4.073554e+05
18    -8.007815e+04     82823.3  1.143217e+05  8.344230e+04  9.177653e+04
19     1.667678e+06   1554254.0  1.393798e+06  1.703328e+06  1.780993e+06
20    -1.736733e+05     45838.7  7.866956e+04  4.983830e+04  8.089149e+04
21     1.075629e+06    364728.0  1.611324e+05  4.386620e+05  1.618576e+05
22    -6.129998e+04   1381744.4  1.346013e+06  1.365174e+06  1.483777e+06
23    -1.348162e+05    948478.0  9.871116e+05  9.522272e+05  9.587863e+05
24    -3.100772e+06  21814994.0  2.270357e+07  2.190123e+07  2.205208e+07

            2017     tCH4_2017          2017     tCH4_2017          2018  \
0   1.154531e+06  2.098958e+06  1.154531e+06  2.098958e+06  1.144591e+06
1   1.303229e+05  3.725173e+05  1.303229e+05  3.725173e+05  1.216152e+05
2   5.400129e+06  6.355071e+06  5.400129e+06  6.355071e+06  5.302173e+06
3   5.423240e+04  1.217299e+04  5.423240e+04  1.217299e+04  5.292500e+04
4   2.425291e+06  9.615327e+05  2.425291e+06  9.615327e+05  2.405614e+06
5   4.620791e+06  6.228451e+06  4.620791e+06  6.228451e+06  4.661155e+06
6   8.723360e+04  9.620217e+04  8.723360e+04  9.620217e+04  9.393660e+04
7   1.180030e+05  5.443679e+04  1.180030e+05  5.443679e+04  1.094638e+05
```

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8	3.237003e+05	2.708935e+05	3.237003e+05	2.708935e+05	3.222450e+05
9	4.737453e+05	4.517045e+05	4.737453e+05	4.517045e+05	4.793627e+05
10	1.584897e+05	1.463222e+05	1.584897e+05	1.463222e+05	1.549113e+05
11	9.394070e+04	1.168063e+04	9.394070e+04	1.168063e+04	8.333360e+04
12	8.445630e+04	5.911841e+04	8.445630e+04	5.911841e+04	1.110490e+05
13	1.087030e+06	1.205169e+06	1.087030e+06	1.205169e+06	1.118850e+06
14	1.226563e+05	1.111291e+05	1.226563e+05	1.111291e+05	1.252385e+05
15	1.625746e+05	8.081300e+04	1.625746e+05	8.081300e+04	1.538908e+05
16	4.060833e+05	5.372641e+05	4.060833e+05	5.372641e+05	3.934042e+05
17	1.609862e+06	3.836830e+05	1.609862e+06	3.836830e+05	1.606048e+06
18	8.459620e+04	1.085457e+05	8.459620e+04	1.085457e+05	8.394330e+04
19	1.714466e+06	1.164699e+06	1.714466e+06	1.164699e+06	1.702989e+06
20	4.999120e+04	8.705634e+04	4.999120e+04	8.705634e+04	4.941410e+04
21	3.362555e+05	1.684799e+05	3.362555e+05	1.684799e+05	4.121775e+05
22	1.360552e+06	1.406437e+06	1.360552e+06	1.406437e+06	1.336231e+06
23	9.590840e+05	9.727103e+05	9.590840e+05	9.727103e+05	9.575896e+05
24	2.205893e+07	2.237234e+07	2.205893e+07	2.237234e+07	2.202456e+07

	tCH4_2018	2019	tCH4_2019
0	2.141231e+06	1.144745e+06	2.070985e+06
1	3.717030e+05	1.110848e+05	3.294713e+05
2	5.413962e+06	5.214455e+06	5.603352e+06
3	1.405410e+04	5.209850e+04	1.148324e+04
4	1.176982e+06	2.257604e+06	1.266668e+06
5	6.589798e+06	4.621417e+06	7.501556e+06
6	8.875744e+04	9.610340e+04	9.500199e+04
7	4.469902e+04	1.108951e+05	4.566914e+04
8	1.548252e+05	3.205818e+05	2.332056e+05
9	5.592610e+05	4.683789e+05	5.947277e+05
10	1.293543e+05	1.532609e+05	1.327782e+05
11	1.009675e+04	7.700550e+04	1.461058e+04
12	9.018914e+04	1.021563e+05	8.476088e+04
13	1.372447e+06	1.083100e+06	1.256888e+06
14	1.066525e+05	1.224538e+05	1.056287e+05
15	9.200752e+04	1.562154e+05	1.164235e+05
16	4.532297e+05	4.247551e+05	6.528548e+05
17	4.175210e+05	1.556226e+06	3.584550e+05
18	8.662578e+04	8.293700e+04	9.655062e+04
19	9.166575e+05	1.553836e+06	1.305046e+06
20	8.138151e+04	4.915200e+04	8.990870e+04
21	1.657254e+05	3.501365e+05	1.691351e+05
22	1.317455e+06	1.318431e+06	1.269751e+06
23	9.475920e+05	9.316100e+05	1.017605e+06
24	2.179462e+07	2.142703e+07	2.340491e+07

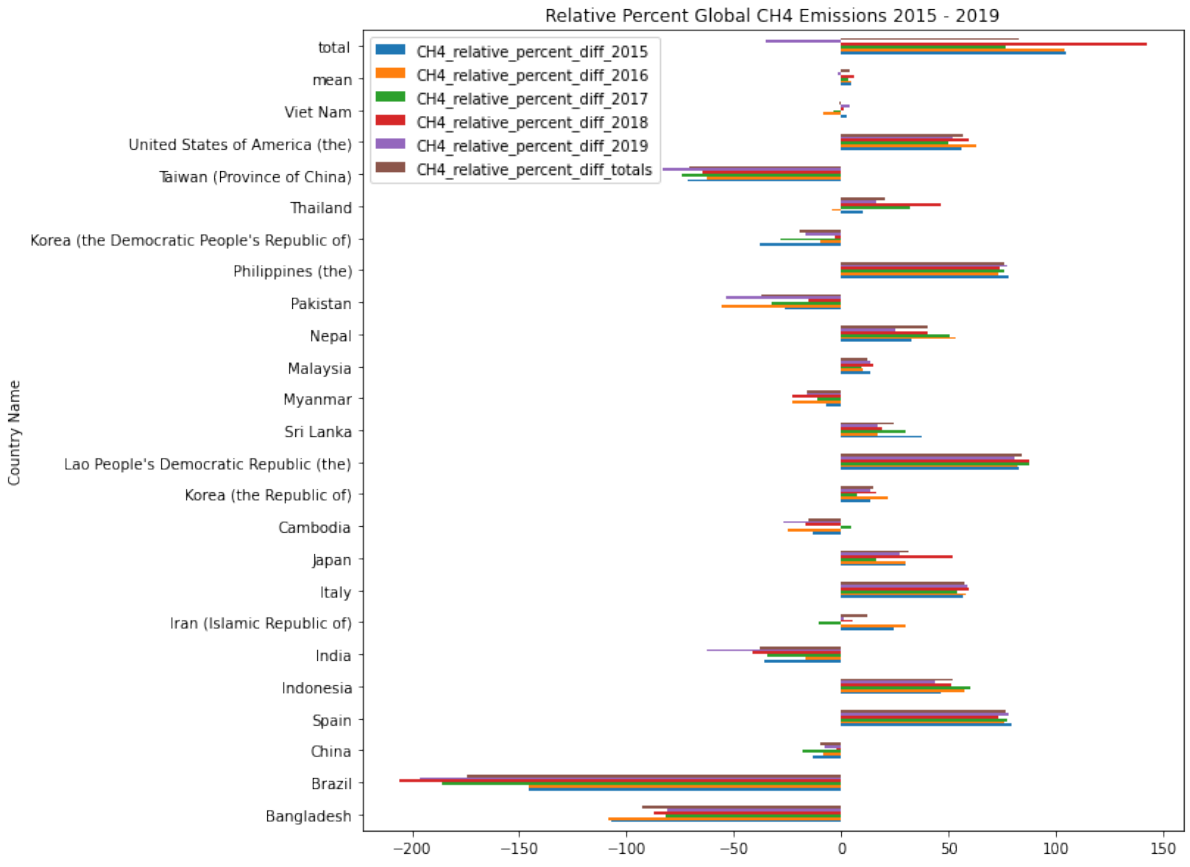
Methane Emissions Insights

- FAOSTAT underestimated by about 2.8 percent in comparison to TRACE.
- FAOSTAT undestimated a total of 3,100,772 tonnes of methane over a 5 year period.

Let's review the bar chart below to better understand the data.

```
merge_geo_df.plot(kind = "barh", x = 'country_name_FAOSTAT', y = ['CH4_relative_
↪percent_diff_2015', 'CH4_relative_percent_diff_2016','CH4_relative_percent_diff_2017
↪', 'CH4_relative_percent_diff_2018', 'CH4_relative_percent_diff_2019','CH4_relative_
↪percent_diff_totals'], xlabel = "Country Name", ylabel = "Tonnes CH4", title =
↪"Relative Percent Global CH4 Emissions 2015 - 2019", figsize = (10,10))
```

```
<AxesSubplot:title={'center':'Relative Percent Global CH4 Emissions 2015 - 2019'},␣
↪ylabel='Country Name'>
```

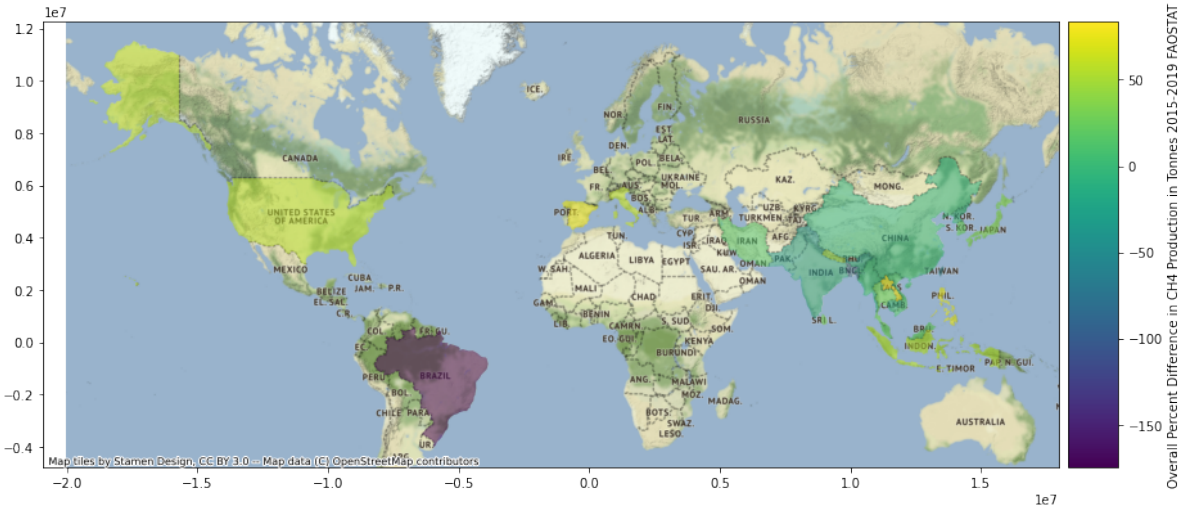


2.2.3 Major Differences Between FAOSTAT and TRACE for Certain Countries

FaoSTAT methods underestimate nearly as often as they overestimate; however, large producer such as Brazil, Bangladesh, China, and India generate large amounts of emissions not considered by FAOSTAT.

The following map illustrates these differences well.

```
fig, ax = plt.subplots(1, 1,figsize=(15,15))
divider = make_axes_locatable(ax)
cax = divider.append_axes("right", size="5%", pad=0.1)
merge_map = merge_geo_df.plot(column='CH4_relative_percent_diff_totals', ax=ax,␣
↪legend=True, cax=cax, alpha = .5,legend_kwds={'label': "Overall Percent Difference␣
↪in CH4 Production in Tonnes 2015-2019 FAOSTAT",
                        'orientation': "vertical"})
cx.add_basemap(merge_map, zoom=3)
```



2.2.4 FAOSTAT Under Estimation in Brazil China, India, and Bangledesh.

Brazil's emissions are greatly undercounted over the 5 year period. A factor greater than the difference in emission conversion factors would predict. Rice Paddies in cultivation may be hidden from satellites by tree cover or altitude. China, India, and Bangladesh too differ, but at a smaller scale. It is likely that the TRACE data are nearly equivalent to the FAOSTAT data for these contries.

2.3 The Case for Climate Trace Estimates

The TRACE and the FAOSTAT methods could both erroneously estimate methane emissions. Climate Trace's advantage is that hecatares of cultivation are estimated from satellite imaging as opposed to government reports. The result of which is a falsifiable report supported by empirical evidence. When calculating the CO2 equivalency of CH4 emissions it is safer to use the TRACE data because the data collection methodology is rigorous.

2.4 Estimating CO2 Equivalency

CH4 can be converted to CO2 equivalent by multiplying the 1 kilogram of CH4 by 25 (Econometra). The dataframe below has been precalculated view the documentation *here*.

```
co2_data = merge_geo_df[['country_name_TRACE', 'continent','CO2_abs_percent_diff_
 ↪totals', 'CO2_relative_percent_diff_totals', 'CO2_diff_totals','tCO2_2015_FAOSTAT',
 ↪'tCO2_2015_TRACE', 'tCO2_2016_FAOSTAT', 'tCO2_2016_TRACE', 'tCO2_2017_FAOSTAT',
 ↪'tCO2_2017_TRACE','tCO2_2018_FAOSTAT','tCO2_2018_TRACE', 'tCO2_2019_FAOSTAT','tCO2_
 ↪2019_TRACE']].copy()
```

Note: All differences are recorded as FAOSTAT - TRACE.

2.4.1 Tonnes C02 2015 - 2019 TRACE Estimations

```
TRACE_CO2_df = merge_geo_df[['country_name_TRACE','CO2_abs_percent_diff_totals', 'CO2_
 ↪relative_percent_diff_totals', 'CO2_diff_totals','tCO2_2015_TRACE','tCO2_2016_TRACE
 ↪','tCO2_2017_TRACE','tCO2_2018_TRACE','tCO2_2019_TRACE']].copy()
TRACE_CO2_df['Means'] = TRACE_CO2_df.select_dtypes(np.number).mean(axis=1)
TRACE_CO2_df['Totals'] = TRACE_CO2_df[['country_name_TRACE','tCO2_2015_TRACE','tCO2_
 ↪2016_TRACE','tCO2_2017_TRACE','tCO2_2018_TRACE','tCO2_2019_TRACE']].select_
 ↪dtypes(np.number).sum(axis=1)
TRACE_CO2_df
```

	country_name_TRACE	CO2_abs_percent_diff_totals	\
0	Bangladesh	63.425917	
1	Brazil	93.222402	
2	China	9.421813	
3	Spain	124.705066	
4	Indonesia	70.153790	
5	India	32.086209	
6	Iran (Islamic Republic of)	13.260902	
7	Italy	80.187551	
8	Japan	36.874729	
9	Cambodia	14.304565	
10	Korea (the Republic of)	15.813819	
11	Lao People's Democratic Republic (the)	145.627378	
12	Sri Lanka	27.569003	
13	Myanmar	14.697380	
14	Malaysia	13.043224	
15	Nepal	50.437328	
16	Pakistan	31.154530	
17	Philippines (the)	121.748165	
18	Korea (the Democratic People's Republic of)	17.492669	
19	Thailand	22.551331	
20	Taiwan (Province of China)	52.458032	
21	United States of America (the)	78.850049	
22	Viet Nam	0.902428	
23	mean	49.129925	
24	total	1129.988279	

	CO2_relative_percent_diff_totals	CO2_diff_totals	tCO2_2015_TRACE	\

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```
0                          -92.881337    -1.316277e+08     5.861049e+07
1                         -174.610414    -2.742306e+07     8.525583e+06
2                           -9.887609    -6.605732e+07     1.533412e+08
3                           76.811284     5.173455e+06     2.853661e+05
4                           51.936188     1.543040e+08     3.209122e+07
5                          -38.217479    -2.201589e+08     1.554972e+08
6                           12.436318     1.631548e+06     2.193602e+06
7                           57.238482     8.169930e+06     1.248992e+06
8                           31.134372     1.263498e+07     5.763662e+06
9                          -15.406481    -8.925421e+06     1.238675e+07
10                          14.655057     2.923897e+06     3.629695e+06
11                          84.268427     9.369313e+06     4.152924e+05
12                          24.229137     3.343972e+06     2.076407e+06
13                         -15.863111    -2.141788e+07     2.830206e+07
14                          12.244674     1.884223e+06     2.643498e+06
15                          40.279401     7.700079e+06     2.518697e+06
16                         -36.903009    -1.835125e+07     1.213108e+07
17                          75.679166     1.486006e+08     8.580052e+06
18                         -19.169278    -2.001954e+06     2.858041e+06
19                          20.266184     4.169196e+07     3.484495e+07
20                         -71.109302    -4.341833e+06     1.966739e+06
21                          56.553728     2.689073e+07     4.028310e+06
22                          -0.906518    -1.532499e+06     3.365033e+07
23                           3.599038    -3.370404e+06     2.467779e+07
24                          82.777881    -7.751930e+07     5.675891e+08

    tCO2_2016_TRACE  tCO2_2017_TRACE  tCO2_2018_TRACE  tCO2_2019_TRACE  \
0      5.695395e+07     5.247394e+07     5.353076e+07     5.177463e+07
1      7.760473e+06     9.312934e+06     9.292575e+06     8.236783e+06
2      1.464883e+08     1.588768e+08     1.353491e+08     1.400838e+08
3      3.337007e+05     3.043248e+05     3.513524e+05     2.870810e+05
4      2.557824e+07     2.403832e+07     2.942454e+07     3.166670e+07
5      1.327353e+08     1.557113e+08     1.647450e+08     1.875389e+08
6      2.295030e+06     2.405054e+06     2.218936e+06     2.375050e+06
7      1.234446e+06     1.360920e+06     1.117475e+06     1.141729e+06
8      5.710333e+06     6.772337e+06     3.870631e+06     5.830141e+06
9      1.432925e+07     1.129261e+07     1.398153e+07     1.486819e+07
10     3.186493e+06     3.658056e+06     3.233858e+06     3.319455e+06
11     4.241102e+05     2.920158e+05     2.524186e+05     3.652645e+05
12     2.529358e+06     1.477960e+06     2.254728e+06     2.119022e+06
13     3.227014e+07     3.012923e+07     3.431117e+07     3.142221e+07
14     2.775123e+06     2.778227e+06     2.666313e+06     2.640717e+06
15     1.666790e+06     2.020325e+06     2.300188e+06     2.910588e+06
16     1.486480e+07     1.343160e+07     1.133074e+07     1.632137e+07
17     1.018389e+07     9.592074e+06     1.043803e+07     8.961374e+06
18     2.294413e+06     2.713641e+06     2.165645e+06     2.413765e+06
19     4.452483e+07     2.911748e+07     2.291644e+07     3.262615e+07
20     2.022287e+06     2.176408e+06     2.034538e+06     2.247717e+06
21     4.046440e+06     4.211999e+06     4.143136e+06     4.228377e+06
22     3.709441e+07     3.516092e+07     3.293637e+07     3.174377e+07
23     2.396966e+07     2.431776e+07     2.368980e+07     2.544012e+07
24     5.513021e+08     5.593084e+08     5.448654e+08     5.851228e+08

          Means        Totals
0  1.771450e+07  2.733438e+08
1  1.963150e+06  4.312835e+07
```

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```
2   8.351022e+07  7.341391e+08
3   8.419352e+05  1.561825e+06
4   3.713789e+07  1.427990e+08
5   7.200858e+07  7.962276e+08
6   1.639906e+06  1.148767e+07
7   1.784204e+06  6.103562e+06
8   5.072769e+06  2.794710e+07
9   7.241612e+06  6.685832e+07
10  2.493936e+06  1.702756e+07
11  1.389831e+06  1.749102e+06
12  1.725187e+06  1.045748e+07
13  1.687712e+07  1.564348e+08
14  1.923516e+06  1.350388e+07
15  2.389595e+06  1.141659e+07
16  6.216042e+06  6.807960e+07
17  2.454452e+07  4.775541e+07
18  1.305444e+06  1.244551e+07
19  2.571523e+07  1.640298e+08
20  7.632299e+05  1.044769e+07
21  5.943640e+06  2.065826e+07
22  2.113166e+07  1.705858e+08
23  1.484060e+07  1.220951e+08
24  3.413337e+08  2.808188e+09
```

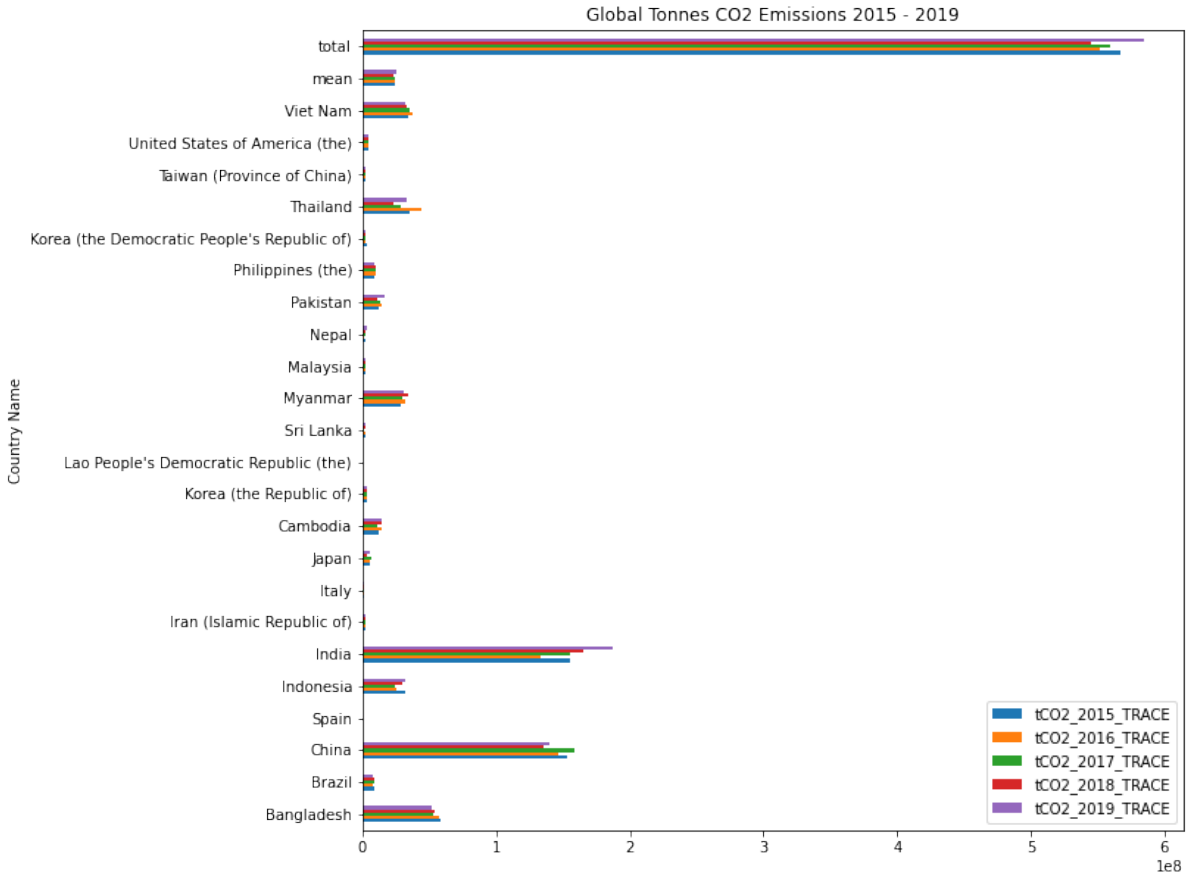
Note: Note a mean of 561,637,600 tonnes CO2equiv produced between annualy 2015 - 2019.

CO2 Data Insights

- Total difference in 3,370,404 tonnes of CO2equiv between the FAOSTAT and TRACE data.
- TRACE reports 2,808,188,000 Tonnes of CO2equiv produced between 2015 to 2019.
- There is a relative percent difference of -2.8 percent.

```
TRACE_CO2_df.plot(kind = "barh", x = 'country_name_TRACE', y = ['tCO2_2015_TRACE',
↪'tCO2_2016_TRACE','tCO2_2017_TRACE','tCO2_2018_TRACE','tCO2_2019_TRACE',], xlabel =
↪"Country Name", ylabel = "Tonnes CO2", title = "Global Tonnes CO2 Emissions 2015 -␣
↪2019", figsize = (10,10))
```

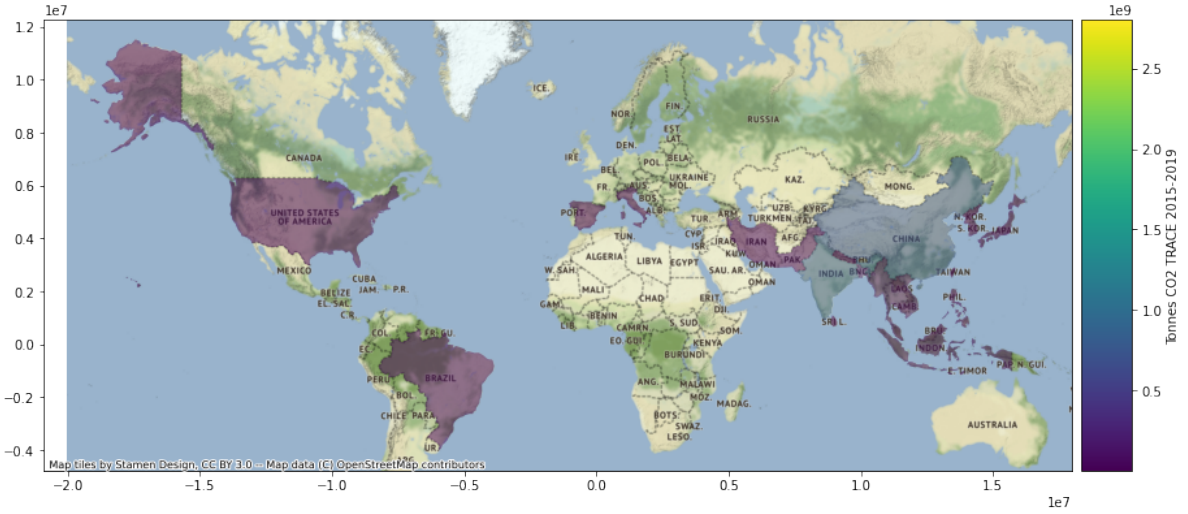
```
<AxesSubplot:title={'center':'Global Tonnes CO2 Emissions 2015 - 2019'}, ylabel=
↪'Country Name'>
```



The Worst Offenders are the Most Dependent on Rice Cultivation

The worst offenders are China, India, and Bangladesh. These states struggle with feeding their massive populations. Including CO2equiv in carbon goals may harm the people of these countries.

```
fig, ax = plt.subplots(1, 1,figsize=(15,15))
divider = make_axes_locatable(ax)
cax = divider.append_axes("right", size="5%", pad=0.1)
merge_map = merge_geo_df.plot(column='Total_CO2_TRACE', ax=ax, legend=True, cax=cax,␣
↪alpha = .5,legend_kwds={'label':  "Tonnes CO2 TRACE 2015-2019",
                         'orientation': "vertical"})
cx.add_basemap(merge_map, zoom=3)
```



Note: Values in billions.

2.5 Conclusions

2.5.1 FAOSTAT Likely Undercounts Emissions

The TRACE data set on average reports about 2.8 percent more methane emissions than the FAOSTAT data set. This equates to a total methane emmissions estimates difference of 3,100,772 tonnes over a 5 year period. The CO2equiv over that same period is 77,519,300 tonnes. Neither value is negligible.

2.5.2 Countries Should Attempt to Reduce Methane Emssions

The 20 and 100 year warming potentials for methane emsission are 84 and 28 (WG1AR5_Chapter08, Pg 73). These factors will impact our climate if nothing is done. Unfortunately, the countries that produce the most methane from rice cultivation are also those most dependent on the grain. To make the change, realistic solutions must be provided to feed people culturally and geographically dependent on rice cultivation.

Part II

Analysis of The University of Malaysia Paper

CHAPTER

THREE

REPLICATING THE UNIVERSITY OF MALYSIA PAPER.

3.1 Imports

```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import scipy.stats as stats
```

3.2 University of Malaysia Data

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/ch4_2015-2021.xlsx"

malaysia_emissions_df = pd.read_excel(filepath)
```

```
# Selecting 2020 columns
malaysia_2020 = malaysia_emissions_df[["iso3_country","country_name", "tCH4_2020"]].
↪copy()
```

```
malaysia_2020
```

	iso3_country	country_name	tCH4_2020
0	BGD	Bangladesh	2.106781e+06
1	BRA	Brazil	4.902874e+05
2	CHN	China	6.402353e+06
3	ESP	Spain	1.305461e+04
4	IDN	Indonesia	1.188195e+06
5	IND	India	7.599764e+06
6	IRN	Iran (Islamic Republic of)	9.600254e+04
7	ITA	Italy	5.101547e+04
8	JPN	Japan	2.835167e+05
9	KHM	Cambodia	6.412802e+05
10	KOR	Korea (the Republic of)	1.165467e+05
11	LAO	Lao People's Democratic Republic (the)	2.136270e+04
12	LKA	Sri Lanka	9.248238e+04
13	MMR	Myanmar	1.221904e+06
14	MYS	Malaysia	1.127141e+05
15	NPL	Nepal	7.168401e+04

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```
16          PAK                                       Pakistan  6.401201e+05
17          PHL                                  Philippines (the)  4.462836e+05
18          PRK  Korea (the Democratic People's Republic of)  8.581038e+04
19          THA                                       Thailand  1.520788e+06
20          TWN                     Taiwan (Province of China)  8.333327e+04
21          USA                  United States of America (the)  1.941455e+05
22          VNM                                       Viet Nam  1.374450e+06
23          NaN                                          Total  2.485387e+07
```

3.3 FAOSTAT Data 2019

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/emissions_csv_fao_emiss_
↪csv_ch4_fao_2015_2019_tonnes.xlsx"

faostat_emissions_df = pd.read_excel(filepath)
```

```
faostat_2019 = faostat_emissions_df[['code', 'country', 'country_fao', 2019]].copy()
```

```
faostat_2019
```

```
   code                                       country  \
0   BGD                                    Bangladesh
1   BRA                                        Brazil
2   CHN                                         China
3   ESP                                         Spain
4   IDN                                     Indonesia
5   IND                                         India
6   IRN                      Iran (Islamic Republic of)
7   ITA                                         Italy
8   JPN                                         Japan
9   KHM                                      Cambodia
10  KOR                          Korea (the Republic of)
11  LAO          Lao People's Democratic Republic (the)
12  LKA                                     Sri Lanka
13  MMR                                       Myanmar
14  MYS                                      Malaysia
15  NPL                                         Nepal
16  PAK                                      Pakistan
17  PHL                                Philippines (the)
18  PRK  Korea (the Democratic People's Republic of)
19  THA                                      Thailand
20  TWN                      Taiwan (Province of China)
21  USA                   United States of America (the)
22  VNM                                      Viet Nam
23  NaN                                           NaN

                            country_fao        2019
0                            Bangladesh   1144745.4
1                                Brazil    111084.8
2                        China, mainland   5214454.7
3                                 Spain     52098.5
```

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```
4                                Indonesia   2257604.3
5                                    India   4621416.8
6                Iran (Islamic Republic of)     96103.4
7                                    Italy    110895.1
8                                    Japan    320581.8
9                                 Cambodia    468378.9
10                       Republic of Korea    153260.9
11       Lao People's Democratic Republic     77005.5
12                               Sri Lanka    102156.3
13                                 Myanmar   1083100.3
14                                Malaysia    122453.8
15                                   Nepal    156215.4
16                                Pakistan    424755.1
17                             Philippines   1556225.8
18  Democratic People's Republic of Korea     82937.0
19                                Thailand   1553835.5
20               China, Taiwan Province of     49152.0
21                United States of America    350136.5
22                                Viet Nam   1318431.1
23                                   Total  23446028.9
```

```
faostat_2019.rename(columns={"code": "iso3_country"}, inplace =True)
```

3.4 Merging Data on Iso3 Country Code

```
merged2020_df = faostat_2019.merge(malaysia_2020, on='iso3_country', how='left',␣
↪sort=False)
```

```
merged2020_df
```

```
   iso3_country                                        country  \
0           BGD                                     Bangladesh
1           BRA                                         Brazil
2           CHN                                          China
3           ESP                                          Spain
4           IDN                                      Indonesia
5           IND                                          India
6           IRN                       Iran (Islamic Republic of)
7           ITA                                          Italy
8           JPN                                          Japan
9           KHM                                       Cambodia
10          KOR                           Korea (the Republic of)
11          LAO         Lao People's Democratic Republic (the)
12          LKA                                      Sri Lanka
13          MMR                                        Myanmar
14          MYS                                       Malaysia
15          NPL                                          Nepal
16          PAK                                       Pakistan
17          PHL                                 Philippines (the)
18          PRK  Korea (the Democratic People's Republic of)
19          THA                                       Thailand
```

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```
20          TWN                     Taiwan (Province of China)
21          USA                United States of America (the)
22          VNM                                     Viet Nam
23          NaN                                          NaN

                              country_fao        2019  \
0                              Bangladesh   1144745.4
1                                  Brazil    111084.8
2                           China, mainland   5214454.7
3                                   Spain     52098.5
4                               Indonesia   2257604.3
5                                   India   4621416.8
6               Iran (Islamic Republic of)     96103.4
7                                   Italy    110895.1
8                                   Japan    320581.8
9                                Cambodia    468378.9
10                      Republic of Korea    153260.9
11       Lao People's Democratic Republic     77005.5
12                             Sri Lanka    102156.3
13                               Myanmar   1083100.3
14                              Malaysia    122453.8
15                                 Nepal    156215.4
16                              Pakistan    424755.1
17                            Philippines   1556225.8
18  Democratic People's Republic of Korea     82937.0
19                              Thailand   1553835.5
20              China, Taiwan Province of     49152.0
21               United States of America    350136.5
22                              Viet Nam   1318431.1
23                                 Total  23446028.9

                                    country_name     tCH4_2020
0                                     Bangladesh  2.106781e+06
1                                         Brazil  4.902874e+05
2                                          China  6.402353e+06
3                                          Spain  1.305461e+04
4                                      Indonesia  1.188195e+06
5                                          India  7.599764e+06
6                        Iran (Islamic Republic of)  9.600254e+04
7                                          Italy  5.101547e+04
8                                          Japan  2.835167e+05
9                                       Cambodia  6.412802e+05
10                         Korea (the Republic of)  1.165467e+05
11       Lao People's Democratic Republic (the)  2.136270e+04
12                                     Sri Lanka  9.248238e+04
13                                       Myanmar  1.221904e+06
14                                      Malaysia  1.127141e+05
15                                         Nepal  7.168401e+04
16                                      Pakistan  6.401201e+05
17                                Philippines (the)  4.462836e+05
18  Korea (the Democratic People's Republic of)  8.581038e+04
19                                      Thailand  1.520788e+06
20                      Taiwan (Province of China)  8.333327e+04
21                  United States of America (the)  1.941455e+05
22                                      Viet Nam  1.374450e+06
23                                         Total  2.485387e+07
```

3.4.1 Calculate difference in Tonnes Between the Estimates

```
# Calculate Difference in tons
merged2020_df['diff_2020'] = merged2020_df[2019] - merged2020_df['tCH4_2020']
```

3.4.2 Calculating the Percent Differences Between the Estimates

```
merged2020_df['abs_percent_diff_2020'] = (abs((merged2020_df[2019] - merged2020_df[
↪'tCH4_2020']))/(merged2020_df[2019] + merged2020_df["tCH4_2020"])/2)*100

merged2020_df['relative_percent_diff_2020'] = (merged2020_df[2019] - merged2020_df[
↪'tCH4_2020'])/(merged2020_df[2019])*100
```

```
merged2020_df
```

```
   iso3_country                                      country  \
0           BGD                                   Bangladesh
1           BRA                                       Brazil
2           CHN                                        China
3           ESP                                        Spain
4           IDN                                    Indonesia
5           IND                                        India
6           IRN                    Iran (Islamic Republic of)
7           ITA                                        Italy
8           JPN                                        Japan
9           KHM                                     Cambodia
10          KOR                         Korea (the Republic of)
11          LAO       Lao People's Democratic Republic (the)
12          LKA                                    Sri Lanka
13          MMR                                      Myanmar
14          MYS                                    Malaysia
15          NPL                                       Nepal
16          PAK                                    Pakistan
17          PHL                              Philippines (the)
18          PRK  Korea (the Democratic People's Republic of)
19          THA                                    Thailand
20          TWN                    Taiwan (Province of China)
21          USA                United States of America (the)
22          VNM                                    Viet Nam
23          NaN                                         NaN

                            country_fao        2019  \
0                            Bangladesh   1144745.4
1                                Brazil    111084.8
2                    China, mainland   5214454.7
3                                 Spain     52098.5
4                             Indonesia   2257604.3
5                                 India   4621416.8
6          Iran (Islamic Republic of)     96103.4
7                                 Italy    110895.1
8                                 Japan    320581.8
9                              Cambodia    468378.9
10                   Republic of Korea    153260.9
```

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```
11       Lao People's Democratic Republic     77005.5
12                             Sri Lanka    102156.3
13                               Myanmar   1083100.3
14                              Malaysia    122453.8
15                                 Nepal    156215.4
16                              Pakistan    424755.1
17                           Philippines   1556225.8
18  Democratic People's Republic of Korea     82937.0
19                              Thailand   1553835.5
20              China, Taiwan Province of     49152.0
21               United States of America    350136.5
22                              Viet Nam   1318431.1
23                                 Total  23446028.9

                                  country_name     tCH4_2020     diff_2020  \
0                                   Bangladesh  2.106781e+06 -9.620360e+05
1                                       Brazil  4.902874e+05 -3.792026e+05
2                                        China  6.402353e+06 -1.187898e+06
3                                        Spain  1.305461e+04  3.904389e+04
4                                    Indonesia  1.188195e+06  1.069409e+06
5                                        India  7.599764e+06 -2.978347e+06
6                    Iran (Islamic Republic of)  9.600254e+04  1.008569e+02
7                                        Italy  5.101547e+04  5.987963e+04
8                                        Japan  2.835167e+05  3.706513e+04
9                                     Cambodia  6.412802e+05 -1.729013e+05
10                       Korea (the Republic of)  1.165467e+05  3.671416e+04
11      Lao People's Democratic Republic (the)  2.136270e+04  5.564280e+04
12                                   Sri Lanka  9.248238e+04  9.673917e+03
13                                     Myanmar  1.221904e+06 -1.388038e+05
14                                    Malaysia  1.127141e+05  9.739707e+03
15                                       Nepal  7.168401e+04  8.453139e+04
16                                    Pakistan  6.401201e+05 -2.153650e+05
17                             Philippines (the)  4.462836e+05  1.109942e+06
18  Korea (the Democratic People's Republic of)  8.581038e+04 -2.873381e+03
19                                    Thailand  1.520788e+06  3.304738e+04
20                    Taiwan (Province of China)  8.333327e+04 -3.418127e+04
21                United States of America (the)  1.941455e+05  1.559910e+05
22                                    Viet Nam  1.374450e+06 -5.601846e+04
23                                       Total  2.485387e+07 -1.407846e+06

    abs_percent_diff_2020  relative_percent_diff_2020
0               14.793604                  -84.039294
1               31.528112                 -341.363191
2                5.112843                  -22.780874
3               29.963187                   74.942454
4               15.517575                   47.369198
5               12.185184                  -64.446615
6                0.026250                    0.104946
7               18.491575                   53.996641
8                3.067805                   11.561831
9                7.790740                  -36.914836
10               6.803765                   23.955330
11              28.282917                   72.258210
12               2.485096                    9.469721
13               3.010923                  -12.815417
14               2.070799                    7.953781
```

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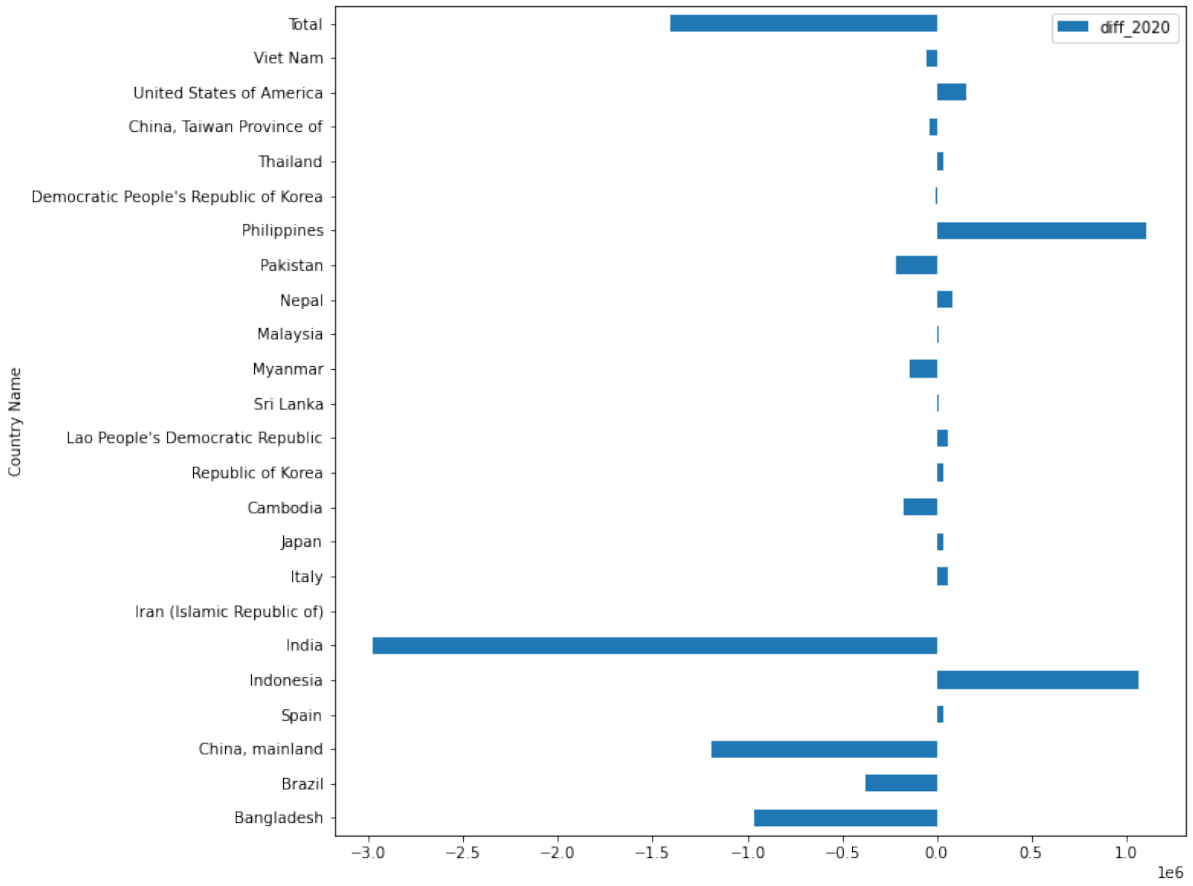
```
15              18.545767                  54.112071
16              10.112219                 -50.703341
17              27.713784                  71.322699
18               0.851385                  -3.464534
19               0.537422                   2.126826
20              12.900027                 -69.541975
21              14.329984                  44.551492
22               1.040122                  -4.248873
23               1.457400                  -6.004623
```

3.4.3 Tonnes CH4 FAOSTAT - TRACE Plot

```
merged2020_df.plot(kind = "barh", x = 'country_fao', y = ["diff_2020"], xlabel =
↪"Country Name", ylabel = "Tonnes CH4", figsize = (10,10))
```

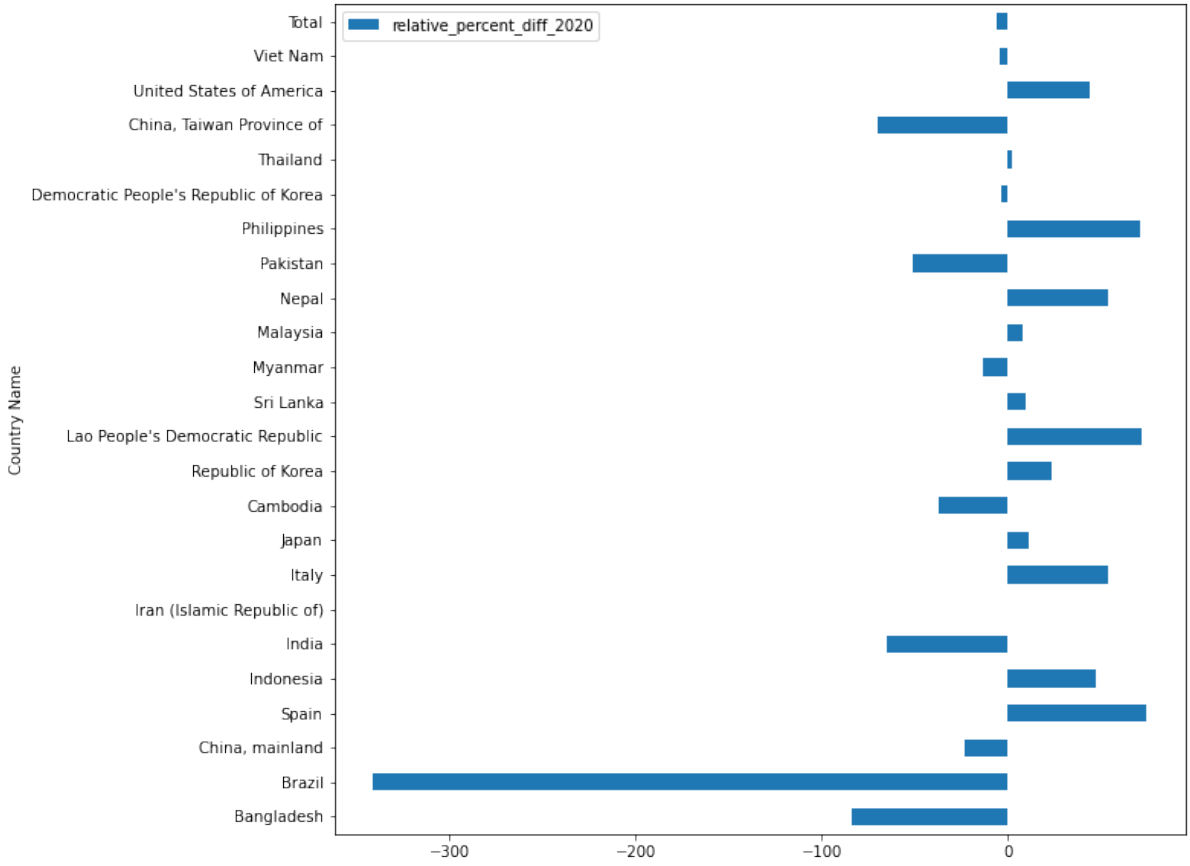
```
<AxesSubplot:ylabel='Country Name'>
```



3.4.4 Percent Difference FAOSTAT - TRACE

```
merged2020_df.plot(kind = "barh", x = 'country_fao', y = ["relative_percent_diff_2020
↪"], xlabel = "Country Name", ylabel = "Tonnes CH4", figsize=(10,10))
```

```
<AxesSubplot:ylabel='Country Name'>
```



3.5 Recreating the Malysia Paper with 2018 Data.

3.5.1 University of Malaysia Data

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/ch4_2015-2021.xlsx"

malaysia_emissions_df = pd.read_excel(filepath)
```

```
# Selecting 2020 columns
malaysia_2020 = malaysia_emissions_df[["iso3_country","country_name", "tCH4_2020"]].
↪copy()
```

```
malaysia_2020
```

	iso3_country	country_name	tCH4_2020
0	BGD	Bangladesh	2.106781e+06
1	BRA	Brazil	4.902874e+05
2	CHN	China	6.402353e+06
3	ESP	Spain	1.305461e+04
4	IDN	Indonesia	1.188195e+06
5	IND	India	7.599764e+06
6	IRN	Iran (Islamic Republic of)	9.600254e+04
7	ITA	Italy	5.101547e+04
8	JPN	Japan	2.835167e+05
9	KHM	Cambodia	6.412802e+05
10	KOR	Korea (the Republic of)	1.165467e+05
11	LAO	Lao People's Democratic Republic (the)	2.136270e+04
12	LKA	Sri Lanka	9.248238e+04
13	MMR	Myanmar	1.221904e+06
14	MYS	Malaysia	1.127141e+05
15	NPL	Nepal	7.168401e+04
16	PAK	Pakistan	6.401201e+05
17	PHL	Philippines (the)	4.462836e+05
18	PRK	Korea (the Democratic People's Republic of)	8.581038e+04
19	THA	Thailand	1.520788e+06
20	TWN	Taiwan (Province of China)	8.333327e+04
21	USA	United States of America (the)	1.941455e+05
22	VNM	Viet Nam	1.374450e+06
23	NaN	Total	2.485387e+07

3.6 FAOSTAT Data 2018

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/emissions_csv_fao_emiss_
↪csv_ch4_fao_2015_2019_tonnes.xlsx"

faostat_emissions_df = pd.read_excel(filepath)
```

```
faostat_2018 = faostat_emissions_df[['code', 'country', 'country_fao', 2018]].copy()
```

```
faostat_2018
```

	code	country	\
0	BGD	Bangladesh	
1	BRA	Brazil	
2	CHN	China	
3	ESP	Spain	
4	IDN	Indonesia	
5	IND	India	
6	IRN	Iran (Islamic Republic of)	
7	ITA	Italy	
8	JPN	Japan	
9	KHM	Cambodia	
10	KOR	Korea (the Republic of)	
11	LAO	Lao People's Democratic Republic (the)	
12	LKA	Sri Lanka	

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```
13  MMR                                        Myanmar
14  MYS                                       Malaysia
15  NPL                                          Nepal
16  PAK                                       Pakistan
17  PHL                                Philippines (the)
18  PRK  Korea (the Democratic People's Republic of)
19  THA                                       Thailand
20  TWN                    Taiwan (Province of China)
21  USA                 United States of America (the)
22  VNM                                       Viet Nam
23  NaN                                            NaN

                              country_fao        2018
0                              Bangladesh   1144591.0
1                                  Brazil    121615.2
2                          China, mainland   5302173.1
3                                   Spain     52925.0
4                                Indonesia   2405613.8
5                                    India   4661154.9
6              Iran (Islamic Republic of)     93936.6
7                                    Italy    109463.8
8                                    Japan    322245.0
9                                 Cambodia    479362.7
10                       Republic of Korea    154911.3
11       Lao People's Democratic Republic     83333.6
12                               Sri Lanka    111049.0
13                                 Myanmar   1118850.0
14                                Malaysia    125238.5
15                                   Nepal    153890.8
16                                Pakistan    393404.2
17                              Philippines   1606047.8
18  Democratic People's Republic of Korea     83943.3
19                                Thailand   1702989.1
20             China, Taiwan Province of     49414.1
21              United States of America    412177.5
22                                Viet Nam   1336231.2
23                                   Total  24042561.5
```

```
faostat_2018.rename(columns={"code": "iso3_country"}, inplace =True)
```

3.6.1 Merging Data on Iso3 Country Code

```
merged2020_df = faostat_2018.merge(malaysia_2020, on='iso3_country', how='left',␣
↪sort=False)
```

```
merged2020_df
```

```
   iso3_country                                    country  \
0           BGD                                 Bangladesh
1           BRA                                     Brazil
2           CHN                                      China
```

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```
3          ESP                                        Spain
4          IDN                                    Indonesia
5          IND                                        India
6          IRN                     Iran (Islamic Republic of)
7          ITA                                        Italy
8          JPN                                        Japan
9          KHM                                     Cambodia
10         KOR                          Korea (the Republic of)
11         LAO       Lao People's Democratic Republic (the)
12         LKA                                    Sri Lanka
13         MMR                                     Myanmar
14         MYS                                    Malaysia
15         NPL                                       Nepal
16         PAK                                    Pakistan
17         PHL                                Philippines (the)
18         PRK  Korea (the Democratic People's Republic of)
19         THA                                    Thailand
20         TWN                     Taiwan (Province of China)
21         USA                 United States of America (the)
22         VNM                                    Viet Nam
23         NaN                                         NaN

                               country_fao        2018  \
0                               Bangladesh   1144591.0
1                                   Brazil    121615.2
2                           China, mainland   5302173.1
3                                    Spain     52925.0
4                                Indonesia   2405613.8
5                                    India   4661154.9
6                Iran (Islamic Republic of)     93936.6
7                                    Italy    109463.8
8                                    Japan    322245.0
9                                 Cambodia    479362.7
10                       Republic of Korea    154911.3
11         Lao People's Democratic Republic     83333.6
12                               Sri Lanka    111049.0
13                                 Myanmar   1118850.0
14                                Malaysia    125238.5
15                                   Nepal    153890.8
16                                Pakistan    393404.2
17                              Philippines   1606047.8
18  Democratic People's Republic of Korea     83943.3
19                                Thailand   1702989.1
20             China, Taiwan Province of     49414.1
21              United States of America    412177.5
22                                Viet Nam   1336231.2
23                                   Total  24042561.5

                                   country_name     tCH4_2020
0                                    Bangladesh  2.106781e+06
1                                        Brazil  4.902874e+05
2                                         China  6.402353e+06
3                                         Spain  1.305461e+04
4                                     Indonesia  1.188195e+06
5                                         India  7.599764e+06
6                       Iran (Islamic Republic of)  9.600254e+04
```

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```
7                                        Italy  5.101547e+04
8                                        Japan  2.835167e+05
9                                     Cambodia  6.412802e+05
10                       Korea (the Republic of)  1.165467e+05
11       Lao People's Democratic Republic (the)  2.136270e+04
12                                    Sri Lanka  9.248238e+04
13                                      Myanmar  1.221904e+06
14                                     Malaysia  1.127141e+05
15                                        Nepal  7.168401e+04
16                                     Pakistan  6.401201e+05
17                             Philippines (the)  4.462836e+05
18  Korea (the Democratic People's Republic of)  8.581038e+04
19                                     Thailand  1.520788e+06
20                   Taiwan (Province of China)  8.333327e+04
21               United States of America (the)  1.941455e+05
22                                     Viet Nam  1.374450e+06
23                                        Total  2.485387e+07
```

3.6.2 Calculate difference in Tonnes Between the Estimates

```
# Calculate Difference in tons
merged2020_df['diff_2020'] = merged2020_df[2018] - merged2020_df['tCH4_2020']
```

3.6.3 Calculating the Percent Differences Between the Estimates

```
merged2020_df['abs_percent_diff_2020'] = (abs((merged2020_df[2018] - merged2020_df[
↪'tCH4_2020']))/(merged2020_df[2018] + merged2020_df["tCH4_2020"])/2)*100

merged2020_df['relative_percent_diff_2020'] = (merged2020_df[2018] - merged2020_df[
↪'tCH4_2020'])/(merged2020_df[2018])*100
```

```
merged2020_df
```

```
   iso3_country                                      country  \
0           BGD                                   Bangladesh
1           BRA                                       Brazil
2           CHN                                        China
3           ESP                                        Spain
4           IDN                                    Indonesia
5           IND                                        India
6           IRN                    Iran (Islamic Republic of)
7           ITA                                        Italy
8           JPN                                        Japan
9           KHM                                     Cambodia
10          KOR                       Korea (the Republic of)
11          LAO       Lao People's Democratic Republic (the)
12          LKA                                    Sri Lanka
13          MMR                                      Myanmar
14          MYS                                     Malaysia
15          NPL                                        Nepal
```

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```
16          PAK                                      Pakistan
17          PHL                                Philippines (the)
18          PRK  Korea (the Democratic People's Republic of)
19          THA                                      Thailand
20          TWN                    Taiwan (Province of China)
21          USA                United States of America (the)
22          VNM                                      Viet Nam
23          NaN                                           NaN

                              country_fao        2018  \
0                              Bangladesh   1144591.0
1                                  Brazil    121615.2
2                          China, mainland   5302173.1
3                                   Spain     52925.0
4                                Indonesia   2405613.8
5                                    India   4661154.9
6               Iran (Islamic Republic of)     93936.6
7                                    Italy    109463.8
8                                    Japan    322245.0
9                                 Cambodia    479362.7
10                       Republic of Korea    154911.3
11       Lao People's Democratic Republic     83333.6
12                              Sri Lanka    111049.0
13                                Myanmar   1118850.0
14                               Malaysia    125238.5
15                                  Nepal    153890.8
16                               Pakistan    393404.2
17                             Philippines   1606047.8
18  Democratic People's Republic of Korea     83943.3
19                               Thailand   1702989.1
20              China, Taiwan Province of     49414.1
21               United States of America    412177.5
22                               Viet Nam   1336231.2
23                                  Total  24042561.5

                                    country_name     tCH4_2020     diff_2020  \
0                                     Bangladesh  2.106781e+06 -9.621904e+05
1                                         Brazil  4.902874e+05 -3.686722e+05
2                                          China  6.402353e+06 -1.100180e+06
3                                          Spain  1.305461e+04  3.987039e+04
4                                       Indonesia  1.188195e+06  1.217419e+06
5                                           India  7.599764e+06 -2.938609e+06
6                         Iran (Islamic Republic of)  9.600254e+04 -2.065943e+03
7                                          Italy  5.101547e+04  5.844833e+04
8                                          Japan  2.835167e+05  3.872833e+04
9                                       Cambodia  6.412802e+05 -1.619175e+05
10                        Korea (the Republic of)  1.165467e+05  3.836456e+04
11       Lao People's Democratic Republic (the)  2.136270e+04  6.197090e+04
12                                     Sri Lanka  9.248238e+04  1.856662e+04
13                                       Myanmar  1.221904e+06 -1.030541e+05
14                                      Malaysia  1.127141e+05  1.252441e+04
15                                         Nepal  7.168401e+04  8.220679e+04
16                                      Pakistan  6.401201e+05 -2.467159e+05
17                                Philippines (the)  4.462836e+05  1.159764e+06
18  Korea (the Democratic People's Republic of)  8.581038e+04 -1.867081e+03
19                                      Thailand  1.520788e+06  1.822010e+05
```

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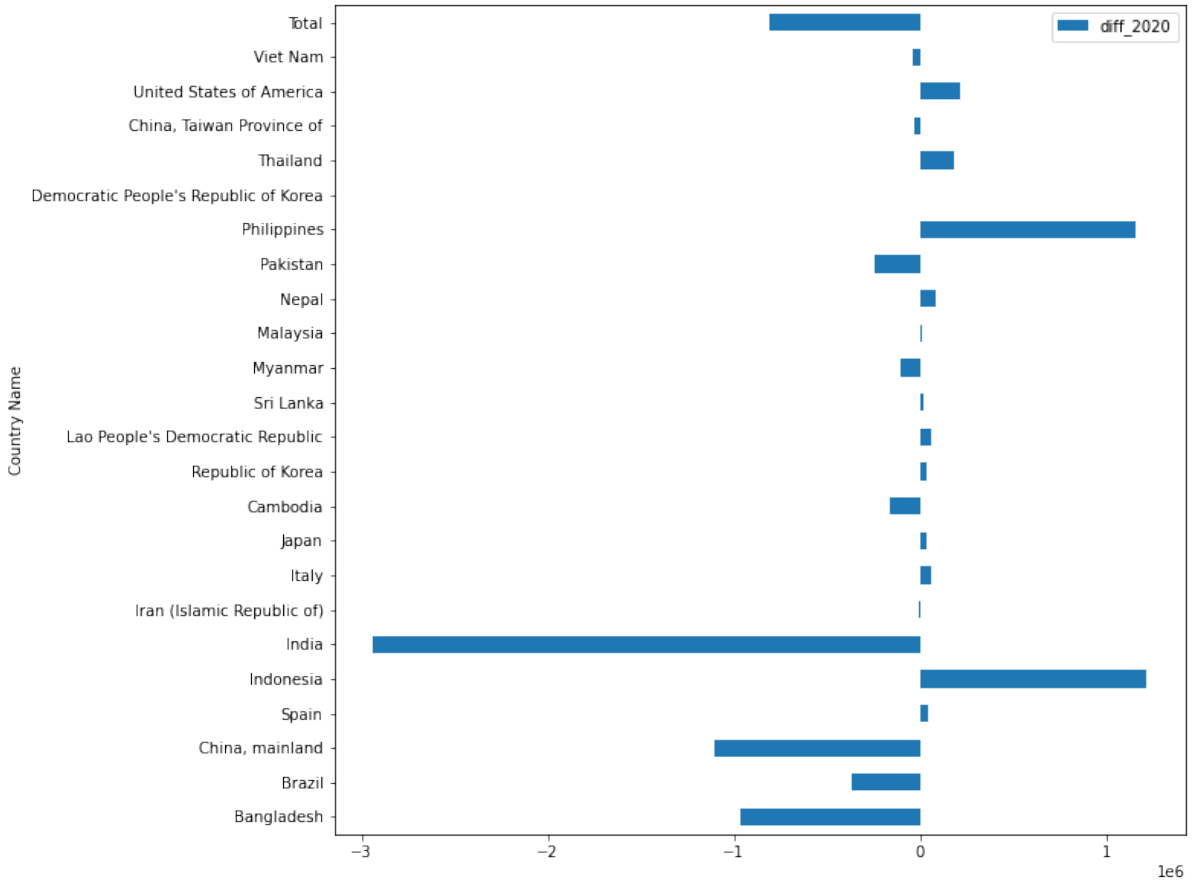
```
20                   Taiwan (Province of China)  8.333327e+04 -3.391917e+04
21                United States of America (the)  1.941455e+05  2.180320e+05
22                                     Viet Nam  1.374450e+06 -3.821836e+04
23                                        Total  2.485387e+07 -8.113131e+05

    abs_percent_diff_2020  relative_percent_diff_2020
0               14.796680                  -84.064120
1               30.125073                 -303.146497
2                4.699806                  -20.749605
3               30.214181                   75.333763
4               16.937719                   50.607398
5               11.983640                  -63.044646
6                0.543843                   -2.199295
7               18.210554                   53.395122
8                3.196664                   12.018286
9                7.224313                  -33.777660
10               7.066388                   24.765498
11              29.595551                   74.364837
12               4.561119                   16.719301
13               2.201302                   -9.210718
14               2.631702                   10.000444
15              18.221624                   53.418910
16              11.935661                  -62.713090
17              28.254800                   72.212312
18               0.549938                   -2.224216
19               2.825893                   10.698893
20              12.775835                  -68.642698
21              17.979860                   52.897608
22               0.704959                   -2.860161
23               0.829624                   -3.374487
```

3.6.4 Tonnes CH4 FAOSTAT - TRACE Plot

```
merged2020_df.plot(kind = "barh", x = 'country_fao', y = ["diff_2020"], xlabel =
↪"Country Name", ylabel = "Tonnes CH4", figsize = (10,10))
```

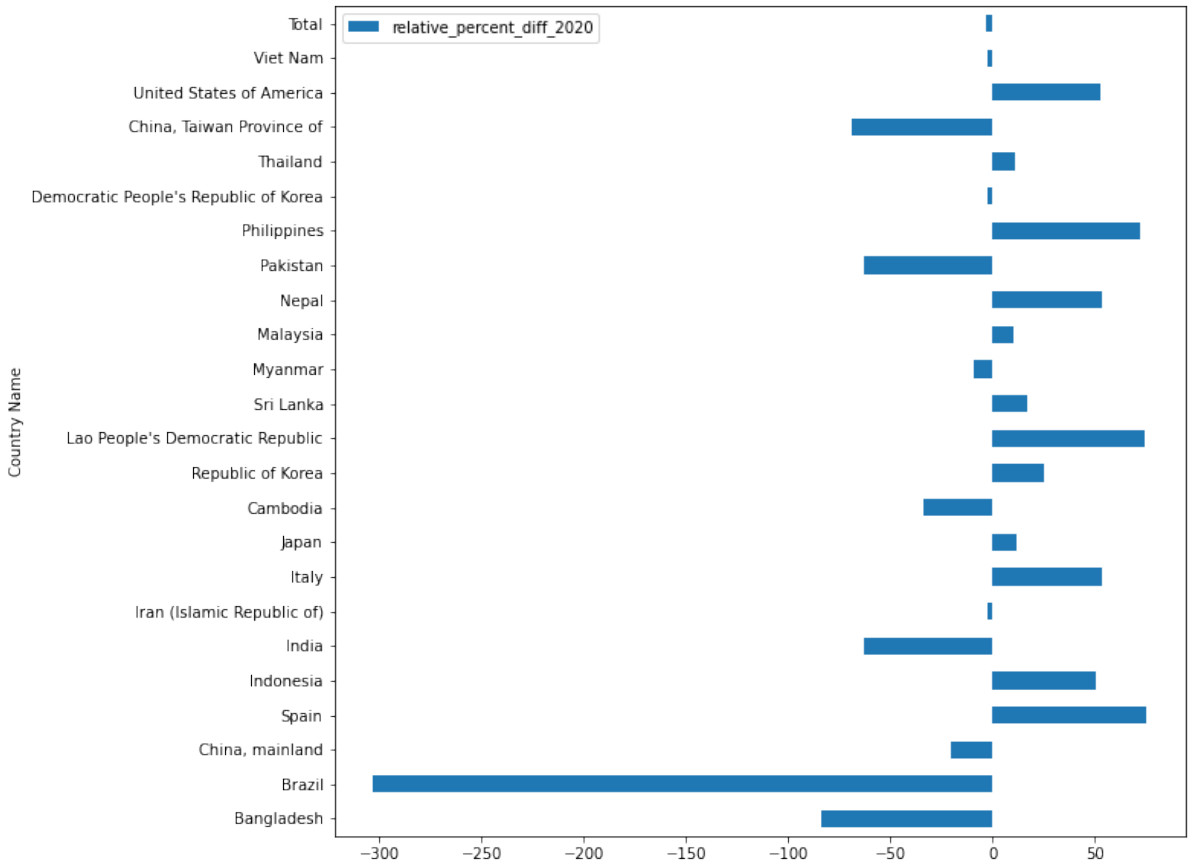
```
<AxesSubplot:ylabel='Country Name'>
```



3.6.5 Percent Difference FAOSTAT - TRACE

```
merged2020_df.plot(kind = "barh", x = 'country_fao', y = ["relative_percent_diff_2020
↪"], xlabel = "Country Name", ylabel = "Tonnes CH4", figsize=(10,10))
```

```
<AxesSubplot:ylabel='Country Name'>
```



3.7 Recreating the Malysia Paper same year

3.7.1 University of Malaysia Data

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/ch4_2015-2021.xlsx"

malaysia_emissions_df = pd.read_excel(filepath)
```

```
# Selecting 2020 columns
malaysia_2018 = malaysia_emissions_df[["iso3_country","country_name", "tCH4_2018"]].
↪copy()
```

```
malaysia_2018
```

	iso3_country	country_name	tCH4_2018
0	BGD	Bangladesh	2.141231e+06
1	BRA	Brazil	3.717030e+05
2	CHN	China	5.413962e+06
3	ESP	Spain	1.405410e+04
4	IDN	Indonesia	1.176982e+06
5	IND	India	6.589798e+06

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```
6           IRN                    Iran (Islamic Republic of)  8.875744e+04
7           ITA                                         Italy  4.469902e+04
8           JPN                                         Japan  1.548252e+05
9           KHM                                      Cambodia  5.592610e+05
10          KOR                          Korea (the Republic of)  1.293543e+05
11          LAO       Lao People's Democratic Republic (the)  1.009675e+04
12          LKA                                     Sri Lanka  9.018914e+04
13          MMR                                       Myanmar  1.372447e+06
14          MYS                                      Malaysia  1.066525e+05
15          NPL                                         Nepal  9.200752e+04
16          PAK                                      Pakistan  4.532297e+05
17          PHL                                Philippines (the)  4.175210e+05
18          PRK  Korea (the Democratic People's Republic of)  8.662578e+04
19          THA                                      Thailand  9.166575e+05
20          TWN                    Taiwan (Province of China)  8.138151e+04
21          USA                United States of America (the)  1.657254e+05
22          VNM                                     Viet Nam  1.317455e+06
23          NaN                                        Total  2.179462e+07
```

3.8 FAOSTAT Data 2018

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/emissions_csv_fao_emiss_
↪csv_ch4_fao_2015_2019_tonnes.xlsx"

faostat_emissions_df = pd.read_excel(filepath)
```

```
faostat_2018 = faostat_emissions_df[['code', 'country', 'country_fao', 2018]].copy()
```

```
faostat_2018
```

```
   code                                      country  \
0   BGD                                   Bangladesh
1   BRA                                       Brazil
2   CHN                                        China
3   ESP                                        Spain
4   IDN                                    Indonesia
5   IND                                        India
6   IRN                    Iran (Islamic Republic of)
7   ITA                                        Italy
8   JPN                                        Japan
9   KHM                                     Cambodia
10  KOR                          Korea (the Republic of)
11  LAO       Lao People's Democratic Republic (the)
12  LKA                                    Sri Lanka
13  MMR                                      Myanmar
14  MYS                                     Malaysia
15  NPL                                        Nepal
16  PAK                                     Pakistan
17  PHL                               Philippines (the)
18  PRK  Korea (the Democratic People's Republic of)
19  THA                                     Thailand
```

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```
20  TWN                    Taiwan (Province of China)
21  USA                United States of America (the)
22  VNM                                     Viet Nam
23  NaN                                          NaN

                              country_fao        2018
0                              Bangladesh   1144591.0
1                                  Brazil    121615.2
2                          China, mainland   5302173.1
3                                   Spain     52925.0
4                               Indonesia   2405613.8
5                                   India   4661154.9
6               Iran (Islamic Republic of)     93936.6
7                                   Italy    109463.8
8                                   Japan    322245.0
9                                Cambodia    479362.7
10                      Republic of Korea    154911.3
11       Lao People's Democratic Republic     83333.6
12                             Sri Lanka    111049.0
13                               Myanmar   1118850.0
14                              Malaysia    125238.5
15                                 Nepal    153890.8
16                              Pakistan    393404.2
17                           Philippines   1606047.8
18  Democratic People's Republic of Korea     83943.3
19                              Thailand   1702989.1
20              China, Taiwan Province of     49414.1
21               United States of America    412177.5
22                              Viet Nam   1336231.2
23                                 Total  24042561.5
```

```
faostat_2018.rename(columns={"code": "iso3_country"}, inplace =True)
```

3.8.1 Merging Data on Iso3 Country Code

```
merged2018_df = faostat_2018.merge(malaysia_2018, on='iso3_country', how='left',␣
↪sort=False)
```

```
merged2018_df
```

```
   iso3_country                                    country  \
0           BGD                                 Bangladesh
1           BRA                                     Brazil
2           CHN                                      China
3           ESP                                      Spain
4           IDN                                  Indonesia
5           IND                                      India
6           IRN                  Iran (Islamic Republic of)
7           ITA                                      Italy
8           JPN                                      Japan
9           KHM                                   Cambodia
```

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```
10          KOR                       Korea (the Republic of)
11          LAO       Lao People's Democratic Republic (the)
12          LKA                                     Sri Lanka
13          MMR                                       Myanmar
14          MYS                                      Malaysia
15          NPL                                         Nepal
16          PAK                                      Pakistan
17          PHL                                Philippines (the)
18          PRK  Korea (the Democratic People's Republic of)
19          THA                                      Thailand
20          TWN                   Taiwan (Province of China)
21          USA               United States of America (the)
22          VNM                                      Viet Nam
23          NaN                                           NaN

                             country_fao        2018  \
0                             Bangladesh   1144591.0
1                                 Brazil    121615.2
2                          China, mainland   5302173.1
3                                  Spain     52925.0
4                              Indonesia   2405613.8
5                                  India   4661154.9
6              Iran (Islamic Republic of)     93936.6
7                                  Italy    109463.8
8                                  Japan    322245.0
9                               Cambodia    479362.7
10                       Republic of Korea    154911.3
11      Lao People's Democratic Republic     83333.6
12                            Sri Lanka    111049.0
13                              Myanmar   1118850.0
14                             Malaysia    125238.5
15                                Nepal    153890.8
16                             Pakistan    393404.2
17                           Philippines   1606047.8
18  Democratic People's Republic of Korea     83943.3
19                             Thailand   1702989.1
20              China, Taiwan Province of     49414.1
21               United States of America    412177.5
22                             Viet Nam   1336231.2
23                                Total  24042561.5

                                  country_name     tCH4_2018
0                                   Bangladesh  2.141231e+06
1                                       Brazil  3.717030e+05
2                                        China  5.413962e+06
3                                        Spain  1.405410e+04
4                                    Indonesia  1.176982e+06
5                                        India  6.589798e+06
6                      Iran (Islamic Republic of)  8.875744e+04
7                                        Italy  4.469902e+04
8                                        Japan  1.548252e+05
9                                     Cambodia  5.592610e+05
10                       Korea (the Republic of)  1.293543e+05
11      Lao People's Democratic Republic (the)  1.009675e+04
12                                   Sri Lanka  9.018914e+04
13                                     Myanmar  1.372447e+06
```

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```
14                                    Malaysia  1.066525e+05
15                                       Nepal  9.200752e+04
16                                    Pakistan  4.532297e+05
17                           Philippines (the)  4.175210e+05
18  Korea (the Democratic People's Republic of)  8.662578e+04
19                                    Thailand  9.166575e+05
20                    Taiwan (Province of China)  8.138151e+04
21                United States of America (the)  1.657254e+05
22                                    Viet Nam  1.317455e+06
23                                       Total  2.179462e+07
```

3.8.2 Calculate difference in Tonnes Between the Estimates

```
# Calculate Difference in tons
merged2018_df['diff_2018'] = merged2018_df[2018] - merged2018_df['tCH4_2018']
```

3.8.3 Calculating the Percent Differences Between the Estimates

```
merged2018_df['abs_percent_diff_2018'] = (abs((merged2018_df[2018] - merged2018_df[
↪'tCH4_2018']))/(merged2018_df[2018] + merged2018_df["tCH4_2018"])/2)*100

merged2018_df['relative_percent_diff_2018'] = (merged2018_df[2018] - merged2018_df[
↪'tCH4_2018'])/(merged2018_df[2018])*100
```

```
merged2018_df
```

```
   iso3_country                                      country  \
0           BGD                                   Bangladesh
1           BRA                                       Brazil
2           CHN                                        China
3           ESP                                        Spain
4           IDN                                    Indonesia
5           IND                                        India
6           IRN                    Iran (Islamic Republic of)
7           ITA                                        Italy
8           JPN                                        Japan
9           KHM                                     Cambodia
10          KOR                         Korea (the Republic of)
11          LAO       Lao People's Democratic Republic (the)
12          LKA                                    Sri Lanka
13          MMR                                      Myanmar
14          MYS                                     Malaysia
15          NPL                                        Nepal
16          PAK                                     Pakistan
17          PHL                               Philippines (the)
18          PRK  Korea (the Democratic People's Republic of)
19          THA                                     Thailand
20          TWN                    Taiwan (Province of China)
21          USA                United States of America (the)
22          VNM                                     Viet Nam
```

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```
23          NaN                                            NaN

                               country_fao        2018  \
0                               Bangladesh   1144591.0
1                                   Brazil    121615.2
2                           China, mainland   5302173.1
3                                    Spain     52925.0
4                                Indonesia   2405613.8
5                                    India   4661154.9
6                Iran (Islamic Republic of)     93936.6
7                                    Italy    109463.8
8                                    Japan    322245.0
9                                 Cambodia    479362.7
10                       Republic of Korea    154911.3
11       Lao People's Democratic Republic     83333.6
12                               Sri Lanka    111049.0
13                                 Myanmar   1118850.0
14                                Malaysia    125238.5
15                                   Nepal    153890.8
16                                Pakistan    393404.2
17                              Philippines   1606047.8
18  Democratic People's Republic of Korea     83943.3
19                                Thailand   1702989.1
20              China, Taiwan Province of     49414.1
21               United States of America    412177.5
22                                Viet Nam   1336231.2
23                                   Total  24042561.5

                                    country_name     tCH4_2018     diff_2018  \
0                                     Bangladesh  2.141231e+06 -9.966395e+05
1                                         Brazil  3.717030e+05 -2.500878e+05
2                                          China  5.413962e+06 -1.117892e+05
3                                          Spain  1.405410e+04  3.887090e+04
4                                       Indonesia  1.176982e+06  1.228632e+06
5                                          India  6.589798e+06 -1.928643e+06
6                        Iran (Islamic Republic of)  8.875744e+04  5.179159e+03
7                                          Italy  4.469902e+04  6.476478e+04
8                                          Japan  1.548252e+05  1.674198e+05
9                                       Cambodia  5.592610e+05 -7.989830e+04
10                         Korea (the Republic of)  1.293543e+05  2.555698e+04
11       Lao People's Democratic Republic (the)  1.009675e+04  7.323685e+04
12                                     Sri Lanka  9.018914e+04  2.085986e+04
13                                       Myanmar  1.372447e+06 -2.535969e+05
14                                      Malaysia  1.066525e+05  1.858597e+04
15                                         Nepal  9.200752e+04  6.188328e+04
16                                      Pakistan  4.532297e+05 -5.982552e+04
17                                Philippines (the)  4.175210e+05  1.188527e+06
18  Korea (the Democratic People's Republic of)  8.662578e+04 -2.682481e+03
19                                      Thailand  9.166575e+05  7.863316e+05
20                      Taiwan (Province of China)  8.138151e+04 -3.196741e+04
21               United States of America (the)  1.657254e+05  2.464521e+05
22                                      Viet Nam  1.317455e+06  1.877621e+04
23                                         Total  2.179462e+07  2.247946e+06

    abs_percent_diff_2018  relative_percent_diff_2018
0               15.165759                  -87.073857
```

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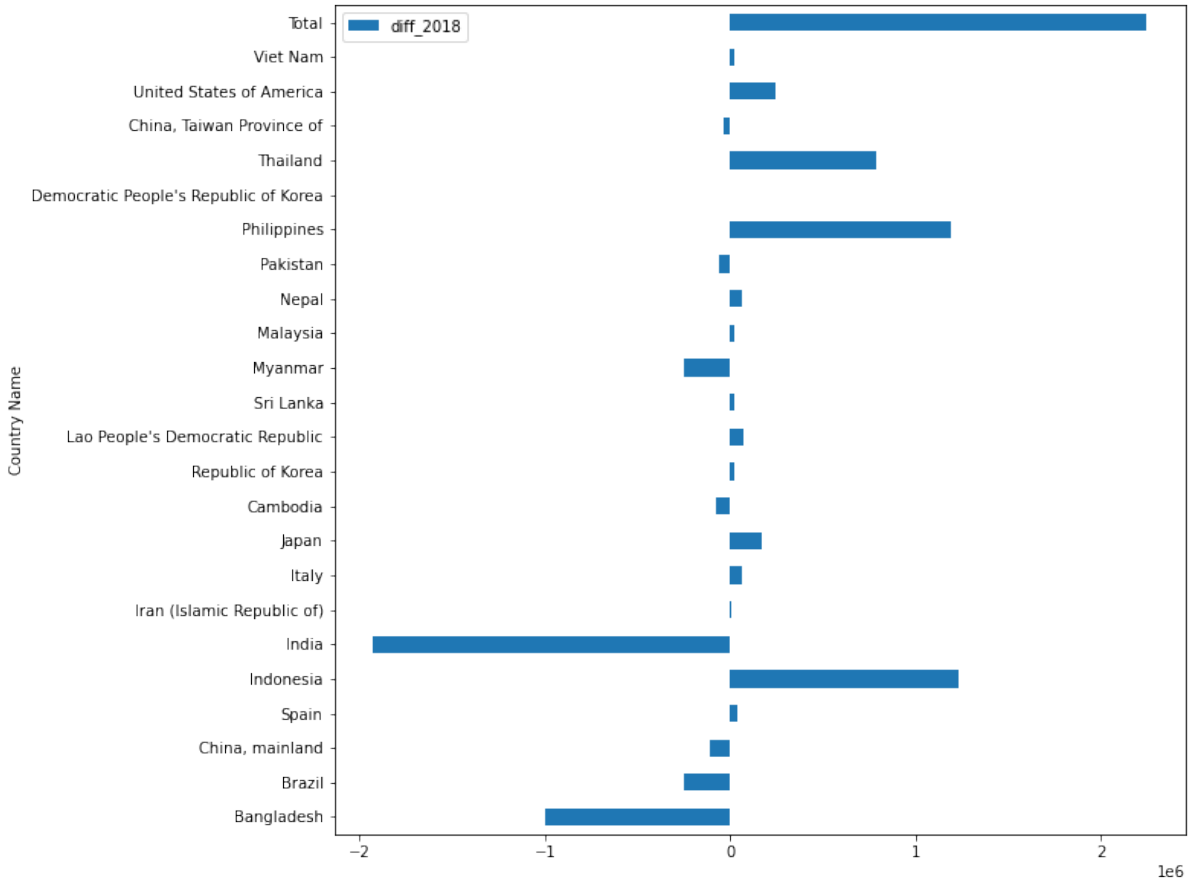
```
1               25.347513               -205.638590
2                0.521593                 -2.108366
3               29.017189                  73.445258
4               17.147238                  51.073546
5                8.571022                 -41.376939
6                1.417441                   5.513463
7               21.005319                  59.165480
8               17.546657                  51.954183
9                3.846355                 -16.667610
10               4.495264                  16.497815
11              39.193291                  87.883944
12               5.182880                  18.784377
13               5.089656                 -22.665852
14               4.007480                  14.840462
15              12.583102                  40.212459
16               3.533140                 -15.207139
17              29.367095                  74.003201
18               0.786333                  -3.195586
19              15.008352                  46.173612
20              12.220368                 -64.692890
21              21.322962                  59.792699
22               0.353776                   1.405162
23               2.452099                   9.349861
```

3.8.4 Tonnes CH4 FAOSTAT - TRACE Plot

```
merged2018_df.plot(kind = "barh", x = 'country_fao', y = ["diff_2018"], xlabel =
↪"Country Name", ylabel = "Tonnes CH4", figsize = (10,10))
```

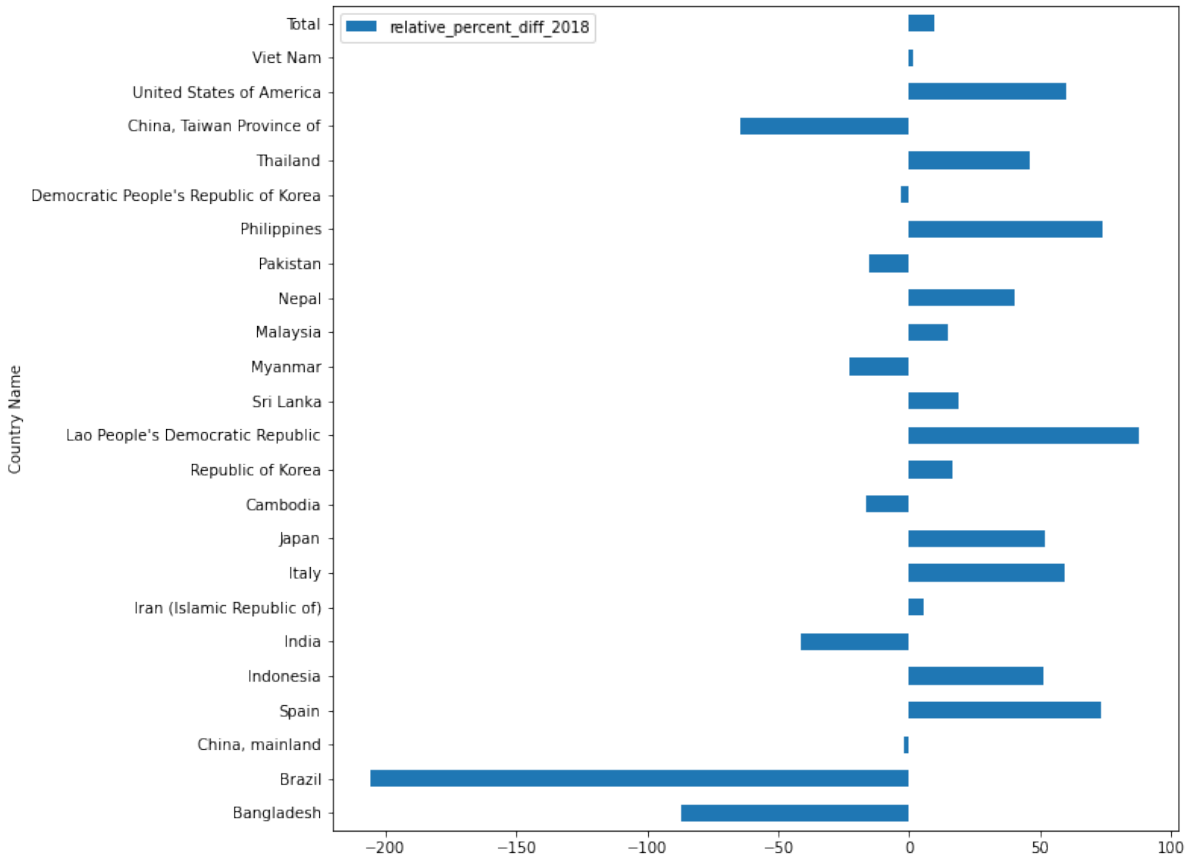
```
<AxesSubplot:ylabel='Country Name'>
```



3.8.5 Percent Difference FAOSTAT - TRACE

```
merged2018_df.plot(kind = "barh", x = 'country_fao', y = ["relative_percent_diff_2018
↪"], xlabel = "Country Name", ylabel = "Tonnes CH4", figsize=(10,10))
```

```
<AxesSubplot:ylabel='Country Name'>
```



3.9 Impressions

I was not able to replicate the results exactly. I reviewed the included paper to find that the university misleadingly rounded to three decimal places. I did not manipulate the raw data.

I found that the overall difference in reporting is only about 6 percent between 2019 and 2020. The methodology is somewhat misleading as well, because when considering the previous 5 years of data demonstrated a consistent 3 percent difference. When comparing the TRACE data to itself it does seem to show a significant increase between 2019 and 2020 emissions. I'll test this next.

CHAPTER

FOUR

HYPOTHESIS TESTING THE UNIVERSITY OF MALAYSIA PAPER

4.1 Claims

- That the distributions do not differ between 2020 and 2019
- That the means do no differ between 2020 and 2019

4.2 What will be testing.

- That the Data are independent and evenly distributed: Test for normality
  - Shapiro-Wilk Test
- That the means between 2019 and 2020 do not differ: Parametric Statistical Hypothesis Tests
  - T Test because we have less than 25 observations
- If nonparametirc: That the distributions between 2019 and 2020 do not differ Mann-Whitney U Test

4.3 Data Import

```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import scipy.stats as stats
```

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/ch4_2015-2021.xlsx"

hypothesis_testing_df = pd.read_excel(filepath)
```

4.3.1 Drop total row from the data

```
hypothesis_testing_df = hypothesis_testing_df.loc[(hypothesis_testing_df['country_name
↪'] != "Total")].copy() #copying to avoid modifying slices in memory.  Old df should␣
↪also drop from memory in production environment.
```

```
hypothesis_testing_df
```

	iso3_country	country_name	tCH4_2015	tCH4_2016	tCH4_2017	tCH4_2018	tCH4_2019	tCH4_2020
0	BGD	Bangladesh	2.344420e+06	2.278158e+06	2.098958e+06	2.141231e+06	2.070985e+06	2.106781e+06
1	BRA	Brazil	3.410233e+05	3.104189e+05	3.725173e+05	3.717030e+05	3.294713e+05	4.902874e+05
2	CHN	China	6.133647e+06	5.859531e+06	6.355071e+06	5.413962e+06	5.603352e+06	6.402353e+06
3	ESP	Spain	1.141464e+04	1.334803e+04	1.217299e+04	1.405410e+04	1.148324e+04	1.305461e+04
4	IDN	Indonesia	1.283649e+06	1.023129e+06	9.615327e+05	1.176982e+06	1.266668e+06	1.188195e+06
5	IND	India	6.219887e+06	5.309413e+06	6.228451e+06	6.589798e+06	7.501556e+06	7.599764e+06
6	IRN	Iran (Islamic Republic of)	8.774407e+04	9.180121e+04	9.620217e+04	8.875744e+04	9.500199e+04	9.600254e+04
7	ITA	Italy	4.995968e+04	4.937785e+04	5.443679e+04	4.469902e+04	4.566914e+04	5.101547e+04
8	JPN	Japan	2.305465e+05	2.284133e+05	2.708935e+05	1.548252e+05	2.332056e+05	2.835167e+05
9	KHM	Cambodia	4.954698e+05	5.731698e+05	4.517045e+05	5.592610e+05	5.947277e+05	6.412802e+05
10	KOR	Korea (the Republic of)	1.451878e+05	1.274597e+05	1.463222e+05	1.293543e+05	1.327782e+05	1.165467e+05
11	LAO	Lao People's Democratic Republic (the)	1.661169e+04	1.696441e+04	1.168063e+04	1.009675e+04	1.461058e+04	2.136270e+04
12	LKA	Sri Lanka	8.305626e+04	1.011743e+05	5.911841e+04	9.018914e+04	8.476088e+04	9.248238e+04
13	MMR	Myanmar	1.132082e+06	1.290806e+06	1.205169e+06	1.372447e+06	1.256888e+06	1.221904e+06
14	MYS	Malaysia	1.057399e+05	1.110049e+05	1.111291e+05	1.066525e+05	1.056287e+05	1.127141e+05
15	NPL	Nepal	1.007479e+05	6.667161e+04	8.081300e+04	9.200752e+04	1.164235e+05	7.168401e+04
16	PAK	Pakistan	4.852431e+05	5.945922e+05	5.372641e+05	4.532297e+05	6.528548e+05	6.401201e+05
17	PHL	Philippines (the)	3.432021e+05	4.073554e+05	3.836830e+05	4.175210e+05	3.584550e+05	4.462836e+05
18	PRK	Korea (the Democratic People's Republic of)	1.143217e+05	9.177653e+04	1.085457e+05	8.662578e+04	9.655062e+04	8.581038e+04
19	THA	Thailand	1.393798e+06	1.780993e+06	1.164699e+06	9.166575e+05	1.305046e+06	1.520788e+06
20	TWN	Taiwan (Province of China)	7.866956e+04	8.089149e+04	8.705634e+04	8.138151e+04	8.990870e+04	8.333327e+04
21	USA	United States of America (the)	1.611324e+05	1.618576e+05	1.684799e+05	1.657254e+05	1.691351e+05	1.941455e+05
22	VNM	Viet Nam	1.346013e+06					

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```
22  1.483777e+06  1.406437e+06  1.317455e+06  1.269751e+06  1.374450e+06

       tCH4_2021
0   1.983974e+06
1   4.544874e+05
2   6.068210e+06
3   8.531579e+03
4   1.009936e+06
5   6.567960e+06
6   9.053525e+04
7   5.089759e+04
8   1.574007e+05
9   5.644891e+05
10  1.013006e+05
11  1.475014e+04
12  8.466966e+04
13  1.289837e+06
14  1.069696e+05
15  4.811408e+04
16  4.849205e+05
17  4.383270e+05
18  7.735988e+04
19  8.528673e+05
20  6.619861e+04
21  1.634842e+05
22  1.502787e+06
```

4.3.2 Test for Normality: Shapiro-Wilk

2019

```
## Selecting Malaysia 2019 Data
data_2019 = hypothesis_testing_df['tCH4_2019']
data_2019
```

```
0     2.070985e+06
1     3.294713e+05
2     5.603352e+06
3     1.148324e+04
4     1.266668e+06
5     7.501556e+06
6     9.500199e+04
7     4.566914e+04
8     2.332056e+05
9     5.947277e+05
10    1.327782e+05
11    1.461058e+04
12    8.476088e+04
13    1.256888e+06
14    1.056287e+05
15    1.164235e+05
16    6.528548e+05
17    3.584550e+05
```

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```
18    9.655062e+04
19    1.305046e+06
20    8.990870e+04
21    1.691351e+05
22    1.269751e+06
Name: tCH4_2019, dtype: float64
```

```
results = stats.shapiro(data_2019)
print('stat=%.3f, p=%.3f' % (results.statistic, results.pvalue))
if results.pvalue > 0.05:
        print('Probably Gaussian')
else:
        print('Probably not Gaussian')
```

```
stat=0.567, p=0.000
Probably not Gaussian
```

Results

The distribution is not gausian so a non-paremtric test must be completed. It is not necessary to perform this test on the 2020 data, but I will do so anyways for practice.

2020

```
## Selecting the Malaysia Data 2020
data_2020 = hypothesis_testing_df['tCH4_2020']
```

```
results = stats.shapiro(data_2020)
print('stat=%.3f, p=%.3f' % (results.statistic, results.pvalue))
if results.pvalue > 0.05:
        print('Probably Gaussian')
else:
        print('Probably not Gaussian')
```

```
stat=0.565, p=0.000
Probably not Gaussian
```

Results

The 2020 data is not gausian which verifies that we will need to perform a non parmetric test

4.3.3 Independence of Samples.

We have to assume that the samples are independent of each other as we know they are dependent on hecatares.Though the correlations are rather high this is due to the smiliarity of hectares per year. Thus the amount of ch4 is similiar

4.3.4 Distribution Similiarity

Mann-Whitney U Test

```
# Example of the Mann-Whitney U Test

stat, p = stats.mannwhitneyu(data_2019, data_2020)
print('stat=%.3f, p=%.3f' % (stat, p))
if p > 0.05:
        print('Probably the same distribution')
else:
        print('Probably different distributions')
```

```
stat=266.000, p=0.982
Probably the same distribution
```

4.3.5 Kruskal Wallis test

```
stat, p = stats.kruskal(data_2019, data_2020)
print('stat=%.3f, p=%.3f' % (stat, p))
if p > 0.05:
        print('Probably the same distribution')
else:
        print('Probably different distributions')
```

```
stat=0.001, p=0.974
Probably the same distribution
```

4.3.6 Friedman Test

Just for the sake of it I will compare data across all distributions

```
# Example of the Friedman Test
#data_2014 = hypothesis_testing_df['tCH4_2014']
data_2015 = hypothesis_testing_df['tCH4_2015']
data_2016 = hypothesis_testing_df['tCH4_2016']
data_2017 = hypothesis_testing_df['tCH4_2017']
data_2018 = hypothesis_testing_df['tCH4_2018']

stat, p = stats.friedmanchisquare(data_2015, data_2016, data_2017, data_2018, data_
↪2019, data_2020)
print('stat=%.3f, p=%.3f' % (stat, p))
if p > 0.05:
        print('Probably the same distribution')
```

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```
else:
        print('Probably different distributions')
```

```
stat=11.472, p=0.043
Probably different distributions
```

Results.

Some distributions differ from one another. Which those are have yet to be discovered. For the sake of this analysis I will not attempt to identify them.

The statment that the distributions of the 2019 and 2020 data do not differ cannot differ. That said we also cannot claim that the means are statistically equivalent as the data is not parametric.

Part III

Data Exploration

CHAPTER

FIVE

EMISSIONS ESTIMATION DATA: A COMPARISON BETWEEN FAOSTAT AND UNIVERSITY OF MALYSIA ESTIMATES

5.1 Import

```
import pandas as pd
import matplotlib.pyplot as plt
import geopandas as gpd
import folium
import contextily as cx
from shapely.geometry import Point, LineString, Polygon
import numpy as np
from scipy.spatial import cKDTree
from geopy.distance import distance
import scipy.stats as stats
```

```
/Users/jnapolitano/venvs/finance/lib/python3.9/site-packages/geopandas/_compat.
↪py:111: UserWarning: The Shapely GEOS version (3.10.2-CAPI-1.16.0) is␣
↪incompatible with the GEOS version PyGEOS was compiled with (3.10.1-CAPI-1.16.0).
↪ Conversions between both will be slow.
  warnings.warn(
```

5.1.1 Dependencies

- Geopandas
- pandas
- openpyxl

5.2 Exploration Plan

5.2.1 Data Imports

- /Users/jnapolitano/Projects/wattime-takehome/data/ch4_2015-2021.xlsx
- /Users/jnapolitano/Projects/wattime-takehome/data/emissions_csv_fao_emiss_csv_ch4_fao_2015_2019_tonnes.xlsx

5.2.2 Import Data Frames

Since jupyter caches the data to the notebook json I can import the dataframes that I will be using together.

If I were to build automated scripts to perform the analysis I would only load the data necessary to perform a process.

5.2.3 Experiment with Plots for each Set

I don't know exactly which plots I want to include in the final report.

I 'll plot a few for each data set

5.2.4 Calculate differences between the datasets

- create a differences data frame
- write to file for use
- plot

5.3 University of Malaysia Emission Estimates

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/ch4_2015-2021.xlsx"

malaysia_emissions_df = pd.read_excel(filepath)
```

5.3.1 Print Df Head

```
malaysia_emissions_df
```

```
   iso3_country                                country_name     tCH4_2015  \
0           BGD                                  Bangladesh  2.344420e+06
1           BRA                                      Brazil  3.410233e+05
2           CHN                                       China  6.133647e+06
3           ESP                                       Spain  1.141464e+04
4           IDN                                   Indonesia  1.283649e+06
5           IND                                       India  6.219887e+06
6           IRN                Iran (Islamic Republic of)  8.774407e+04
7           ITA                                       Italy  4.995968e+04
8           JPN                                       Japan  2.305465e+05
9           KHM                                    Cambodia  4.954698e+05
10          KOR                      Korea (the Republic of)  1.451878e+05
11          LAO       Lao People's Democratic Republic (the)  1.661169e+04
12          LKA                                   Sri Lanka  8.305626e+04
13          MMR                                     Myanmar  1.132082e+06
14          MYS                                    Malaysia  1.057399e+05
15          NPL                                       Nepal  1.007479e+05
16          PAK                                    Pakistan  4.852431e+05
17          PHL                          Philippines (the)  3.432021e+05
18          PRK  Korea (the Democratic People's Republic of)  1.143217e+05
```

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```
19          THA                                       Thailand  1.393798e+06
20          TWN                    Taiwan (Province of China)  7.866956e+04
21          USA                 United States of America (the)  1.611324e+05
22          VNM                                       Viet Nam  1.346013e+06
23          NaN                                          Total  2.270357e+07

       tCH4_2016     tCH4_2017     tCH4_2018     tCH4_2019     tCH4_2020  \
0   2.278158e+06  2.098958e+06  2.141231e+06  2.070985e+06  2.106781e+06
1   3.104189e+05  3.725173e+05  3.717030e+05  3.294713e+05  4.902874e+05
2   5.859531e+06  6.355071e+06  5.413962e+06  5.603352e+06  6.402353e+06
3   1.334803e+04  1.217299e+04  1.405410e+04  1.148324e+04  1.305461e+04
4   1.023129e+06  9.615327e+05  1.176982e+06  1.266668e+06  1.188195e+06
5   5.309413e+06  6.228451e+06  6.589798e+06  7.501556e+06  7.599764e+06
6   9.180121e+04  9.620217e+04  8.875744e+04  9.500199e+04  9.600254e+04
7   4.937785e+04  5.443679e+04  4.469902e+04  4.566914e+04  5.101547e+04
8   2.284133e+05  2.708935e+05  1.548252e+05  2.332056e+05  2.835167e+05
9   5.731698e+05  4.517045e+05  5.592610e+05  5.947277e+05  6.412802e+05
10  1.274597e+05  1.463222e+05  1.293543e+05  1.327782e+05  1.165467e+05
11  1.696441e+04  1.168063e+04  1.009675e+04  1.461058e+04  2.136270e+04
12  1.011743e+05  5.911841e+04  9.018914e+04  8.476088e+04  9.248238e+04
13  1.290806e+06  1.205169e+06  1.372447e+06  1.256888e+06  1.221904e+06
14  1.110049e+05  1.111291e+05  1.066525e+05  1.056287e+05  1.127141e+05
15  6.667161e+04  8.081300e+04  9.200752e+04  1.164235e+05  7.168401e+04
16  5.945922e+05  5.372641e+05  4.532297e+05  6.528548e+05  6.401201e+05
17  4.073554e+05  3.836830e+05  4.175210e+05  3.584550e+05  4.462836e+05
18  9.177653e+04  1.085457e+05  8.662578e+04  9.655062e+04  8.581038e+04
19  1.780993e+06  1.164699e+06  9.166575e+05  1.305046e+06  1.520788e+06
20  8.089149e+04  8.705634e+04  8.138151e+04  8.990870e+04  8.333327e+04
21  1.618576e+05  1.684799e+05  1.657254e+05  1.691351e+05  1.941455e+05
22  1.483777e+06  1.406437e+06  1.317455e+06  1.269751e+06  1.374450e+06
23  2.205208e+07  2.237234e+07  2.179462e+07  2.340491e+07  2.485387e+07

       tCH4_2021
0   1.983974e+06
1   4.544874e+05
2   6.068210e+06
3   8.531579e+03
4   1.009936e+06
5   6.567960e+06
6   9.053525e+04
7   5.089759e+04
8   1.574007e+05
9   5.644891e+05
10  1.013006e+05
11  1.475014e+04
12  8.466966e+04
13  1.289837e+06
14  1.069696e+05
15  4.811408e+04
16  4.849205e+05
17  4.383270e+05
18  7.735988e+04
19  8.528673e+05
20  6.619861e+04
21  1.634842e+05
22  1.502787e+06
23  2.218801e+07
```

5.3.2 Calculate Co2 Equivalency

```
malaysia_emissions_df['tCO2_2015'] = (malaysia_emissions_df['tCH4_2015'] * 25)
malaysia_emissions_df['tCO2_2016'] = (malaysia_emissions_df['tCH4_2016'] * 25)
malaysia_emissions_df['tCO2_2017'] = (malaysia_emissions_df['tCH4_2017'] * 25)
malaysia_emissions_df['tCO2_2018'] = (malaysia_emissions_df['tCH4_2018'] * 25)
malaysia_emissions_df['tCO2_2019'] = (malaysia_emissions_df['tCH4_2019'] * 25)
```

5.3.3 Calculate Means

```
malaysia_emissions_df.loc['mean'] = malaysia_emissions_df.loc[(malaysia_emissions_df[
↪'country_name'] != "Total")].select_dtypes(np.number).mean()
malaysia_emissions_df.at['mean','country_name'] = 'mean'
malaysia_emissions_df
```

	iso3_country	country_name	tCH4_2015	\
0	BGD	Bangladesh	2.344420e+06	
1	BRA	Brazil	3.410233e+05	
2	CHN	China	6.133647e+06	
3	ESP	Spain	1.141464e+04	
4	IDN	Indonesia	1.283649e+06	
5	IND	India	6.219887e+06	
6	IRN	Iran (Islamic Republic of)	8.774407e+04	
7	ITA	Italy	4.995968e+04	
8	JPN	Japan	2.305465e+05	
9	KHM	Cambodia	4.954698e+05	
10	KOR	Korea (the Republic of)	1.451878e+05	
11	LAO	Lao People's Democratic Republic (the)	1.661169e+04	
12	LKA	Sri Lanka	8.305626e+04	
13	MMR	Myanmar	1.132082e+06	
14	MYS	Malaysia	1.057399e+05	
15	NPL	Nepal	1.007479e+05	
16	PAK	Pakistan	4.852431e+05	
17	PHL	Philippines (the)	3.432021e+05	
18	PRK	Korea (the Democratic People's Republic of)	1.143217e+05	
19	THA	Thailand	1.393798e+06	
20	TWN	Taiwan (Province of China)	7.866956e+04	
21	USA	United States of America (the)	1.611324e+05	
22	VNM	Viet Nam	1.346013e+06	
23	NaN	Total	2.270357e+07	
mean	NaN	mean	9.871116e+05	

	tCH4_2016	tCH4_2017	tCH4_2018	tCH4_2019	tCH4_2020	\
0	2.278158e+06	2.098958e+06	2.141231e+06	2.070985e+06	2.106781e+06	
1	3.104189e+05	3.725173e+05	3.717030e+05	3.294713e+05	4.902874e+05	
2	5.859531e+06	6.355071e+06	5.413962e+06	5.603352e+06	6.402353e+06	
3	1.334803e+04	1.217299e+04	1.405410e+04	1.148324e+04	1.305461e+04	
4	1.023129e+06	9.615327e+05	1.176982e+06	1.266668e+06	1.188195e+06	
5	5.309413e+06	6.228451e+06	6.589798e+06	7.501556e+06	7.599764e+06	
6	9.180121e+04	9.620217e+04	8.875744e+04	9.500199e+04	9.600254e+04	
7	4.937785e+04	5.443679e+04	4.469902e+04	4.566914e+04	5.101547e+04	
8	2.284133e+05	2.708935e+05	1.548252e+05	2.332056e+05	2.835167e+05	
9	5.731698e+05	4.517045e+05	5.592610e+05	5.947277e+05	6.412802e+05	
10	1.274597e+05	1.463222e+05	1.293543e+05	1.327782e+05	1.165467e+05	

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```
11    1.696441e+04  1.168063e+04  1.009675e+04  1.461058e+04  2.136270e+04
12    1.011743e+05  5.911841e+04  9.018914e+04  8.476088e+04  9.248238e+04
13    1.290806e+06  1.205169e+06  1.372447e+06  1.256888e+06  1.221904e+06
14    1.110049e+05  1.111291e+05  1.066525e+05  1.056287e+05  1.127141e+05
15    6.667161e+04  8.081300e+04  9.200752e+04  1.164235e+05  7.168401e+04
16    5.945922e+05  5.372641e+05  4.532297e+05  6.528548e+05  6.401201e+05
17    4.073554e+05  3.836830e+05  4.175210e+05  3.584550e+05  4.462836e+05
18    9.177653e+04  1.085457e+05  8.662578e+04  9.655062e+04  8.581038e+04
19    1.780993e+06  1.164699e+06  9.166575e+05  1.305046e+06  1.520788e+06
20    8.089149e+04  8.705634e+04  8.138151e+04  8.990870e+04  8.333327e+04
21    1.618576e+05  1.684799e+05  1.657254e+05  1.691351e+05  1.941455e+05
22    1.483777e+06  1.406437e+06  1.317455e+06  1.269751e+06  1.374450e+06
23    2.205208e+07  2.237234e+07  2.179462e+07  2.340491e+07  2.485387e+07
mean  9.587863e+05  9.727103e+05  9.475920e+05  1.017605e+06  1.080603e+06

         tCH4_2021     tCO2_2015     tCO2_2016     tCO2_2017     tCO2_2018  \
0     1.983974e+06  5.861049e+07  5.695395e+07  5.247394e+07  5.353076e+07
1     4.544874e+05  8.525583e+06  7.760473e+06  9.312934e+06  9.292575e+06
2     6.068210e+06  1.533412e+08  1.464883e+08  1.588768e+08  1.353491e+08
3     8.531579e+03  2.853661e+05  3.337007e+05  3.043248e+05  3.513524e+05
4     1.009936e+06  3.209122e+07  2.557824e+07  2.403832e+07  2.942454e+07
5     6.567960e+06  1.554972e+08  1.327353e+08  1.557113e+08  1.647450e+08
6     9.053525e+04  2.193602e+06  2.295030e+06  2.405054e+06  2.218936e+06
7     5.089759e+04  1.248992e+06  1.234446e+06  1.360920e+06  1.117475e+06
8     1.574007e+05  5.763662e+06  5.710333e+06  6.772337e+06  3.870631e+06
9     5.644891e+05  1.238675e+07  1.432925e+07  1.129261e+07  1.398153e+07
10    1.013006e+05  3.629695e+06  3.186493e+06  3.658056e+06  3.233858e+06
11    1.475014e+04  4.152924e+05  4.241102e+05  2.920158e+05  2.524186e+05
12    8.466966e+04  2.076407e+06  2.529358e+06  1.477960e+06  2.254728e+06
13    1.289837e+06  2.830206e+07  3.227014e+07  3.012923e+07  3.431117e+07
14    1.069696e+05  2.643498e+06  2.775123e+06  2.778227e+06  2.666313e+06
15    4.811408e+04  2.518697e+06  1.666790e+06  2.020325e+06  2.300188e+06
16    4.849205e+05  1.213108e+07  1.486480e+07  1.343160e+07  1.133074e+07
17    4.383270e+05  8.580052e+06  1.018389e+07  9.592074e+06  1.043803e+07
18    7.735988e+04  2.858041e+06  2.294413e+06  2.713641e+06  2.165645e+06
19    8.528673e+05  3.484495e+07  4.452483e+07  2.911748e+07  2.291644e+07
20    6.619861e+04  1.966739e+06  2.022287e+06  2.176408e+06  2.034538e+06
21    1.634842e+05  4.028310e+06  4.046440e+06  4.211999e+06  4.143136e+06
22    1.502787e+06  3.365033e+07  3.709441e+07  3.516092e+07  3.293637e+07
23    2.218801e+07  5.675891e+08  5.513021e+08  5.593084e+08  5.448654e+08
mean  9.646959e+05  2.467779e+07  2.396966e+07  2.431776e+07  2.368980e+07

         tCO2_2019
0     5.177463e+07
1     8.236783e+06
2     1.400838e+08
3     2.870810e+05
4     3.166670e+07
5     1.875389e+08
6     2.375050e+06
7     1.141729e+06
8     5.830141e+06
9     1.486819e+07
10    3.319455e+06
11    3.652645e+05
12    2.119022e+06
```

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```
13    3.142221e+07
14    2.640717e+06
15    2.910588e+06
16    1.632137e+07
17    8.961374e+06
18    2.413765e+06
19    3.262615e+07
20    2.247717e+06
21    4.228377e+06
22    3.174377e+07
23    5.851228e+08
mean  2.544012e+07
```

5.3.4 Calculate Means and Totals Across Rows

```
mean_series = malaysia_emissions_df[['tCH4_2015','tCH4_2016','tCH4_2017','tCH4_2018',
 ↪'tCH4_2019']].select_dtypes(np.number).mean(axis=1)
total_series = malaysia_emissions_df[['tCH4_2015','tCH4_2016','tCH4_2017','tCH4_2018',
 ↪'tCH4_2019']].select_dtypes(np.number).sum(axis=1)
malaysia_emissions_df["Mean_CH4"] = mean_series
malaysia_emissions_df['Total_CH4'] = total_series
```

```
## the select np.number is uncecessary, but i'm including anyways as it doesnt really␣
 ↪hurt but for a small calculation penalty
mean_series = malaysia_emissions_df[['tCO2_2015','tCO2_2016','tCO2_2017','tCO2_2018',
 ↪'tCO2_2019']].select_dtypes(np.number).mean(axis=1)
total_series = malaysia_emissions_df[['tCO2_2015','tCO2_2016','tCO2_2017','tCO2_2018',
 ↪'tCO2_2019']].select_dtypes(np.number).sum(axis=1)
malaysia_emissions_df["Mean_CO2"] = mean_series
malaysia_emissions_df['Total_CO2'] = total_series
```

```
malaysia_emissions_df.reset_index(inplace=True, drop = True)
```

```
malaysia_emissions_df
```

```
   iso3_country                                  country_name     tCH4_2015  \
0           BGD                                    Bangladesh  2.344420e+06
1           BRA                                        Brazil  3.410233e+05
2           CHN                                         China  6.133647e+06
3           ESP                                         Spain  1.141464e+04
4           IDN                                     Indonesia  1.283649e+06
5           IND                                         India  6.219887e+06
6           IRN                  Iran (Islamic Republic of)  8.774407e+04
7           ITA                                         Italy  4.995968e+04
8           JPN                                         Japan  2.305465e+05
9           KHM                                      Cambodia  4.954698e+05
10          KOR                    Korea (the Republic of)  1.451878e+05
11          LAO       Lao People's Democratic Republic (the)  1.661169e+04
12          LKA                                     Sri Lanka  8.305626e+04
13          MMR                                       Myanmar  1.132082e+06
14          MYS                                      Malaysia  1.057399e+05
```

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```
15          NPL                                          Nepal  1.007479e+05
16          PAK                                       Pakistan  4.852431e+05
17          PHL                                Philippines (the)  3.432021e+05
18          PRK  Korea (the Democratic People's Republic of)  1.143217e+05
19          THA                                       Thailand  1.393798e+06
20          TWN                    Taiwan (Province of China)  7.866956e+04
21          USA                United States of America (the)  1.611324e+05
22          VNM                                       Viet Nam  1.346013e+06
23          NaN                                          Total  2.270357e+07
24          NaN                                           mean  9.871116e+05

       tCH4_2016     tCH4_2017     tCH4_2018     tCH4_2019     tCH4_2020  \
0   2.278158e+06  2.098958e+06  2.141231e+06  2.070985e+06  2.106781e+06
1   3.104189e+05  3.725173e+05  3.717030e+05  3.294713e+05  4.902874e+05
2   5.859531e+06  6.355071e+06  5.413962e+06  5.603352e+06  6.402353e+06
3   1.334803e+04  1.217299e+04  1.405410e+04  1.148324e+04  1.305461e+04
4   1.023129e+06  9.615327e+05  1.176982e+06  1.266668e+06  1.188195e+06
5   5.309413e+06  6.228451e+06  6.589798e+06  7.501556e+06  7.599764e+06
6   9.180121e+04  9.620217e+04  8.875744e+04  9.500199e+04  9.600254e+04
7   4.937785e+04  5.443679e+04  4.469902e+04  4.566914e+04  5.101547e+04
8   2.284133e+05  2.708935e+05  1.548252e+05  2.332056e+05  2.835167e+05
9   5.731698e+05  4.517045e+05  5.592610e+05  5.947277e+05  6.412802e+05
10  1.274597e+05  1.463222e+05  1.293543e+05  1.327782e+05  1.165467e+05
11  1.696441e+04  1.168063e+04  1.009675e+04  1.461058e+04  2.136270e+04
12  1.011743e+05  5.911841e+04  9.018914e+04  8.476088e+04  9.248238e+04
13  1.290806e+06  1.205169e+06  1.372447e+06  1.256888e+06  1.221904e+06
14  1.110049e+05  1.111291e+05  1.066525e+05  1.056287e+05  1.127141e+05
15  6.667161e+04  8.081300e+04  9.200752e+04  1.164235e+05  7.168401e+04
16  5.945922e+05  5.372641e+05  4.532297e+05  6.528548e+05  6.401201e+05
17  4.073554e+05  3.836830e+05  4.175210e+05  3.584550e+05  4.462836e+05
18  9.177653e+04  1.085457e+05  8.662578e+04  9.655062e+04  8.581038e+04
19  1.780993e+06  1.164699e+06  9.166575e+05  1.305046e+06  1.520788e+06
20  8.089149e+04  8.705634e+04  8.138151e+04  8.990870e+04  8.333327e+04
21  1.618576e+05  1.684799e+05  1.657254e+05  1.691351e+05  1.941455e+05
22  1.483777e+06  1.406437e+06  1.317455e+06  1.269751e+06  1.374450e+06
23  2.205208e+07  2.237234e+07  2.179462e+07  2.340491e+07  2.485387e+07
24  9.587863e+05  9.727103e+05  9.475920e+05  1.017605e+06  1.080603e+06

       tCH4_2021     tCO2_2015     tCO2_2016     tCO2_2017     tCO2_2018  \
0   1.983974e+06  5.861049e+07  5.695395e+07  5.247394e+07  5.353076e+07
1   4.544874e+05  8.525583e+06  7.760473e+06  9.312934e+06  9.292575e+06
2   6.068210e+06  1.533412e+08  1.464883e+08  1.588768e+08  1.353491e+08
3   8.531579e+03  2.853661e+05  3.337007e+05  3.043248e+05  3.513524e+05
4   1.009936e+06  3.209122e+07  2.557824e+07  2.403832e+07  2.942454e+07
5   6.567960e+06  1.554972e+08  1.327353e+08  1.557113e+08  1.647450e+08
6   9.053525e+04  2.193602e+06  2.295030e+06  2.405054e+06  2.218936e+06
7   5.089759e+04  1.248992e+06  1.234446e+06  1.360920e+06  1.117475e+06
8   1.574007e+05  5.763662e+06  5.710333e+06  6.772337e+06  3.870631e+06
9   5.644891e+05  1.238675e+07  1.432925e+07  1.129261e+07  1.398153e+07
10  1.013006e+05  3.629695e+06  3.186493e+06  3.658056e+06  3.233858e+06
11  1.475014e+04  4.152924e+05  4.241102e+05  2.920158e+05  2.524186e+05
12  8.466966e+04  2.076407e+06  2.529358e+06  1.477960e+06  2.254728e+06
13  1.289837e+06  2.830206e+07  3.227014e+07  3.012923e+07  3.431117e+07
14  1.069696e+05  2.643498e+06  2.775123e+06  2.778227e+06  2.666313e+06
15  4.811408e+04  2.518697e+06  1.666790e+06  2.020325e+06  2.300188e+06
16  4.849205e+05  1.213108e+07  1.486480e+07  1.343160e+07  1.133074e+07
```

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```
17  4.383270e+05  8.580052e+06  1.018389e+07  9.592074e+06  1.043803e+07
18  7.735988e+04  2.858041e+06  2.294413e+06  2.713641e+06  2.165645e+06
19  8.528673e+05  3.484495e+07  4.452483e+07  2.911748e+07  2.291644e+07
20  6.619861e+04  1.966739e+06  2.022287e+06  2.176408e+06  2.034538e+06
21  1.634842e+05  4.028310e+06  4.046440e+06  4.211999e+06  4.143136e+06
22  1.502787e+06  3.365033e+07  3.709441e+07  3.516092e+07  3.293637e+07
23  2.218801e+07  5.675891e+08  5.513021e+08  5.593084e+08  5.448654e+08
24  9.646959e+05  2.467779e+07  2.396966e+07  2.431776e+07  2.368980e+07

       tCO2_2019      Mean_CH4     Total_CH4      Mean_CO2     Total_CO2
0   5.177463e+07  2.186750e+06  1.093375e+07  5.466875e+07  2.733438e+08
1   8.236783e+06  3.450268e+05  1.725134e+06  8.625670e+06  4.312835e+07
2   1.400838e+08  5.873113e+06  2.936556e+07  1.468278e+08  7.341391e+08
3   2.870810e+05  1.249460e+04  6.247300e+04  3.123650e+05  1.561825e+06
4   3.166670e+07  1.142392e+06  5.711960e+06  2.855980e+07  1.427990e+08
5   1.875389e+08  6.369821e+06  3.184910e+07  1.592455e+08  7.962276e+08
6   2.375050e+06  9.190138e+04  4.595069e+05  2.297534e+06  1.148767e+07
7   1.141729e+06  4.882850e+04  2.441425e+05  1.220712e+06  6.103562e+06
8   5.830141e+06  2.235768e+05  1.117884e+06  5.589421e+06  2.794710e+07
9   1.486819e+07  5.348666e+05  2.674333e+06  1.337166e+07  6.685832e+07
10  3.319455e+06  1.362205e+05  6.811023e+05  3.405512e+06  1.702756e+07
11  3.652645e+05  1.399281e+04  6.996406e+04  3.498203e+05  1.749102e+06
12  2.119022e+06  8.365981e+04  4.182990e+05  2.091495e+06  1.045748e+07
13  3.142221e+07  1.251478e+06  6.257392e+06  3.128696e+07  1.564348e+08
14  2.640717e+06  1.080310e+05  5.401551e+05  2.700775e+06  1.350388e+07
15  2.910588e+06  9.133271e+04  4.566635e+05  2.283318e+06  1.141659e+07
16  1.632137e+07  5.446368e+05  2.723184e+06  1.361592e+07  6.807960e+07
17  8.961374e+06  3.820433e+05  1.910216e+06  9.551082e+06  4.775541e+07
18  2.413765e+06  9.956405e+04  4.978202e+05  2.489101e+06  1.244551e+07
19  3.262615e+07  1.312239e+06  6.561194e+06  3.280597e+07  1.640298e+08
20  2.247717e+06  8.358152e+04  4.179076e+05  2.089538e+06  1.044769e+07
21  4.228377e+06  1.652661e+05  8.263305e+05  4.131652e+06  2.065826e+07
22  3.174377e+07  1.364686e+06  6.823432e+06  3.411716e+07  1.705858e+08
23  5.851228e+08  2.246550e+07  1.123275e+08  5.616376e+08  2.808188e+09
24  2.544012e+07  9.767610e+05  4.883805e+06  2.441902e+07  1.220951e+08
```

5.3.5 Write Data to File

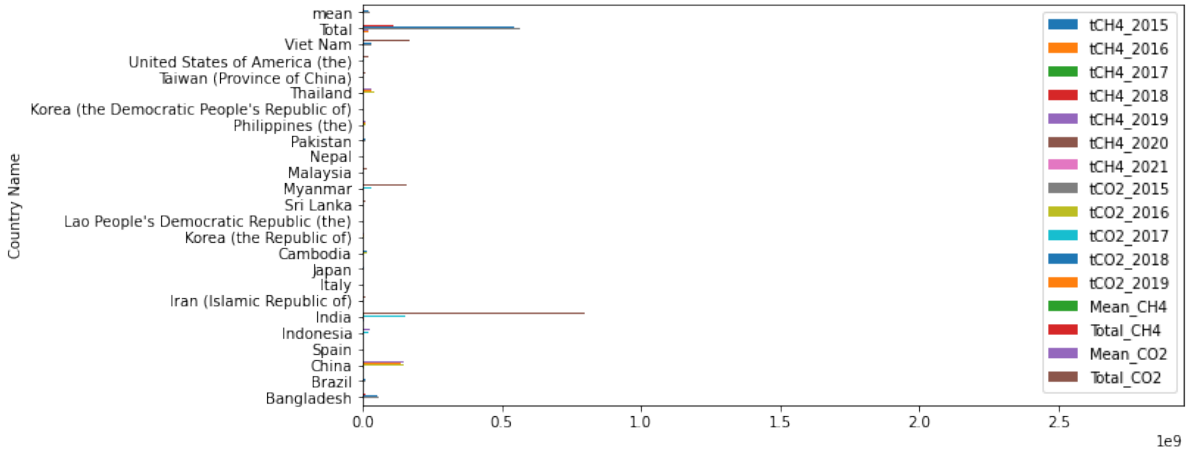
```
outfile = "/Users/jnapolitano/Projects/wattime-takehome/data/TRACE_DATA.csv"

malaysia_emissions_df.to_csv(outfile)
```

5.4 University of Malaysia Plots

5.4.1 University of Malaysia Bar Plot

```
malaysia_emissions_df.plot(kind = "barh", x = 'country_name', xlabel = "Country Name",
 ↪ ylabel = "CH4 Tonnes", figsize = (10,5))
```

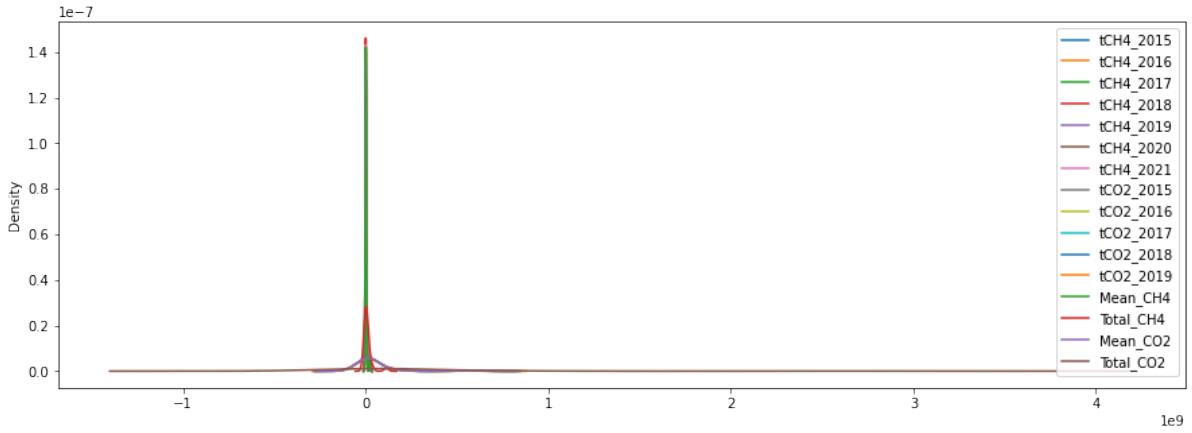
```
<AxesSubplot:ylabel='Country Name'>
```



5.4.2 University of Malaysia Density Plot

```
malaysia_emissions_df.plot(rot = 0, kind = "density", figsize = (15,5))
```

```
<AxesSubplot:ylabel='Density'>
```



I did not exclude totals or mean from the dataframe, but as we can see the second hump in the density graph shows the distribution of totals annualy. Interestingly the 2020 data is shifted further to the right than other years. This actually questions the validity of the study promoted by the University of malaysia

5.5 FAOSTAT Data

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/emissions_csv_fao_emiss_
↪csv_ch4_fao_2015_2019_tonnes.xlsx"

faostat_emissions_df = pd.read_excel(filepath)
```

5.5.1 Print FAOSTAT Data

```
## I didn't write the index to the csv file in the previous step.  IF time permits go␣
↪back and fix this error
faostat_emissions_df
```

```
   code                                        country  \
0   BGD                                     Bangladesh
1   BRA                                         Brazil
2   CHN                                          China
3   ESP                                          Spain
4   IDN                                      Indonesia
5   IND                                          India
6   IRN                      Iran (Islamic Republic of)
7   ITA                                          Italy
8   JPN                                          Japan
9   KHM                                       Cambodia
10  KOR                         Korea (the Republic of)
11  LAO       Lao People's Democratic Republic (the)
12  LKA                                      Sri Lanka
13  MMR                                        Myanmar
14  MYS                                       Malaysia
15  NPL                                          Nepal
16  PAK                                       Pakistan
17  PHL                                Philippines (the)
18  PRK  Korea (the Democratic People's Republic of)
19  THA                                       Thailand
20  TWN                      Taiwan (Province of China)
21  USA                  United States of America (the)
22  VNM                                       Viet Nam
23  NaN                                            NaN

                               country_fao        2015        2016        2017  \
0                               Bangladesh   1131293.4   1093480.4   1154531.0
1                                   Brazil    138910.3    126278.2    130322.9
2                           China, mainland   5406593.9   5399920.0   5400129.0
3                                    Spain     55082.2     55073.1     54232.4
4                                Indonesia   2407953.5   2387656.4   2425290.6
5                                    India   4580248.4   4559136.4   4620790.8
6              Iran (Islamic Republic of)     116486.7    131008.5     87233.6
7                                    Italy    114574.8    118003.0    118003.0
8                                    Japan    330353.1    326403.0    323700.3
9                                 Cambodia    436826.0    459003.1    473745.3
10                      Republic of Korea    167862.2    163534.1    158489.7
11       Lao People's Democratic Republic     94826.8     95630.0     93940.7
12                               Sri Lanka    132640.0    121756.3     84456.3
```

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```
13                                Myanmar   1059409.6   1052287.7   1087029.5
14                               Malaysia    121942.6    123232.8    122656.3
15                                  Nepal    149262.2    142723.7    162574.6
16                               Pakistan    383529.3    381361.8    406083.3
17                            Philippines   1557810.6   1524292.5   1609862.5
18  Democratic People's Republic of Korea     82823.3     83442.3     84596.2
19                               Thailand   1554254.0   1703327.7   1714465.6
20              China, Taiwan Province of     45838.7     49838.3     49991.2
21               United States of America    364728.0    438662.0    336255.5
22                               Viet Nam   1381744.4   1365173.8   1360551.6
23                                  Total  23829994.0  23917225.1  24075931.9

          2018        2019  2020  2021
0    1144591.0   1144745.4   NaN   NaN
1     121615.2    111084.8   NaN   NaN
2    5302173.1   5214454.7   NaN   NaN
3      52925.0     52098.5   NaN   NaN
4    2405613.8   2257604.3   NaN   NaN
5    4661154.9   4621416.8   NaN   NaN
6      93936.6     96103.4   NaN   NaN
7     109463.8    110895.1   NaN   NaN
8     322245.0    320581.8   NaN   NaN
9     479362.7    468378.9   NaN   NaN
10    154911.3    153260.9   NaN   NaN
11     83333.6     77005.5   NaN   NaN
12    111049.0    102156.3   NaN   NaN
13   1118850.0   1083100.3   NaN   NaN
14    125238.5    122453.8   NaN   NaN
15    153890.8    156215.4   NaN   NaN
16    393404.2    424755.1   NaN   NaN
17   1606047.8   1556225.8   NaN   NaN
18     83943.3     82937.0   NaN   NaN
19   1702989.1   1553835.5   NaN   NaN
20     49414.1     49152.0   NaN   NaN
21    412177.5    350136.5   NaN   NaN
22   1336231.2   1318431.1   NaN   NaN
23  24042561.5  23446028.9   NaN   NaN
```

5.5.2 Change code to iso3_country

```
faostat_emissions_df.rename(columns={"code": "iso3_country"}, inplace =True)
faostat_emissions_df.rename(columns={"country": "country_name"}, inplace =True)
# The column title is not a string.  It is understood as an int or a datetime.
#faostat_emissions_df['2015']
faostat_emissions_df
```

```
   iso3_country                                country_name  \
0           BGD                                  Bangladesh
1           BRA                                      Brazil
2           CHN                                       China
3           ESP                                       Spain
4           IDN                                   Indonesia
5           IND                                       India
```

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```
6          IRN                    Iran (Islamic Republic of)
7          ITA                                         Italy
8          JPN                                         Japan
9          KHM                                      Cambodia
10         KOR                          Korea (the Republic of)
11         LAO       Lao People's Democratic Republic (the)
12         LKA                                     Sri Lanka
13         MMR                                      Myanmar
14         MYS                                     Malaysia
15         NPL                                        Nepal
16         PAK                                     Pakistan
17         PHL                                Philippines (the)
18         PRK  Korea (the Democratic People's Republic of)
19         THA                                     Thailand
20         TWN                    Taiwan (Province of China)
21         USA                United States of America (the)
22         VNM                                     Viet Nam
23         NaN                                          NaN

                              country_fao        2015        2016        2017  \
0                              Bangladesh   1131293.4   1093480.4   1154531.0
1                                  Brazil    138910.3    126278.2    130322.9
2                           China, mainland   5406593.9   5399920.0   5400129.0
3                                   Spain     55082.2     55073.1     54232.4
4                               Indonesia   2407953.5   2387656.4   2425290.6
5                                   India   4580248.4   4559136.4   4620790.8
6               Iran (Islamic Republic of)    116486.7    131008.5     87233.6
7                                   Italy    114574.8    118003.0    118003.0
8                                   Japan    330353.1    326403.0    323700.3
9                                Cambodia    436826.0    459003.1    473745.3
10                         Republic of Korea    167862.2    163534.1    158489.7
11       Lao People's Democratic Republic     94826.8     95630.0     93940.7
12                              Sri Lanka    132640.0    121756.3     84456.3
13                                Myanmar   1059409.6   1052287.7   1087029.5
14                               Malaysia    121942.6    123232.8    122656.3
15                                  Nepal    149262.2    142723.7    162574.6
16                               Pakistan    383529.3    381361.8    406083.3
17                             Philippines   1557810.6   1524292.5   1609862.5
18  Democratic People's Republic of Korea     82823.3     83442.3     84596.2
19                               Thailand   1554254.0   1703327.7   1714465.6
20              China, Taiwan Province of     45838.7     49838.3     49991.2
21               United States of America    364728.0    438662.0    336255.5
22                               Viet Nam   1381744.4   1365173.8   1360551.6
23                                  Total  23829994.0  23917225.1  24075931.9

          2018        2019  2020  2021
0    1144591.0   1144745.4   NaN   NaN
1     121615.2    111084.8   NaN   NaN
2    5302173.1   5214454.7   NaN   NaN
3      52925.0     52098.5   NaN   NaN
4    2405613.8   2257604.3   NaN   NaN
5    4661154.9   4621416.8   NaN   NaN
6      93936.6     96103.4   NaN   NaN
7     109463.8    110895.1   NaN   NaN
8     322245.0    320581.8   NaN   NaN
9     479362.7    468378.9   NaN   NaN
```

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```
10    154911.3    153260.9   NaN   NaN
11     83333.6     77005.5   NaN   NaN
12    111049.0    102156.3   NaN   NaN
13   1118850.0   1083100.3   NaN   NaN
14    125238.5    122453.8   NaN   NaN
15    153890.8    156215.4   NaN   NaN
16    393404.2    424755.1   NaN   NaN
17   1606047.8   1556225.8   NaN   NaN
18     83943.3     82937.0   NaN   NaN
19   1702989.1   1553835.5   NaN   NaN
20     49414.1     49152.0   NaN   NaN
21    412177.5    350136.5   NaN   NaN
22   1336231.2   1318431.1   NaN   NaN
23  24042561.5  23446028.9   NaN   NaN
```

5.5.3 Set country_name total to total

```
faostat_emissions_df.at[23,'country_name'] = 'Total'
```

5.5.4 Drop Fao Country Code

```
faostat_emissions_df.drop(labels = ['country_fao'], axis=1, inplace=True)
faostat_emissions_df
```

```
   iso3_country                                    country_name        2015  \
0           BGD                                      Bangladesh   1131293.4
1           BRA                                          Brazil    138910.3
2           CHN                                           China   5406593.9
3           ESP                                           Spain     55082.2
4           IDN                                       Indonesia   2407953.5
5           IND                                           India   4580248.4
6           IRN                        Iran (Islamic Republic of)    116486.7
7           ITA                                           Italy    114574.8
8           JPN                                           Japan    330353.1
9           KHM                                        Cambodia    436826.0
10          KOR                          Korea (the Republic of)    167862.2
11          LAO       Lao People's Democratic Republic (the)      94826.8
12          LKA                                       Sri Lanka    132640.0
13          MMR                                         Myanmar   1059409.6
14          MYS                                        Malaysia    121942.6
15          NPL                                           Nepal    149262.2
16          PAK                                        Pakistan    383529.3
17          PHL                                 Philippines (the)   1557810.6
18          PRK  Korea (the Democratic People's Republic of)      82823.3
19          THA                                        Thailand   1554254.0
20          TWN                      Taiwan (Province of China)     45838.7
21          USA                  United States of America (the)    364728.0
22          VNM                                        Viet Nam   1381744.4
23          NaN                                           Total  23829994.0
```

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	2016	2017	2018	2019	2020	2021
0	1093480.4	1154531.0	1144591.0	1144745.4	NaN	NaN
1	126278.2	130322.9	121615.2	111084.8	NaN	NaN
2	5399920.0	5400129.0	5302173.1	5214454.7	NaN	NaN
3	55073.1	54232.4	52925.0	52098.5	NaN	NaN
4	2387656.4	2425290.6	2405613.8	2257604.3	NaN	NaN
5	4559136.4	4620790.8	4661154.9	4621416.8	NaN	NaN
6	131008.5	87233.6	93936.6	96103.4	NaN	NaN
7	118003.0	118003.0	109463.8	110895.1	NaN	NaN
8	326403.0	323700.3	322245.0	320581.8	NaN	NaN
9	459003.1	473745.3	479362.7	468378.9	NaN	NaN
10	163534.1	158489.7	154911.3	153260.9	NaN	NaN
11	95630.0	93940.7	83333.6	77005.5	NaN	NaN
12	121756.3	84456.3	111049.0	102156.3	NaN	NaN
13	1052287.7	1087029.5	1118850.0	1083100.3	NaN	NaN
14	123232.8	122656.3	125238.5	122453.8	NaN	NaN
15	142723.7	162574.6	153890.8	156215.4	NaN	NaN
16	381361.8	406083.3	393404.2	424755.1	NaN	NaN
17	1524292.5	1609862.5	1606047.8	1556225.8	NaN	NaN
18	83442.3	84596.2	83943.3	82937.0	NaN	NaN
19	1703327.7	1714465.6	1702989.1	1553835.5	NaN	NaN
20	49838.3	49991.2	49414.1	49152.0	NaN	NaN
21	438662.0	336255.5	412177.5	350136.5	NaN	NaN
22	1365173.8	1360551.6	1336231.2	1318431.1	NaN	NaN
23	23917225.1	24075931.9	24042561.5	23446028.9	NaN	NaN

5.5.5 Calculate Co2 Equivalency

```
faostat_emissions_df['tCO2_2015'] = faostat_emissions_df[2015] * 25
faostat_emissions_df['tCO2_2016'] = faostat_emissions_df[2016] * 25
faostat_emissions_df['tCO2_2017'] = faostat_emissions_df[2017] * 25
faostat_emissions_df['tCO2_2018'] = faostat_emissions_df[2018] * 25
faostat_emissions_df['tCO2_2019'] = faostat_emissions_df[2019] * 25
```

5.5.6 Calculate Means

```
faostat_emissions_df.loc['mean'] = faostat_emissions_df.loc[(faostat_emissions_df[
↪'country_name'] != "Total")].select_dtypes(np.number).mean()
faostat_emissions_df.at['mean','country_name'] = 'mean'
faostat_emissions_df.reset_index(inplace=True, drop=True)
#faostat_emissions_df.at['mean','country_fao'] = 'mean'
```

5.5.7 Calculate Means and Totals Across Rows

```
mean_series = faostat_emissions_df[[2015,2016,2017,2018,2019]].select_dtypes(np.
 ↪number).mean(axis=1)
total_series = faostat_emissions_df[[2015,2016,2017,2018,2019]].select_dtypes(np.
 ↪number).sum(axis=1)
faostat_emissions_df["Mean_CH4"] = mean_series
faostat_emissions_df['Total_CH4'] = total_series
```

```
## the select np.number is uncecessary, but i'm including anyways as it doesnt really␣
 ↪hurt but for a small calculation penalty
mean_series = faostat_emissions_df[['tCO2_2015','tCO2_2016','tCO2_2017','tCO2_2018',
 ↪'tCO2_2019']].select_dtypes(np.number).mean(axis=1)
total_series = faostat_emissions_df[['tCO2_2015','tCO2_2016','tCO2_2017','tCO2_2018',
 ↪'tCO2_2019']].select_dtypes(np.number).sum(axis=1)
faostat_emissions_df["Mean_CO2"] = mean_series
faostat_emissions_df['Total_CO2'] = total_series
```

```
faostat_emissions_df.reset_index(inplace=True, drop=True)
```

```
faostat_emissions_df
```

```
   iso3_country                                    country_name        2015  \
0           BGD                                      Bangladesh   1131293.4
1           BRA                                          Brazil    138910.3
2           CHN                                           China   5406593.9
3           ESP                                           Spain     55082.2
4           IDN                                       Indonesia   2407953.5
5           IND                                           India   4580248.4
6           IRN                        Iran (Islamic Republic of)    116486.7
7           ITA                                           Italy    114574.8
8           JPN                                           Japan    330353.1
9           KHM                                        Cambodia    436826.0
10          KOR                          Korea (the Republic of)    167862.2
11          LAO       Lao People's Democratic Republic (the)      94826.8
12          LKA                                       Sri Lanka    132640.0
13          MMR                                         Myanmar   1059409.6
14          MYS                                        Malaysia    121942.6
15          NPL                                           Nepal    149262.2
16          PAK                                        Pakistan    383529.3
17          PHL                                Philippines (the)   1557810.6
18          PRK  Korea (the Democratic People's Republic of)      82823.3
19          THA                                        Thailand   1554254.0
20          TWN                      Taiwan (Province of China)     45838.7
21          USA                   United States of America (the)    364728.0
22          VNM                                        Viet Nam   1381744.4
23          NaN                                           Total  23829994.0
24          NaN                                            mean    948478.0

             2016          2017          2018          2019  2020  2021  \
0   1.093480e+06  1.154531e+06  1.144591e+06  1.144745e+06   NaN   NaN
1   1.262782e+05  1.303229e+05  1.216152e+05  1.110848e+05   NaN   NaN
2   5.399920e+06  5.400129e+06  5.302173e+06  5.214455e+06   NaN   NaN
3   5.507310e+04  5.423240e+04  5.292500e+04  5.209850e+04   NaN   NaN
```

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```
4   2.387656e+06  2.425291e+06  2.405614e+06  2.257604e+06   NaN   NaN
5   4.559136e+06  4.620791e+06  4.661155e+06  4.621417e+06   NaN   NaN
6   1.310085e+05  8.723360e+04  9.393660e+04  9.610340e+04   NaN   NaN
7   1.180030e+05  1.180030e+05  1.094638e+05  1.108951e+05   NaN   NaN
8   3.264030e+05  3.237003e+05  3.222450e+05  3.205818e+05   NaN   NaN
9   4.590031e+05  4.737453e+05  4.793627e+05  4.683789e+05   NaN   NaN
10  1.635341e+05  1.584897e+05  1.549113e+05  1.532609e+05   NaN   NaN
11  9.563000e+04  9.394070e+04  8.333360e+04  7.700550e+04   NaN   NaN
12  1.217563e+05  8.445630e+04  1.110490e+05  1.021563e+05   NaN   NaN
13  1.052288e+06  1.087030e+06  1.118850e+06  1.083100e+06   NaN   NaN
14  1.232328e+05  1.226563e+05  1.252385e+05  1.224538e+05   NaN   NaN
15  1.427237e+05  1.625746e+05  1.538908e+05  1.562154e+05   NaN   NaN
16  3.813618e+05  4.060833e+05  3.934042e+05  4.247551e+05   NaN   NaN
17  1.524292e+06  1.609862e+06  1.606048e+06  1.556226e+06   NaN   NaN
18  8.344230e+04  8.459620e+04  8.394330e+04  8.293700e+04   NaN   NaN
19  1.703328e+06  1.714466e+06  1.702989e+06  1.553836e+06   NaN   NaN
20  4.983830e+04  4.999120e+04  4.941410e+04  4.915200e+04   NaN   NaN
21  4.386620e+05  3.362555e+05  4.121775e+05  3.501365e+05   NaN   NaN
22  1.365174e+06  1.360552e+06  1.336231e+06  1.318431e+06   NaN   NaN
23  2.391723e+07  2.407593e+07  2.404256e+07  2.344603e+07   NaN   NaN
24  9.522272e+05  9.590840e+05  9.575896e+05  9.316100e+05   NaN   NaN

      tCO2_2015     tCO2_2016     tCO2_2017     tCO2_2018     tCO2_2019  \
0    28282335.0  2.733701e+07  2.886328e+07  2.861478e+07  2.861863e+07
1     3472757.5  3.156955e+06  3.258072e+06  3.040380e+06  2.777120e+06
2   135164847.5  1.349980e+08  1.350032e+08  1.325543e+08  1.303614e+08
3     1377055.0  1.376828e+06  1.355810e+06  1.323125e+06  1.302462e+06
4    60198837.5  5.969141e+07  6.063226e+07  6.014035e+07  5.644011e+07
5   114506210.0  1.139784e+08  1.155198e+08  1.165289e+08  1.155354e+08
6     2912167.5  3.275212e+06  2.180840e+06  2.348415e+06  2.402585e+06
7     2864370.0  2.950075e+06  2.950075e+06  2.736595e+06  2.772378e+06
8     8258827.5  8.160075e+06  8.092508e+06  8.056125e+06  8.014545e+06
9    10920650.0  1.147508e+07  1.184363e+07  1.198407e+07  1.170947e+07
10    4196555.0  4.088352e+06  3.962243e+06  3.872783e+06  3.831522e+06
11    2370670.0  2.390750e+06  2.348518e+06  2.083340e+06  1.925138e+06
12    3316000.0  3.043908e+06  2.111408e+06  2.776225e+06  2.553908e+06
13   26485240.0  2.630719e+07  2.717574e+07  2.797125e+07  2.707751e+07
14    3048565.0  3.080820e+06  3.066408e+06  3.130962e+06  3.061345e+06
15    3731555.0  3.568093e+06  4.064365e+06  3.847270e+06  3.905385e+06
16    9588232.5  9.534045e+06  1.015208e+07  9.835105e+06  1.061888e+07
17   38945265.0  3.810731e+07  4.024656e+07  4.015120e+07  3.890564e+07
18    2070582.5  2.086058e+06  2.114905e+06  2.098582e+06  2.073425e+06
19   38856350.0  4.258319e+07  4.286164e+07  4.257473e+07  3.884589e+07
20    1145967.5  1.245958e+06  1.249780e+06  1.235352e+06  1.228800e+06
21    9118200.0  1.096655e+07  8.406388e+06  1.030444e+07  8.753412e+06
22   34543610.0  3.412934e+07  3.401379e+07  3.340578e+07  3.296078e+07
23  595749850.0  5.979306e+08  6.018983e+08  6.010640e+08  5.861507e+08
24   23711950.0  2.380568e+07  2.397710e+07  2.393974e+07  2.329025e+07

        Mean_CH4     Total_CH4      Mean_CO2     Total_CO2
0   1.133728e+06  5.668641e+06  2.834321e+07  1.417160e+08
1   1.256423e+05  6.282114e+05  3.141057e+06  1.570528e+07
2   5.344654e+06  2.672327e+07  1.336164e+08  6.680818e+08
3   5.388224e+04  2.694112e+05  1.347056e+06  6.735280e+06
4   2.376824e+06  1.188412e+07  5.942059e+07  2.971030e+08
5   4.608549e+06  2.304275e+07  1.152137e+08  5.760687e+08
```

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```
6   1.049538e+05  5.247688e+05  2.623844e+06  1.311922e+07
7   1.141879e+05  5.709397e+05  2.854698e+06  1.427349e+07
8   3.246566e+05  1.623283e+06  8.116416e+06  4.058208e+07
9   4.634632e+05  2.317316e+06  1.158658e+07  5.793290e+07
10  1.596116e+05  7.980582e+05  3.990291e+06  1.995146e+07
11  8.894732e+04  4.447366e+05  2.223683e+06  1.111842e+07
12  1.104116e+05  5.520579e+05  2.760290e+06  1.380145e+07
13  1.080135e+06  5.400677e+06  2.700339e+07  1.350169e+08
14  1.231048e+05  6.155240e+05  3.077620e+06  1.538810e+07
15  1.529333e+05  7.646667e+05  3.823334e+06  1.911667e+07
16  3.978267e+05  1.989134e+06  9.945668e+06  4.972834e+07
17  1.570848e+06  7.854239e+06  3.927120e+07  1.963560e+08
18  8.354842e+04  4.177421e+05  2.088710e+06  1.044355e+07
19  1.645774e+06  8.228872e+06  4.114436e+07  2.057218e+08
20  4.884686e+04  2.442343e+05  1.221172e+06  6.105858e+06
21  3.803919e+05  1.901960e+06  9.509798e+06  4.754899e+07
22  1.352426e+06  6.762132e+06  3.381066e+07  1.690533e+08
23  2.386235e+07  1.193117e+08  5.965587e+08  2.982794e+09
24  9.497978e+05  4.748989e+06  2.374494e+07  1.187247e+08
```

5.5.8 FAOSTAT Data to File

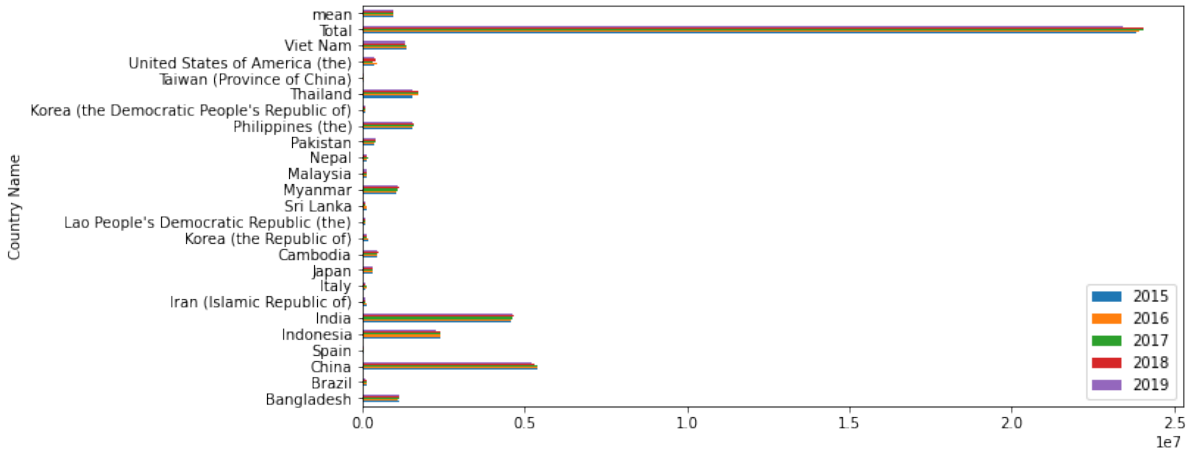
```
outfile = "/Users/jnapolitano/Projects/wattime-takehome/data/FAOSTAT_DATA.csv"

faostat_emissions_df.to_csv(outfile)
```

5.6 FaoSTAT PLOTS

5.6.1 FAOSTAT Hectare Estimates Bar Plot

```
faostat_emissions_df.plot(kind = "barh", x = 'country_name', y = [2015, 2016, 2017,␣
↪2018, 2019], xlabel = "Country Name", ylabel = "Tonnes CH4", figsize = (10,5))
```

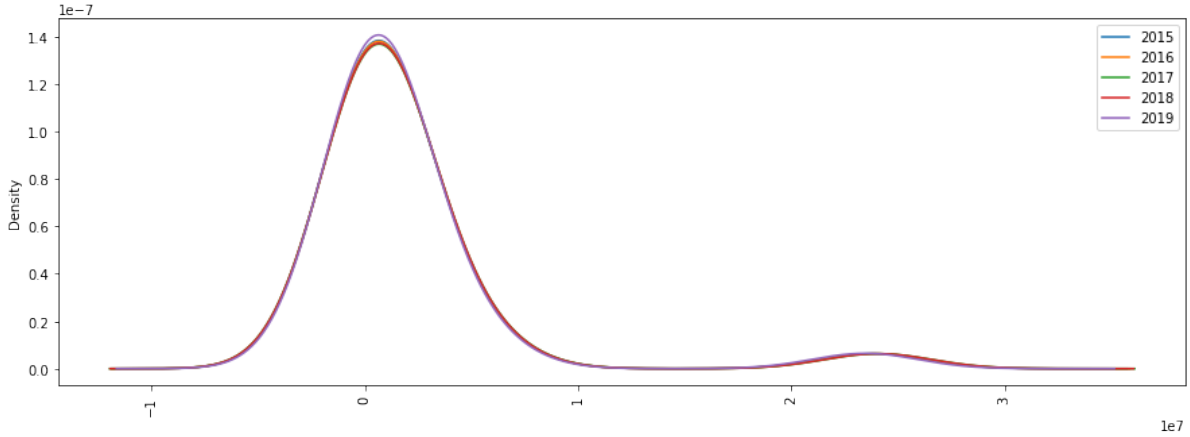
```
<AxesSubplot:ylabel='Country Name'>
```



5.6.2 FAOSTAT Density Plot

```
faostat_emissions_df.plot(rot = 90, kind = "density",y = [2015, 2016, 2017, 2018,␣
↪2019], figsize = (15,5))
```

```
<AxesSubplot:ylabel='Density'>
```



The density plot is fairly consistent. There is nearly no variation between nations and in total. The 2020 data may show otherwise as the Malaysian data shows.

5.7 Join Df's by ISO3 Country

5.7.1 Drop totals and means from the original df.

Because I am joining on iso3 country country code if the totals and means are located at different indexes we may experience merge and calculation errors

```
faostat_emissions_df = faostat_emissions_df[(faostat_emissions_df["country_name"] !=
↪"Total") & (faostat_emissions_df['country_name'] != 'mean')].copy()
```

```
malaysia_emissions_df = malaysia_emissions_df[(malaysia_emissions_df["country_name"] !
 ↪= "Total") & (malaysia_emissions_df['country_name'] != 'mean')].copy()
```

```
faostat_emissions_df
```

```
   iso3_country                                  country_name       2015  \
0           BGD                                    Bangladesh  1131293.4
1           BRA                                        Brazil   138910.3
2           CHN                                         China  5406593.9
3           ESP                                         Spain    55082.2
4           IDN                                     Indonesia  2407953.5
5           IND                                         India  4580248.4
6           IRN                     Iran (Islamic Republic of)   116486.7
7           ITA                                         Italy   114574.8
8           JPN                                         Japan   330353.1
9           KHM                                      Cambodia   436826.0
10          KOR                        Korea (the Republic of)   167862.2
11          LAO       Lao People's Democratic Republic (the)    94826.8
12          LKA                                     Sri Lanka   132640.0
13          MMR                                       Myanmar  1059409.6
14          MYS                                      Malaysia   121942.6
15          NPL                                         Nepal   149262.2
16          PAK                                      Pakistan   383529.3
17          PHL                                Philippines (the)  1557810.6
18          PRK  Korea (the Democratic People's Republic of)    82823.3
19          THA                                      Thailand  1554254.0
20          TWN                     Taiwan (Province of China)    45838.7
21          USA                 United States of America (the)   364728.0
22          VNM                                      Viet Nam  1381744.4

         2016       2017       2018       2019  2020  2021    tCO2_2015  \
0   1093480.4  1154531.0  1144591.0  1144745.4   NaN   NaN   28282335.0
1    126278.2   130322.9   121615.2   111084.8   NaN   NaN    3472757.5
2   5399920.0  5400129.0  5302173.1  5214454.7   NaN   NaN  135164847.5
3     55073.1    54232.4    52925.0    52098.5   NaN   NaN    1377055.0
4   2387656.4  2425290.6  2405613.8  2257604.3   NaN   NaN   60198837.5
5   4559136.4  4620790.8  4661154.9  4621416.8   NaN   NaN  114506210.0
6    131008.5    87233.6    93936.6    96103.4   NaN   NaN    2912167.5
7    118003.0   118003.0   109463.8   110895.1   NaN   NaN    2864370.0
8    326403.0   323700.3   322245.0   320581.8   NaN   NaN    8258827.5
9    459003.1   473745.3   479362.7   468378.9   NaN   NaN   10920650.0
10   163534.1   158489.7   154911.3   153260.9   NaN   NaN    4196555.0
11    95630.0    93940.7    83333.6    77005.5   NaN   NaN    2370670.0
12   121756.3    84456.3   111049.0   102156.3   NaN   NaN    3316000.0
13  1052287.7  1087029.5  1118850.0  1083100.3   NaN   NaN   26485240.0
14   123232.8   122656.3   125238.5   122453.8   NaN   NaN    3048565.0
15   142723.7   162574.6   153890.8   156215.4   NaN   NaN    3731555.0
16   381361.8   406083.3   393404.2   424755.1   NaN   NaN    9588232.5
17  1524292.5  1609862.5  1606047.8  1556225.8   NaN   NaN   38945265.0
18    83442.3    84596.2    83943.3    82937.0   NaN   NaN    2070582.5
19  1703327.7  1714465.6  1702989.1  1553835.5   NaN   NaN   38856350.0
20    49838.3    49991.2    49414.1    49152.0   NaN   NaN    1145967.5
21   438662.0   336255.5   412177.5   350136.5   NaN   NaN    9118200.0
22  1365173.8  1360551.6  1336231.2  1318431.1   NaN   NaN   34543610.0
```

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```
      tCO2_2016    tCO2_2017    tCO2_2018    tCO2_2019    Mean_CH4  \
0    27337010.0   28863275.0   28614775.0   28618635.0  1133728.24
1     3156955.0    3258072.5    3040380.0    2777120.0   125642.28
2   134998000.0  135003225.0  132554327.5  130361367.5  5344654.14
3     1376827.5    1355810.0    1323125.0    1302462.5    53882.24
4    59691410.0   60632265.0   60140345.0   56440107.5  2376823.72
5   113978410.0  115519770.0  116528872.5  115535420.0  4608549.46
6     3275212.5    2180840.0    2348415.0    2402585.0   104953.76
7     2950075.0    2950075.0    2736595.0    2772377.5   114187.94
8     8160075.0    8092507.5    8056125.0    8014545.0   324656.64
9    11475077.5   11843632.5   11984067.5   11709472.5   463463.20
10    4088352.5    3962242.5    3872782.5    3831522.5   159611.64
11    2390750.0    2348517.5    2083340.0    1925137.5    88947.32
12    3043907.5    2111407.5    2776225.0    2553907.5   110411.58
13   26307192.5   27175737.5   27971250.0   27077507.5  1080135.42
14    3080820.0    3066407.5    3130962.5    3061345.0   123104.80
15    3568092.5    4064365.0    3847270.0    3905385.0   152933.34
16    9534045.0   10152082.5    9835105.0   10618877.5   397826.74
17   38107312.5   40246562.5   40151195.0   38905645.0  1570847.84
18    2086057.5    2114905.0    2098582.5    2073425.0    83548.42
19   42583192.5   42861640.0   42574727.5   38845887.5  1645774.38
20    1245957.5    1249780.0    1235352.5    1228800.0    48846.86
21   10966550.0    8406387.5   10304437.5    8753412.5   380391.90
22   34129345.0   34013790.0   33405780.0   32960777.5  1352426.42

     Total_CH4     Mean_CO2    Total_CO2
0    5668641.2   28343206.0  141716030.0
1     628211.4    3141057.0   15705285.0
2   26723270.7  133616353.5  668081767.5
3     269411.2    1347056.0    6735280.0
4   11884118.6   59420593.0  297102965.0
5   23042747.3  115213736.5  576068682.5
6     524768.8    2623844.0   13119220.0
7     570939.7    2854698.5   14273492.5
8    1623283.2    8116416.0   40582080.0
9    2317316.0   11586580.0   57932900.0
10    798058.2    3990291.0   19951455.0
11    444736.6    2223683.0   11118415.0
12    552057.9    2760289.5   13801447.5
13   5400677.1   27003385.5  135016927.5
14    615524.0    3077620.0   15388100.0
15    764666.7    3823333.5   19116667.5
16   1989133.7    9945668.5   49728342.5
17   7854239.2   39271196.0  196355980.0
18    417742.1    2088710.5   10443552.5
19   8228871.9   41144359.5  205721797.5
20    244234.3    1221171.5    6105857.5
21   1901959.5    9509797.5   47548987.5
22   6762132.1   33810660.5  169053302.5
```

```
malaysia_emissions_df
```

```
   iso3_country                                country_name     tCH4_2015  \
0           BGD                                  Bangladesh  2.344420e+06
1           BRA                                      Brazil  3.410233e+05
```

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```
2           CHN                                          China  6.133647e+06
3           ESP                                          Spain  1.141464e+04
4           IDN                                      Indonesia  1.283649e+06
5           IND                                          India  6.219887e+06
6           IRN                    Iran (Islamic Republic of)  8.774407e+04
7           ITA                                          Italy  4.995968e+04
8           JPN                                          Japan  2.305465e+05
9           KHM                                       Cambodia  4.954698e+05
10          KOR                         Korea (the Republic of)  1.451878e+05
11          LAO       Lao People's Democratic Republic (the)  1.661169e+04
12          LKA                                      Sri Lanka  8.305626e+04
13          MMR                                        Myanmar  1.132082e+06
14          MYS                                       Malaysia  1.057399e+05
15          NPL                                          Nepal  1.007479e+05
16          PAK                                       Pakistan  4.852431e+05
17          PHL                                Philippines (the)  3.432021e+05
18          PRK  Korea (the Democratic People's Republic of)  1.143217e+05
19          THA                                       Thailand  1.393798e+06
20          TWN                    Taiwan (Province of China)  7.866956e+04
21          USA                United States of America (the)  1.611324e+05
22          VNM                                       Viet Nam  1.346013e+06

      tCH4_2016     tCH4_2017     tCH4_2018     tCH4_2019     tCH4_2020  \
0   2.278158e+06  2.098958e+06  2.141231e+06  2.070985e+06  2.106781e+06
1   3.104189e+05  3.725173e+05  3.717030e+05  3.294713e+05  4.902874e+05
2   5.859531e+06  6.355071e+06  5.413962e+06  5.603352e+06  6.402353e+06
3   1.334803e+04  1.217299e+04  1.405410e+04  1.148324e+04  1.305461e+04
4   1.023129e+06  9.615327e+05  1.176982e+06  1.266668e+06  1.188195e+06
5   5.309413e+06  6.228451e+06  6.589798e+06  7.501556e+06  7.599764e+06
6   9.180121e+04  9.620217e+04  8.875744e+04  9.500199e+04  9.600254e+04
7   4.937785e+04  5.443679e+04  4.469902e+04  4.566914e+04  5.101547e+04
8   2.284133e+05  2.708935e+05  1.548252e+05  2.332056e+05  2.835167e+05
9   5.731698e+05  4.517045e+05  5.592610e+05  5.947277e+05  6.412802e+05
10  1.274597e+05  1.463222e+05  1.293543e+05  1.327782e+05  1.165467e+05
11  1.696441e+04  1.168063e+04  1.009675e+04  1.461058e+04  2.136270e+04
12  1.011743e+05  5.911841e+04  9.018914e+04  8.476088e+04  9.248238e+04
13  1.290806e+06  1.205169e+06  1.372447e+06  1.256888e+06  1.221904e+06
14  1.110049e+05  1.111291e+05  1.066525e+05  1.056287e+05  1.127141e+05
15  6.667161e+04  8.081300e+04  9.200752e+04  1.164235e+05  7.168401e+04
16  5.945922e+05  5.372641e+05  4.532297e+05  6.528548e+05  6.401201e+05
17  4.073554e+05  3.836830e+05  4.175210e+05  3.584550e+05  4.462836e+05
18  9.177653e+04  1.085457e+05  8.662578e+04  9.655062e+04  8.581038e+04
19  1.780993e+06  1.164699e+06  9.166575e+05  1.305046e+06  1.520788e+06
20  8.089149e+04  8.705634e+04  8.138151e+04  8.990870e+04  8.333327e+04
21  1.618576e+05  1.684799e+05  1.657254e+05  1.691351e+05  1.941455e+05
22  1.483777e+06  1.406437e+06  1.317455e+06  1.269751e+06  1.374450e+06

      tCH4_2021     tCO2_2015     tCO2_2016     tCO2_2017     tCO2_2018  \
0   1.983974e+06  5.861049e+07  5.695395e+07  5.247394e+07  5.353076e+07
1   4.544874e+05  8.525583e+06  7.760473e+06  9.312934e+06  9.292575e+06
2   6.068210e+06  1.533412e+08  1.464883e+08  1.588768e+08  1.353491e+08
3   8.531579e+03  2.853661e+05  3.337007e+05  3.043248e+05  3.513524e+05
4   1.009936e+06  3.209122e+07  2.557824e+07  2.403832e+07  2.942454e+07
5   6.567960e+06  1.554972e+08  1.327353e+08  1.557113e+08  1.647450e+08
6   9.053525e+04  2.193602e+06  2.295030e+06  2.405054e+06  2.218936e+06
7   5.089759e+04  1.248992e+06  1.234446e+06  1.360920e+06  1.117475e+06
```

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8	1.574007e+05	5.763662e+06	5.710333e+06	6.772337e+06	3.870631e+06
9	5.644891e+05	1.238675e+07	1.432925e+07	1.129261e+07	1.398153e+07
10	1.013006e+05	3.629695e+06	3.186493e+06	3.658056e+06	3.233858e+06
11	1.475014e+04	4.152924e+05	4.241102e+05	2.920158e+05	2.524186e+05
12	8.466966e+04	2.076407e+06	2.529358e+06	1.477960e+06	2.254728e+06
13	1.289837e+06	2.830206e+07	3.227014e+07	3.012923e+07	3.431117e+07
14	1.069696e+05	2.643498e+06	2.775123e+06	2.778227e+06	2.666313e+06
15	4.811408e+04	2.518697e+06	1.666790e+06	2.020325e+06	2.300188e+06
16	4.849205e+05	1.213108e+07	1.486480e+07	1.343160e+07	1.133074e+07
17	4.383270e+05	8.580052e+06	1.018389e+07	9.592074e+06	1.043803e+07
18	7.735988e+04	2.858041e+06	2.294413e+06	2.713641e+06	2.165645e+06
19	8.528673e+05	3.484495e+07	4.452483e+07	2.911748e+07	2.291644e+07
20	6.619861e+04	1.966739e+06	2.022287e+06	2.176408e+06	2.034538e+06
21	1.634842e+05	4.028310e+06	4.046440e+06	4.211999e+06	4.143136e+06
22	1.502787e+06	3.365033e+07	3.709441e+07	3.516092e+07	3.293637e+07

	tCO2_2019	Mean_CH4	Total_CH4	Mean_CO2	Total_CO2
0	5.177463e+07	2.186750e+06	1.093375e+07	5.466875e+07	2.733438e+08
1	8.236783e+06	3.450268e+05	1.725134e+06	8.625670e+06	4.312835e+07
2	1.400838e+08	5.873113e+06	2.936556e+07	1.468278e+08	7.341391e+08
3	2.870810e+05	1.249460e+04	6.247300e+04	3.123650e+05	1.561825e+06
4	3.166670e+07	1.142392e+06	5.711960e+06	2.855980e+07	1.427990e+08
5	1.875389e+08	6.369821e+06	3.184910e+07	1.592455e+08	7.962276e+08
6	2.375050e+06	9.190138e+04	4.595069e+05	2.297534e+06	1.148767e+07
7	1.141729e+06	4.882850e+04	2.441425e+05	1.220712e+06	6.103562e+06
8	5.830141e+06	2.235768e+05	1.117884e+06	5.589421e+06	2.794710e+07
9	1.486819e+07	5.348666e+05	2.674333e+06	1.337166e+07	6.685832e+07
10	3.319455e+06	1.362205e+05	6.811023e+05	3.405512e+06	1.702756e+07
11	3.652645e+05	1.399281e+04	6.996406e+04	3.498203e+05	1.749102e+06
12	2.119022e+06	8.365981e+04	4.182990e+05	2.091495e+06	1.045748e+07
13	3.142221e+07	1.251478e+06	6.257392e+06	3.128696e+07	1.564348e+08
14	2.640717e+06	1.080310e+05	5.401551e+05	2.700775e+06	1.350388e+07
15	2.910588e+06	9.133271e+04	4.566635e+05	2.283318e+06	1.141659e+07
16	1.632137e+07	5.446368e+05	2.723184e+06	1.361592e+07	6.807960e+07
17	8.961374e+06	3.820433e+05	1.910216e+06	9.551082e+06	4.775541e+07
18	2.413765e+06	9.956405e+04	4.978202e+05	2.489101e+06	1.244551e+07
19	3.262615e+07	1.312239e+06	6.561194e+06	3.280597e+07	1.640298e+08
20	2.247717e+06	8.358152e+04	4.179076e+05	2.089538e+06	1.044769e+07
21	4.228377e+06	1.652661e+05	8.263305e+05	4.131652e+06	2.065826e+07
22	3.174377e+07	1.364686e+06	6.823432e+06	3.411716e+07	1.705858e+08

```
merged_df = faostat_emissions_df.merge(malaysia_emissions_df,suffixes=('_FAOSTAT', '_
↪TRACE'), on='iso3_country', how='left', sort=False)
```

5.7.2 Dropping 2020 and 2021 from the data sets

I will only compare data compiled from the same year.

```
merged_df.drop([2020, 2021, "tCH4_2020","tCH4_2021"], axis = 1, inplace = True)
```

```
merged_df
```

```
   iso3_country                          country_name_FAOSTAT       2015  \
0           BGD                                    Bangladesh  1131293.4
1           BRA                                        Brazil   138910.3
2           CHN                                         China  5406593.9
3           ESP                                         Spain    55082.2
4           IDN                                     Indonesia  2407953.5
5           IND                                         India  4580248.4
6           IRN                  Iran (Islamic Republic of)   116486.7
7           ITA                                         Italy   114574.8
8           JPN                                         Japan   330353.1
9           KHM                                      Cambodia   436826.0
10          KOR                    Korea (the Republic of)   167862.2
11          LAO       Lao People's Democratic Republic (the)    94826.8
12          LKA                                     Sri Lanka   132640.0
13          MMR                                       Myanmar  1059409.6
14          MYS                                      Malaysia   121942.6
15          NPL                                         Nepal   149262.2
16          PAK                                      Pakistan   383529.3
17          PHL                             Philippines (the)  1557810.6
18          PRK  Korea (the Democratic People's Republic of)    82823.3
19          THA                                      Thailand  1554254.0
20          TWN                  Taiwan (Province of China)    45838.7
21          USA               United States of America (the)   364728.0
22          VNM                                     Viet Nam  1381744.4

         2016       2017       2018       2019  tCO2_2015_FAOSTAT  \
0   1093480.4  1154531.0  1144591.0  1144745.4         28282335.0
1    126278.2   130322.9   121615.2   111084.8          3472757.5
2   5399920.0  5400129.0  5302173.1  5214454.7        135164847.5
3     55073.1    54232.4    52925.0    52098.5          1377055.0
4   2387656.4  2425290.6  2405613.8  2257604.3         60198837.5
5   4559136.4  4620790.8  4661154.9  4621416.8        114506210.0
6    131008.5    87233.6    93936.6    96103.4          2912167.5
7    118003.0   118003.0   109463.8   110895.1          2864370.0
8    326403.0   323700.3   322245.0   320581.8          8258827.5
9    459003.1   473745.3   479362.7   468378.9         10920650.0
10   163534.1   158489.7   154911.3   153260.9          4196555.0
11    95630.0    93940.7    83333.6    77005.5          2370670.0
12   121756.3    84456.3   111049.0   102156.3          3316000.0
13  1052287.7  1087029.5  1118850.0  1083100.3         26485240.0
14   123232.8   122656.3   125238.5   122453.8          3048565.0
15   142723.7   162574.6   153890.8   156215.4          3731555.0
16   381361.8   406083.3   393404.2   424755.1          9588232.5
17  1524292.5  1609862.5  1606047.8  1556225.8         38945265.0
18    83442.3    84596.2    83943.3    82937.0          2070582.5
19  1703327.7  1714465.6  1702989.1  1553835.5         38856350.0
20    49838.3    49991.2    49414.1    49152.0          1145967.5
21   438662.0   336255.5   412177.5   350136.5          9118200.0
22  1365173.8  1360551.6  1336231.2  1318431.1         34543610.0

    tCO2_2016_FAOSTAT  tCO2_2017_FAOSTAT  ...     tCH4_2019  tCO2_2015_TRACE  \
0          27337010.0         28863275.0  ...  2.070985e+06     5.861049e+07
1           3156955.0          3258072.5  ...  3.294713e+05     8.525583e+06
2         134998000.0        135003225.0  ...  5.603352e+06     1.533412e+08
3           1376827.5          1355810.0  ...  1.148324e+04     2.853661e+05
4          59691410.0         60632265.0  ...  1.266668e+06     3.209122e+07
5         113978410.0        115519770.0  ...  7.501556e+06     1.554972e+08
```

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```
6           3275212.5          2180840.0  ...  9.500199e+04     2.193602e+06
7           2950075.0          2950075.0  ...  4.566914e+04     1.248992e+06
8           8160075.0          8092507.5  ...  2.332056e+05     5.763662e+06
9          11475077.5         11843632.5  ...  5.947277e+05     1.238675e+07
10          4088352.5          3962242.5  ...  1.327782e+05     3.629695e+06
11          2390750.0          2348517.5  ...  1.461058e+04     4.152924e+05
12          3043907.5          2111407.5  ...  8.476088e+04     2.076407e+06
13         26307192.5         27175737.5  ...  1.256888e+06     2.830206e+07
14          3080820.0          3066407.5  ...  1.056287e+05     2.643498e+06
15          3568092.5          4064365.0  ...  1.164235e+05     2.518697e+06
16          9534045.0         10152082.5  ...  6.528548e+05     1.213108e+07
17         38107312.5         40246562.5  ...  3.584550e+05     8.580052e+06
18          2086057.5          2114905.0  ...  9.655062e+04     2.858041e+06
19         42583192.5         42861640.0  ...  1.305046e+06     3.484495e+07
20          1245957.5          1249780.0  ...  8.990870e+04     1.966739e+06
21         10966550.0          8406387.5  ...  1.691351e+05     4.028310e+06
22         34129345.0         34013790.0  ...  1.269751e+06     3.365033e+07

    tCO2_2016_TRACE  tCO2_2017_TRACE  tCO2_2018_TRACE  tCO2_2019_TRACE  \
0      5.695395e+07     5.247394e+07     5.353076e+07     5.177463e+07
1      7.760473e+06     9.312934e+06     9.292575e+06     8.236783e+06
2      1.464883e+08     1.588768e+08     1.353491e+08     1.400838e+08
3      3.337007e+05     3.043248e+05     3.513524e+05     2.870810e+05
4      2.557824e+07     2.403832e+07     2.942454e+07     3.166670e+07
5      1.327353e+08     1.557113e+08     1.647450e+08     1.875389e+08
6      2.295030e+06     2.405054e+06     2.218936e+06     2.375050e+06
7      1.234446e+06     1.360920e+06     1.117475e+06     1.141729e+06
8      5.710333e+06     6.772337e+06     3.870631e+06     5.830141e+06
9      1.432925e+07     1.129261e+07     1.398153e+07     1.486819e+07
10     3.186493e+06     3.658056e+06     3.233858e+06     3.319455e+06
11     4.241102e+05     2.920158e+05     2.524186e+05     3.652645e+05
12     2.529358e+06     1.477960e+06     2.254728e+06     2.119022e+06
13     3.227014e+07     3.012923e+07     3.431117e+07     3.142221e+07
14     2.775123e+06     2.778227e+06     2.666313e+06     2.640717e+06
15     1.666790e+06     2.020325e+06     2.300188e+06     2.910588e+06
16     1.486480e+07     1.343160e+07     1.133074e+07     1.632137e+07
17     1.018389e+07     9.592074e+06     1.043803e+07     8.961374e+06
18     2.294413e+06     2.713641e+06     2.165645e+06     2.413765e+06
19     4.452483e+07     2.911748e+07     2.291644e+07     3.262615e+07
20     2.022287e+06     2.176408e+06     2.034538e+06     2.247717e+06
21     4.046440e+06     4.211999e+06     4.143136e+06     4.228377e+06
22     3.709441e+07     3.516092e+07     3.293637e+07     3.174377e+07

   Mean_CH4_TRACE  Total_CH4_TRACE  Mean_CO2_TRACE  Total_CO2_TRACE
0    2.186750e+06     1.093375e+07    5.466875e+07     2.733438e+08
1    3.450268e+05     1.725134e+06    8.625670e+06     4.312835e+07
2    5.873113e+06     2.936556e+07    1.468278e+08     7.341391e+08
3    1.249460e+04     6.247300e+04    3.123650e+05     1.561825e+06
4    1.142392e+06     5.711960e+06    2.855980e+07     1.427990e+08
5    6.369821e+06     3.184910e+07    1.592455e+08     7.962276e+08
6    9.190138e+04     4.595069e+05    2.297534e+06     1.148767e+07
7    4.882850e+04     2.441425e+05    1.220712e+06     6.103562e+06
8    2.235768e+05     1.117884e+06    5.589421e+06     2.794710e+07
9    5.348666e+05     2.674333e+06    1.337166e+07     6.685832e+07
10   1.362205e+05     6.811023e+05    3.405512e+06     1.702756e+07
11   1.399281e+04     6.996406e+04    3.498203e+05     1.749102e+06
```

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```
12   8.365981e+04     4.182990e+05    2.091495e+06     1.045748e+07
13   1.251478e+06     6.257392e+06    3.128696e+07     1.564348e+08
14   1.080310e+05     5.401551e+05    2.700775e+06     1.350388e+07
15   9.133271e+04     4.566635e+05    2.283318e+06     1.141659e+07
16   5.446368e+05     2.723184e+06    1.361592e+07     6.807960e+07
17   3.820433e+05     1.910216e+06    9.551082e+06     4.775541e+07
18   9.956405e+04     4.978202e+05    2.489101e+06     1.244551e+07
19   1.312239e+06     6.561194e+06    3.280597e+07     1.640298e+08
20   8.358152e+04     4.179076e+05    2.089538e+06     1.044769e+07
21   1.652661e+05     8.263305e+05    4.131652e+06     2.065826e+07
22   1.364686e+06     6.823432e+06    3.411716e+07     1.705858e+08

[23 rows x 31 columns]
```

5.7.3 Calculate difference in Ch4 Tonnes Between the Estimates

```
# Calculate Difference in tons
merged_df['CH4_diff_2015'] = merged_df[2015] - merged_df['tCH4_2015']
merged_df['CH4_diff_2016'] = merged_df[2016] - merged_df['tCH4_2016']
merged_df['CH4_diff_2017'] = merged_df[2017] - merged_df['tCH4_2017']
merged_df['CH4_diff_2018'] = merged_df[2018] - merged_df['tCH4_2018']
merged_df['CH4_diff_2019'] = merged_df[2019] - merged_df['tCH4_2019']
merged_df['CH4_diff_means'] = merged_df['Mean_CH4_FAOSTAT'] - merged_df['Mean_CH4_
↪TRACE']
merged_df['CH4_diff_totals'] = merged_df['Total_CH4_FAOSTAT'] - merged_df['Total_CH4_
↪TRACE']
```

```
merged_df
```

```
   iso3_country                          country_name_FAOSTAT       2015  \
0           BGD                                    Bangladesh  1131293.4
1           BRA                                        Brazil   138910.3
2           CHN                                         China  5406593.9
3           ESP                                         Spain    55082.2
4           IDN                                     Indonesia  2407953.5
5           IND                                         India  4580248.4
6           IRN                  Iran (Islamic Republic of)   116486.7
7           ITA                                         Italy   114574.8
8           JPN                                         Japan   330353.1
9           KHM                                      Cambodia   436826.0
10          KOR                        Korea (the Republic of)   167862.2
11          LAO      Lao People's Democratic Republic (the)    94826.8
12          LKA                                     Sri Lanka   132640.0
13          MMR                                       Myanmar  1059409.6
14          MYS                                      Malaysia   121942.6
15          NPL                                         Nepal   149262.2
16          PAK                                      Pakistan   383529.3
17          PHL                               Philippines (the)  1557810.6
18          PRK  Korea (the Democratic People's Republic of)    82823.3
19          THA                                      Thailand  1554254.0
20          TWN                   Taiwan (Province of China)    45838.7
21          USA               United States of America (the)   364728.0
```

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```
22          VNM                                        Viet Nam  1381744.4

         2016       2017       2018       2019  tCO2_2015_FAOSTAT  \
0   1093480.4  1154531.0  1144591.0  1144745.4         28282335.0
1    126278.2   130322.9   121615.2   111084.8          3472757.5
2   5399920.0  5400129.0  5302173.1  5214454.7        135164847.5
3     55073.1    54232.4    52925.0    52098.5          1377055.0
4   2387656.4  2425290.6  2405613.8  2257604.3         60198837.5
5   4559136.4  4620790.8  4661154.9  4621416.8        114506210.0
6    131008.5    87233.6    93936.6    96103.4          2912167.5
7    118003.0   118003.0   109463.8   110895.1          2864370.0
8    326403.0   323700.3   322245.0   320581.8          8258827.5
9    459003.1   473745.3   479362.7   468378.9         10920650.0
10   163534.1   158489.7   154911.3   153260.9          4196555.0
11    95630.0    93940.7    83333.6    77005.5          2370670.0
12   121756.3    84456.3   111049.0   102156.3          3316000.0
13  1052287.7  1087029.5  1118850.0  1083100.3         26485240.0
14   123232.8   122656.3   125238.5   122453.8          3048565.0
15   142723.7   162574.6   153890.8   156215.4          3731555.0
16   381361.8   406083.3   393404.2   424755.1          9588232.5
17  1524292.5  1609862.5  1606047.8  1556225.8         38945265.0
18    83442.3    84596.2    83943.3    82937.0          2070582.5
19  1703327.7  1714465.6  1702989.1  1553835.5         38856350.0
20    49838.3    49991.2    49414.1    49152.0          1145967.5
21   438662.0   336255.5   412177.5   350136.5          9118200.0
22  1365173.8  1360551.6  1336231.2  1318431.1         34543610.0

    tCO2_2016_FAOSTAT  tCO2_2017_FAOSTAT  ...  Total_CH4_TRACE  \
0          27337010.0         28863275.0  ...     1.093375e+07
1           3156955.0          3258072.5  ...     1.725134e+06
2         134998000.0        135003225.0  ...     2.936556e+07
3           1376827.5          1355810.0  ...     6.247300e+04
4          59691410.0         60632265.0  ...     5.711960e+06
5         113978410.0        115519770.0  ...     3.184910e+07
6           3275212.5          2180840.0  ...     4.595069e+05
7           2950075.0          2950075.0  ...     2.441425e+05
8           8160075.0          8092507.5  ...     1.117884e+06
9          11475077.5         11843632.5  ...     2.674333e+06
10          4088352.5          3962242.5  ...     6.811023e+05
11          2390750.0          2348517.5  ...     6.996406e+04
12          3043907.5          2111407.5  ...     4.182990e+05
13         26307192.5         27175737.5  ...     6.257392e+06
14          3080820.0          3066407.5  ...     5.401551e+05
15          3568092.5          4064365.0  ...     4.566635e+05
16          9534045.0         10152082.5  ...     2.723184e+06
17         38107312.5         40246562.5  ...     1.910216e+06
18          2086057.5          2114905.0  ...     4.978202e+05
19         42583192.5         42861640.0  ...     6.561194e+06
20          1245957.5          1249780.0  ...     4.179076e+05
21         10966550.0          8406387.5  ...     8.263305e+05
22         34129345.0         34013790.0  ...     6.823432e+06

    Mean_CO2_TRACE  Total_CO2_TRACE  CH4_diff_2015  CH4_diff_2016  \
0     5.466875e+07     2.733438e+08  -1.213126e+06  -1.184678e+06
1     8.625670e+06     4.312835e+07  -2.021130e+05  -1.841407e+05
2     1.468278e+08     7.341391e+08  -7.270532e+05  -4.596111e+05
```

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```
3     3.123650e+05     1.561825e+06   4.366756e+04   4.172507e+04
4     2.855980e+07     1.427990e+08   1.124305e+06   1.364527e+06
5     1.592455e+08     7.962276e+08  -1.639638e+06  -7.502765e+05
6     2.297534e+06     1.148767e+07   2.874263e+04   3.920729e+04
7     1.220712e+06     6.103562e+06   6.461512e+04   6.862515e+04
8     5.589421e+06     2.794710e+07   9.980661e+04   9.798967e+04
9     1.337166e+07     6.685832e+07  -5.864384e+04  -1.141667e+05
10    3.405512e+06     1.702756e+07   2.267438e+04   3.607436e+04
11    3.498203e+05     1.749102e+06   7.821511e+04   7.866559e+04
12    2.091495e+06     1.045748e+07   4.958374e+04   2.058196e+04
13    3.128696e+07     1.564348e+08  -7.267265e+04  -2.385180e+05
14    2.700775e+06     1.350388e+07   1.620268e+04   1.222789e+04
15    2.283318e+06     1.141659e+07   4.851434e+04   7.605209e+04
16    1.361592e+07     6.807960e+07  -1.017138e+05  -2.132304e+05
17    9.551082e+06     4.775541e+07   1.214609e+06   1.116937e+06
18    2.489101e+06     1.244551e+07  -3.149836e+04  -8.334231e+03
19    3.280597e+07     1.640298e+08   1.604559e+05  -7.766539e+04
20    2.089538e+06     1.044769e+07  -3.283086e+04  -3.105319e+04
21    4.131652e+06     2.065826e+07   2.035956e+05   2.768044e+05
22    3.411716e+07     1.705858e+08   3.573139e+04  -1.186027e+05

    CH4_diff_2017 CH4_diff_2018  CH4_diff_2019  CH4_diff_means  \
0   -9.444266e+05 -9.966395e+05  -9.262397e+05   -1.053022e+06
1   -2.421944e+05 -2.500878e+05  -2.183865e+05   -2.193845e+05
2   -9.549420e+05 -1.117892e+05  -3.888972e+05   -5.284585e+05
3    4.205941e+04  3.887090e+04   4.061526e+04    4.138764e+04
4    1.463758e+06  1.228632e+06   9.909364e+05    1.234432e+06
5   -1.607660e+06 -1.928643e+06  -2.880139e+06   -1.761271e+06
6   -8.968572e+03  5.179159e+03   1.101412e+03    1.305238e+04
7    6.356621e+04  6.476478e+04   6.522596e+04    6.535944e+04
8    5.280682e+04  1.674198e+05   8.737617e+04    1.010798e+05
9    2.204082e+04 -7.989830e+04  -1.263488e+05   -7.140337e+04
10   1.216747e+04  2.555698e+04   2.048269e+04    2.339118e+04
11   8.226007e+04  7.323685e+04   6.239492e+04    7.495451e+04
12   2.533789e+04  2.085986e+04   1.739542e+04    2.675177e+04
13  -1.181398e+05 -2.535969e+05  -1.737880e+05   -1.713431e+05
14   1.152724e+04  1.858597e+04   1.682512e+04    1.507378e+04
15   8.176160e+04  6.188328e+04   3.979186e+04    6.160063e+04
16  -1.311808e+05 -5.982552e+04  -2.280997e+05   -1.468100e+05
17   1.226180e+06  1.188527e+06   1.197771e+06    1.188805e+06
18  -2.394946e+04 -2.682481e+03  -1.361362e+04   -1.601563e+04
19   5.497665e+05  7.863316e+05   2.487897e+05    3.335357e+05
20  -3.706514e+04 -3.196741e+04  -4.075670e+04   -3.473466e+04
21   1.677756e+05  2.464521e+05   1.810014e+05    2.151258e+05
22  -4.588520e+04  1.877621e+04   4.868034e+04   -1.226000e+04

    CH4_diff_totals
0     -5.265110e+06
1     -1.096923e+06
2     -2.642293e+06
3      2.069382e+05
4      6.172158e+06
5     -8.806357e+06
6      6.526191e+04
7      3.267972e+05
8      5.053990e+05
```

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```
9     -3.570168e+05
10     1.169559e+05
11     3.747725e+05
12     1.337589e+05
13    -8.567154e+05
14     7.536891e+04
15     3.080032e+05
16    -7.340502e+05
17     5.944023e+06
18    -8.007815e+04
19     1.667678e+06
20    -1.736733e+05
21     1.075629e+06
22    -6.129998e+04

[23 rows x 38 columns]
```

5.7.4 Calculate difference in C02 Tonnes Between the Estimates

```
# Calculate Difference in tons
merged_df['CO2_diff_2015'] = merged_df['tCO2_2015_FAOSTAT'] - merged_df['tCO2_2015_
 ↪TRACE']
merged_df['CO2_diff_2016'] = merged_df['tCO2_2016_FAOSTAT'] - merged_df['tCO2_2016_
 ↪TRACE']
merged_df['CO2_diff_2017'] = merged_df['tCO2_2017_FAOSTAT'] - merged_df['tCO2_2017_
 ↪TRACE']
merged_df['CO2_diff_2018'] = merged_df['tCO2_2018_FAOSTAT'] - merged_df['tCO2_2018_
 ↪TRACE']
merged_df['CO2_diff_2019'] = merged_df['tCO2_2019_FAOSTAT'] - merged_df['tCO2_2019_
 ↪TRACE']
merged_df['CO2_diff_means'] = merged_df['Mean_CO2_FAOSTAT'] - merged_df['Mean_CO2_
 ↪TRACE']
merged_df['CO2_diff_totals'] = merged_df['Total_CO2_FAOSTAT'] - merged_df['Total_CO2_
 ↪TRACE']
```

5.7.5 Calculating the CH4 Percent Differences Between the Estimates

```
## Calculate Percent Differnces on this data set )*100
# With raw data i could have accomplished this with a groupby.aggregate(lambda x ),␣
 ↪however the pivot tables given are not easy to apply #vectorized functions across␣
 ↪time series
merged_df['CH4_abs_percent_diff_2015'] = ((abs(merged_df[2015] - merged_df['tCH4_2015
 ↪'']))/((merged_df[2015] + merged_df['tCH4_2015'])/2))*100
merged_df['CH4_abs_percent_diff_2016'] = ((abs((merged_df[2016] - merged_df['tCH4_2016
 ↪'']))/((merged_df[2016] + merged_df['tCH4_2016'])/2)))*100
merged_df['CH4_abs_percent_diff_2017'] = ((abs(merged_df[2017] - merged_df['tCH4_2017
 ↪'']))/((merged_df[2017] + merged_df['tCH4_2017'])/2))*100
merged_df['CH4_abs_percent_diff_2018'] = (abs((merged_df[2018] - merged_df['tCH4_2018
 ↪'']))/((merged_df[2018] + merged_df['tCH4_2018'])/2))*100
merged_df['CH4_abs_percent_diff_2019'] = (abs((merged_df[2019] - merged_df['tCH4_2019
 ↪'']))/((merged_df[2019] + merged_df['tCH4_2019'])/2))*100
```

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```
merged_df['CH4_abs_percent_diff_means'] = (abs((merged_df['Mean_CH4_FAOSTAT'] -␣
 ↪merged_df['Mean_CH4_TRACE']))/((merged_df['Mean_CH4_FAOSTAT'] + merged_df['Mean_CH4_
 ↪TRACE'])/2))* 100
merged_df['CH4_abs_percent_diff_totals'] = (abs((merged_df['Total_CH4_FAOSTAT'] -␣
 ↪merged_df['Total_CH4_TRACE']))/((merged_df['Total_CH4_TRACE'] + merged_df['Total_
 ↪CH4_FAOSTAT'])/2))*100


merged_df['CH4_relative_percent_diff_2015'] = ((merged_df[2015] - merged_df['tCH4_2015
 ↪'])/(merged_df[2015]))*100
merged_df['CH4_relative_percent_diff_2016'] = ((merged_df[2016] - merged_df['tCH4_2016
 ↪'])/(merged_df[2016]))*100
merged_df['CH4_relative_percent_diff_2017'] = ((merged_df[2017] - merged_df['tCH4_2017
 ↪'])/(merged_df[2017]))*100
merged_df['CH4_relative_percent_diff_2018'] = ((merged_df[2018] - merged_df['tCH4_2018
 ↪'])/(merged_df[2018]))*100
merged_df['CH4_relative_percent_diff_2019'] = ((merged_df[2019] - merged_df['tCH4_2019
 ↪'])/(merged_df[2019]))*100
merged_df['CH4_relative_percent_diff_means'] = ((merged_df['Mean_CH4_FAOSTAT'] -␣
 ↪merged_df['Mean_CH4_TRACE'])/(merged_df["Mean_CH4_FAOSTAT"]))*100
merged_df['CH4_relative_percent_diff_totals'] = ((merged_df['Total_CH4_FAOSTAT'] -␣
 ↪merged_df['Total_CH4_TRACE'])/(merged_df["Total_CH4_FAOSTAT"]))*100
```

5.7.6 Calculate CO2 Differences

```
## Calculate Percent Differnces on this data set )*100
# With raw data i could have accomplished this with a groupby.aggregate(lambda x ),␣
 ↪however the pivot tables given are not easy to apply #vectorized functions across␣
 ↪time series
merged_df['CO2_abs_percent_diff_2015'] = (abs((merged_df['tCO2_2015_FAOSTAT'] -␣
 ↪merged_df['tCO2_2015_TRACE']))/((merged_df['tCO2_2015_TRACE'] + merged_df['tCO2_
 ↪2015_FAOSTAT'])/2))*100
merged_df['CO2_abs_percent_diff_2016'] = ((abs(merged_df['tCO2_2016_FAOSTAT'] -␣
 ↪merged_df['tCO2_2016_TRACE']))/((merged_df['tCO2_2016_TRACE'] + merged_df['tCO2_
 ↪2016_FAOSTAT'])/2))*100
merged_df['CO2_abs_percent_diff_2017'] = ((abs(merged_df['tCO2_2017_FAOSTAT'] -␣
 ↪merged_df['tCO2_2017_TRACE']))/((merged_df['tCO2_2017_TRACE'] + merged_df['tCO2_
 ↪2017_FAOSTAT'])/2))*100
merged_df['CO2_abs_percent_diff_2018'] = ((abs(merged_df['tCO2_2018_FAOSTAT'] -␣
 ↪merged_df['tCO2_2018_TRACE']))/((merged_df['tCO2_2018_TRACE'] + merged_df['tCO2_
 ↪2018_FAOSTAT'])/2))*100
merged_df['CO2_abs_percent_diff_2019'] = ((abs(merged_df['tCO2_2019_FAOSTAT'] -␣
 ↪merged_df['tCO2_2019_TRACE']))/((merged_df['tCO2_2019_TRACE'] + merged_df['tCO2_
 ↪2019_FAOSTAT'])/2))*100
merged_df['CO2_abs_percent_diff_means'] = ((abs(merged_df['Mean_CO2_FAOSTAT'] -␣
 ↪merged_df['Mean_CO2_TRACE']))/((merged_df['Mean_CO2_FAOSTAT'] + merged_df['Mean_CO2_
 ↪TRACE'])/2))* 100
merged_df['CO2_abs_percent_diff_totals'] = ((abs(merged_df['Total_CO2_FAOSTAT'] -␣
 ↪merged_df['Total_CO2_TRACE']))/((merged_df['Total_CO2_TRACE'] + merged_df['Total_
 ↪CO2_FAOSTAT'])/2))*100


merged_df['CO2_relative_percent_diff_2015'] = ((merged_df['tCO2_2015_FAOSTAT']  -␣
 ↪merged_df['tCO2_2015_TRACE'])/(merged_df['tCO2_2015_FAOSTAT']))*100
```

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```
merged_df['CO2_relative_percent_diff_2016'] = ((merged_df['tCO2_2016_FAOSTAT']  -␣
 ↪merged_df['tCO2_2016_TRACE'])/(merged_df['tCO2_2016_FAOSTAT']))*100
merged_df['CO2_relative_percent_diff_2017'] = ((merged_df['tCO2_2017_FAOSTAT']  -␣
 ↪merged_df['tCO2_2017_TRACE'])/(merged_df['tCO2_2017_FAOSTAT']))*100
merged_df['CO2_relative_percent_diff_2018'] = ((merged_df['tCO2_2018_FAOSTAT']  -␣
 ↪merged_df['tCO2_2018_TRACE'])/(merged_df['tCO2_2018_FAOSTAT']))*100
merged_df['CO2_relative_percent_diff_2019'] = ((merged_df['tCO2_2019_FAOSTAT']  -␣
 ↪merged_df['tCO2_2019_TRACE'])/(merged_df['tCO2_2019_FAOSTAT']))*100
merged_df['CO2_relative_percent_diff_means'] = ((merged_df["Mean_CO2_FAOSTAT"] -␣
 ↪merged_df['Mean_CO2_TRACE'])/(merged_df["Mean_CO2_FAOSTAT"]))*100
merged_df['CO2_relative_percent_diff_totals'] = ((merged_df['Total_CO2_FAOSTAT'] -␣
 ↪merged_df['Total_CO2_TRACE'])/(merged_df["Total_CO2_FAOSTAT"]))*100
```

```
merged_df
```

	iso3_country	country_name_FAOSTAT	2015	2016	2017	2018	2019	tCO2_2015_FAOSTAT
0	BGD	Bangladesh	1131293.4	1093480.4	1154531.0	1144591.0	1144745.4	28282335.0
1	BRA	Brazil	138910.3	126278.2	130322.9	121615.2	111084.8	3472757.5
2	CHN	China	5406593.9	5399920.0	5400129.0	5302173.1	5214454.7	135164847.5
3	ESP	Spain	55082.2	55073.1	54232.4	52925.0	52098.5	1377055.0
4	IDN	Indonesia	2407953.5	2387656.4	2425290.6	2405613.8	2257604.3	60198837.5
5	IND	India	4580248.4	4559136.4	4620790.8	4661154.9	4621416.8	114506210.0
6	IRN	Iran (Islamic Republic of)	116486.7	131008.5	87233.6	93936.6	96103.4	2912167.5
7	ITA	Italy	114574.8	118003.0	118003.0	109463.8	110895.1	2864370.0
8	JPN	Japan	330353.1	326403.0	323700.3	322245.0	320581.8	8258827.5
9	KHM	Cambodia	436826.0	459003.1	473745.3	479362.7	468378.9	10920650.0
10	KOR	Korea (the Republic of)	167862.2	163534.1	158489.7	154911.3	153260.9	4196555.0
11	LAO	Lao People's Democratic Republic (the)	94826.8	95630.0	93940.7	83333.6	77005.5	2370670.0
12	LKA	Sri Lanka	132640.0	121756.3	84456.3	111049.0	102156.3	3316000.0
13	MMR	Myanmar	1059409.6	1052287.7	1087029.5	1118850.0	1083100.3	26485240.0

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```
14   123232.8   122656.3   125238.5   122453.8          3048565.0
15   142723.7   162574.6   153890.8   156215.4          3731555.0
16   381361.8   406083.3   393404.2   424755.1          9588232.5
17  1524292.5  1609862.5  1606047.8  1556225.8         38945265.0
18    83442.3    84596.2    83943.3    82937.0          2070582.5
19  1703327.7  1714465.6  1702989.1  1553835.5         38856350.0
20    49838.3    49991.2    49414.1    49152.0          1145967.5
21   438662.0   336255.5   412177.5   350136.5          9118200.0
22  1365173.8  1360551.6  1336231.2  1318431.1         34543610.0

    tCO2_2016_FAOSTAT  tCO2_2017_FAOSTAT  ...  CO2_abs_percent_diff_2019  \
0          27337010.0         28863275.0  ...                  57.606797
1           3156955.0          3258072.5  ...                  99.141295
2         134998000.0        135003225.0  ...                   7.189945
3           1376827.5          1355810.0  ...                 127.757634
4          59691410.0         60632265.0  ...                  56.234955
5         113978410.0        115519770.0  ...                  47.515394
6           3275212.5          2180840.0  ...                   1.152675
7           2950075.0          2950075.0  ...                  83.321649
8           8160075.0          8092507.5  ...                  31.555853
9          11475077.5         11843632.5  ...                  23.769728
10          4088352.5          3962242.5  ...                  14.321600
11          2390750.0          2348517.5  ...                 136.209544
12          3043907.5          2111407.5  ...                  18.612972
13         26307192.5         27175737.5  ...                  14.853751
14          3080820.0          3066407.5  ...                  14.753544
15          3568092.5          4064365.0  ...                  29.190154
16          9534045.0         10152082.5  ...                  42.334367
17         38107312.5         40246562.5  ...                 125.114417
18          2086057.5          2114905.0  ...                  15.169422
19         42583192.5         42861640.0  ...                  17.404685
20          1245957.5          1249780.0  ...                  58.617135
21         10966550.0          8406387.5  ...                  69.713577
22         34129345.0         34013790.0  ...                   3.761740

    CO2_abs_percent_diff_means  CO2_abs_percent_diff_totals  \
0                    63.425917                    63.425917
1                    93.222402                    93.222402
2                     9.421813                     9.421813
3                   124.705066                   124.705066
4                    70.153790                    70.153790
5                    32.086209                    32.086209
6                    13.260902                    13.260902
7                    80.187551                    80.187551
8                    36.874729                    36.874729
9                    14.304565                    14.304565
10                   15.813819                    15.813819
11                  145.627378                   145.627378
12                   27.569003                    27.569003
13                   14.697380                    14.697380
14                   13.043224                    13.043224
15                   50.437328                    50.437328
16                   31.154530                    31.154530
17                  121.748165                   121.748165
18                   17.492669                    17.492669
19                   22.551331                    22.551331
```

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```
20                   52.458032                   52.458032
21                   78.850049                   78.850049
22                    0.902428                    0.902428

    CO2_relative_percent_diff_2015  CO2_relative_percent_diff_2016  \
0                      -107.233570                     -108.340089
1                      -145.498958                     -145.821472
2                       -13.447527                       -8.511442
3                        79.277072                        75.763074
4                        46.691296                        57.149216
5                       -35.798018                       -16.456550
6                        24.674600                        29.927285
7                        56.395576                        58.155426
8                        30.212099                        30.021068
9                       -13.424988                       -24.872761
10                       13.507737                        22.059230
11                       82.482067                        82.260369
12                       37.382189                        16.904226
13                       -6.859731                       -22.666619
14                       13.287137                         9.922595
15                       32.502761                        53.286238
16                      -26.520489                       -55.912882
17                       77.968948                        73.275770
18                      -38.030793                        -9.988016
19                       10.323662                        -4.559627
20                      -71.622589                       -62.307893
21                       55.821215                        63.101978
22                        2.585962                        -8.687738

    CO2_relative_percent_diff_2017 CO2_relative_percent_diff_2018  \
0                      -81.801753                      -87.073857
1                     -185.841820                     -205.638590
2                      -17.683689                       -2.108366
3                       77.554025                        73.445258
4                       60.353916                        51.073546
5                      -34.791882                       -41.376939
6                      -10.281098                         5.513463
7                       53.868303                        59.165480
8                       16.313490                        51.954183
9                        4.652461                       -16.667610
10                       7.677136                        16.497815
11                      87.565950                        87.883944
12                      30.001182                        18.784377
13                     -10.868129                       -22.665852
14                       9.398001                        14.840462
15                      50.291743                        40.212459
16                     -32.303912                       -15.207139
17                      76.166725                        74.003201
18                     -28.310326                        -3.195586
19                      32.066348                        46.173612
20                     -74.143329                       -64.692890
21                      49.895259                        59.792699
22                      -3.372544                         1.405162

    CO2_relative_percent_diff_2019  CO2_relative_percent_diff_means  \
0                      -80.912284                      -92.881337
```

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```
1                       -196.594424                       -174.610414
2                         -7.458060                         -9.887609
3                         77.958601                         76.811284
4                         43.893273                         51.936188
5                        -62.321563                        -38.217479
6                          1.146070                         12.436318
7                         58.817707                         57.238482
8                         27.255501                         31.134372
9                        -26.975760                        -15.406481
10                        13.364589                         14.655057
11                        81.026578                         84.268427
12                        17.028241                         24.229137
13                       -16.045425                        -15.863111
14                        13.739977                         12.244674
15                        25.472433                         40.279401
16                       -53.701452                        -36.903009
17                        76.966391                         75.679166
18                       -16.414407                        -19.169278
19                        16.011325                         20.266184
20                       -82.919716                        -71.109302
21                        51.694526                         56.553728
22                         3.692293                         -0.906518

    CO2_relative_percent_diff_totals
0                          -92.881337
1                         -174.610414
2                           -9.887609
3                            76.811284
4                            51.936188
5                           -38.217479
6                            12.436318
7                            57.238482
8                            31.134372
9                           -15.406481
10                           14.655057
11                           84.268427
12                           24.229137
13                          -15.863111
14                           12.244674
15                           40.279401
16                          -36.903009
17                           75.679166
18                          -19.169278
19                           20.266184
20                          -71.109302
21                           56.553728
22                           -0.906518

[23 rows x 73 columns]
```

5.7.7 Recalculate Means

```
merged_df.loc['mean'] = merged_df.select_dtypes(np.number).mean()
```

```
merged_df.at['mean','country_name_FAOSTAT'] = 'mean'
merged_df.at['mean','country_name_TRACE'] = 'mean'
```

```
merged_df
```

```
     iso3_country                          country_name_FAOSTAT       2015  \
0             BGD                                    Bangladesh  1131293.4
1             BRA                                        Brazil   138910.3
2             CHN                                         China  5406593.9
3             ESP                                         Spain    55082.2
4             IDN                                     Indonesia  2407953.5
5             IND                                         India  4580248.4
6             IRN                  Iran (Islamic Republic of)   116486.7
7             ITA                                         Italy   114574.8
8             JPN                                         Japan   330353.1
9             KHM                                      Cambodia   436826.0
10            KOR                   Korea (the Republic of)   167862.2
11            LAO       Lao People's Democratic Republic (the)    94826.8
12            LKA                                    Sri Lanka   132640.0
13            MMR                                      Myanmar  1059409.6
14            MYS                                     Malaysia   121942.6
15            NPL                                        Nepal   149262.2
16            PAK                                     Pakistan   383529.3
17            PHL                               Philippines (the)  1557810.6
18            PRK  Korea (the Democratic People's Republic of)    82823.3
19            THA                                     Thailand  1554254.0
20            TWN                  Taiwan (Province of China)    45838.7
21            USA               United States of America (the)   364728.0
22            VNM                                     Viet Nam  1381744.4
mean          NaN                                         mean   948478.0

              2016          2017          2018          2019  \
0     1.093480e+06  1.154531e+06  1.144591e+06  1.144745e+06
1     1.262782e+05  1.303229e+05  1.216152e+05  1.110848e+05
2     5.399920e+06  5.400129e+06  5.302173e+06  5.214455e+06
3     5.507310e+04  5.423240e+04  5.292500e+04  5.209850e+04
4     2.387656e+06  2.425291e+06  2.405614e+06  2.257604e+06
5     4.559136e+06  4.620791e+06  4.661155e+06  4.621417e+06
6     1.310085e+05  8.723360e+04  9.393660e+04  9.610340e+04
7     1.180030e+05  1.180030e+05  1.094638e+05  1.108951e+05
8     3.264030e+05  3.237003e+05  3.222450e+05  3.205818e+05
9     4.590031e+05  4.737453e+05  4.793627e+05  4.683789e+05
10    1.635341e+05  1.584897e+05  1.549113e+05  1.532609e+05
11    9.563000e+04  9.394070e+04  8.333360e+04  7.700550e+04
12    1.217563e+05  8.445630e+04  1.110490e+05  1.021563e+05
13    1.052288e+06  1.087030e+06  1.118850e+06  1.083100e+06
14    1.232328e+05  1.226563e+05  1.252385e+05  1.224538e+05
15    1.427237e+05  1.625746e+05  1.538908e+05  1.562154e+05
16    3.813618e+05  4.060833e+05  3.934042e+05  4.247551e+05
17    1.524292e+06  1.609862e+06  1.606048e+06  1.556226e+06
18    8.344230e+04  8.459620e+04  8.394330e+04  8.293700e+04
```

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```
19    1.703328e+06  1.714466e+06  1.702989e+06  1.553836e+06
20    4.983830e+04  4.999120e+04  4.941410e+04  4.915200e+04
21    4.386620e+05  3.362555e+05  4.121775e+05  3.501365e+05
22    1.365174e+06  1.360552e+06  1.336231e+06  1.318431e+06
mean  9.522272e+05  9.590840e+05  9.575896e+05  9.316100e+05

      tCO2_2015_FAOSTAT  tCO2_2016_FAOSTAT  tCO2_2017_FAOSTAT  ...  \
0            28282335.0       2.733701e+07       2.886328e+07  ...
1             3472757.5       3.156955e+06       3.258072e+06  ...
2           135164847.5       1.349980e+08       1.350032e+08  ...
3             1377055.0       1.376828e+06       1.355810e+06  ...
4            60198837.5       5.969141e+07       6.063226e+07  ...
5           114506210.0       1.139784e+08       1.155198e+08  ...
6             2912167.5       3.275212e+06       2.180840e+06  ...
7             2864370.0       2.950075e+06       2.950075e+06  ...
8             8258827.5       8.160075e+06       8.092508e+06  ...
9            10920650.0       1.147508e+07       1.184363e+07  ...
10            4196555.0       4.088352e+06       3.962243e+06  ...
11            2370670.0       2.390750e+06       2.348518e+06  ...
12            3316000.0       3.043908e+06       2.111408e+06  ...
13           26485240.0       2.630719e+07       2.717574e+07  ...
14            3048565.0       3.080820e+06       3.066408e+06  ...
15            3731555.0       3.568093e+06       4.064365e+06  ...
16            9588232.5       9.534045e+06       1.015208e+07  ...
17           38945265.0       3.810731e+07       4.024656e+07  ...
18            2070582.5       2.086058e+06       2.114905e+06  ...
19           38856350.0       4.258319e+07       4.286164e+07  ...
20            1145967.5       1.245958e+06       1.249780e+06  ...
21            9118200.0       1.096655e+07       8.406388e+06  ...
22           34543610.0       3.412934e+07       3.401379e+07  ...
mean         23711950.0       2.380568e+07       2.397710e+07  ...

      CO2_abs_percent_diff_2019  CO2_abs_percent_diff_means  \
0                     57.606797                   63.425917
1                     99.141295                   93.222402
2                      7.189945                    9.421813
3                    127.757634                  124.705066
4                     56.234955                   70.153790
5                     47.515394                   32.086209
6                      1.152675                   13.260902
7                     83.321649                   80.187551
8                     31.555853                   36.874729
9                     23.769728                   14.304565
10                    14.321600                   15.813819
11                   136.209544                  145.627378
12                    18.612972                   27.569003
13                    14.853751                   14.697380
14                    14.753544                   13.043224
15                    29.190154                   50.437328
16                    42.334367                   31.154530
17                   125.114417                  121.748165
18                    15.169422                   17.492669
19                    17.404685                   22.551331
20                    58.617135                   52.458032
21                    69.713577                   78.850049
22                     3.761740                    0.902428
```

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```
mean                   47.621862                    49.129925

      CO2_abs_percent_diff_totals  CO2_relative_percent_diff_2015  \
0                       63.425917                     -107.233570
1                       93.222402                     -145.498958
2                        9.421813                      -13.447527
3                      124.705066                       79.277072
4                       70.153790                       46.691296
5                       32.086209                      -35.798018
6                       13.260902                       24.674600
7                       80.187551                       56.395576
8                       36.874729                       30.212099
9                       14.304565                      -13.424988
10                      15.813819                       13.507737
11                     145.627378                       82.482067
12                      27.569003                       37.382189
13                      14.697380                       -6.859731
14                      13.043224                       13.287137
15                      50.437328                       32.502761
16                      31.154530                      -26.520489
17                     121.748165                       77.968948
18                      17.492669                      -38.030793
19                      22.551331                       10.323662
20                      52.458032                      -71.622589
21                      78.850049                       55.821215
22                       0.902428                        2.585962
mean                    49.129925                        4.551116

      CO2_relative_percent_diff_2016  CO2_relative_percent_diff_2017  \
0                       -108.340089                      -81.801753
1                       -145.821472                     -185.841820
2                         -8.511442                      -17.683689
3                         75.763074                       77.554025
4                         57.149216                       60.353916
5                        -16.456550                      -34.791882
6                         29.927285                      -10.281098
7                         58.155426                       53.868303
8                         30.021068                       16.313490
9                        -24.872761                        4.652461
10                        22.059230                        7.677136
11                        82.260369                       87.565950
12                        16.904226                       30.001182
13                       -22.666619                      -10.868129
14                         9.922595                        9.398001
15                        53.286238                       50.291743
16                       -55.912882                      -32.303912
17                        73.275770                       76.166725
18                        -9.988016                      -28.310326
19                        -4.559627                       32.066348
20                       -62.307893                      -74.143329
21                        63.101978                       49.895259
22                        -8.687738                       -3.372544
mean                       4.508756                        3.322003

     CO2_relative_percent_diff_2018  CO2_relative_percent_diff_2019  \
0                       -87.073857                      -80.912284
```

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```
1                        -205.638590                    -196.594424
2                          -2.108366                      -7.458060
3                          73.445258                      77.958601
4                          51.073546                      43.893273
5                         -41.376939                     -62.321563
6                           5.513463                       1.146070
7                          59.165480                      58.817707
8                          51.954183                      27.255501
9                         -16.667610                     -26.975760
10                         16.497815                      13.364589
11                         87.883944                      81.026578
12                         18.784377                      17.028241
13                        -22.665852                     -16.045425
14                         14.840462                      13.739977
15                         40.212459                      25.472433
16                        -15.207139                     -53.701452
17                         74.003201                      76.966391
18                         -3.195586                     -16.414407
19                         46.173612                      16.011325
20                        -64.692890                     -82.919716
21                         59.792699                      51.694526
22                          1.405162                       3.692293
mean                        6.179080                      -1.533721

      CO2_relative_percent_diff_means  CO2_relative_percent_diff_totals
0                          -92.881337                       -92.881337
1                         -174.610414                      -174.610414
2                           -9.887609                        -9.887609
3                           76.811284                        76.811284
4                           51.936188                        51.936188
5                          -38.217479                       -38.217479
6                           12.436318                        12.436318
7                           57.238482                        57.238482
8                           31.134372                        31.134372
9                          -15.406481                       -15.406481
10                          14.655057                        14.655057
11                          84.268427                        84.268427
12                          24.229137                        24.229137
13                         -15.863111                       -15.863111
14                          12.244674                        12.244674
15                          40.279401                        40.279401
16                         -36.903009                       -36.903009
17                          75.679166                        75.679166
18                         -19.169278                       -19.169278
19                          20.266184                        20.266184
20                         -71.109302                       -71.109302
21                          56.553728                        56.553728
22                          -0.906518                        -0.906518
mean                         3.599038                         3.599038

[24 rows x 73 columns]
```

5.7.8 Recalculate Totals

```
merged_df.loc['total'] = merged_df[merged_df['country_name_FAOSTAT'] != 'mean'].
↪select_dtypes(np.number).sum()
```

```
merged_df.at['total','country_name_FAOSTAT'] = 'total'
merged_df.at['total','country_name_TRACE'] = 'total'
```

```
merged_df.reset_index(inplace=True, drop = True)
```

```
merged_df
```

```
   iso3_country                          country_name_FAOSTAT        2015  \
0           BGD                                    Bangladesh   1131293.4
1           BRA                                        Brazil    138910.3
2           CHN                                         China   5406593.9
3           ESP                                         Spain     55082.2
4           IDN                                     Indonesia   2407953.5
5           IND                                         India   4580248.4
6           IRN                  Iran (Islamic Republic of)    116486.7
7           ITA                                         Italy    114574.8
8           JPN                                         Japan    330353.1
9           KHM                                      Cambodia    436826.0
10          KOR                   Korea (the Republic of)    167862.2
11          LAO       Lao People's Democratic Republic (the)     94826.8
12          LKA                                     Sri Lanka    132640.0
13          MMR                                       Myanmar   1059409.6
14          MYS                                      Malaysia    121942.6
15          NPL                                         Nepal    149262.2
16          PAK                                      Pakistan    383529.3
17          PHL                                Philippines (the)   1557810.6
18          PRK  Korea (the Democratic People's Republic of)     82823.3
19          THA                                      Thailand   1554254.0
20          TWN                   Taiwan (Province of China)     45838.7
21          USA                United States of America (the)    364728.0
22          VNM                                      Viet Nam   1381744.4
23          NaN                                          mean    948478.0
24          NaN                                         total  21814994.0

           2016          2017          2018          2019  tCO2_2015_FAOSTAT  \
0   1.093480e+06  1.154531e+06  1.144591e+06  1.144745e+06          28282335.0
1   1.262782e+05  1.303229e+05  1.216152e+05  1.110848e+05           3472757.5
2   5.399920e+06  5.400129e+06  5.302173e+06  5.214455e+06         135164847.5
3   5.507310e+04  5.423240e+04  5.292500e+04  5.209850e+04           1377055.0
4   2.387656e+06  2.425291e+06  2.405614e+06  2.257604e+06          60198837.5
5   4.559136e+06  4.620791e+06  4.661155e+06  4.621417e+06         114506210.0
6   1.310085e+05  8.723360e+04  9.393660e+04  9.610340e+04           2912167.5
7   1.180030e+05  1.180030e+05  1.094638e+05  1.108951e+05           2864370.0
8   3.264030e+05  3.237003e+05  3.222450e+05  3.205818e+05           8258827.5
9   4.590031e+05  4.737453e+05  4.793627e+05  4.683789e+05          10920650.0
10  1.635341e+05  1.584897e+05  1.549113e+05  1.532609e+05           4196555.0
11  9.563000e+04  9.394070e+04  8.333360e+04  7.700550e+04           2370670.0
12  1.217563e+05  8.445630e+04  1.110490e+05  1.021563e+05           3316000.0
13  1.052288e+06  1.087030e+06  1.118850e+06  1.083100e+06          26485240.0
```

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```
14  1.232328e+05  1.226563e+05  1.252385e+05  1.224538e+05          3048565.0
15  1.427237e+05  1.625746e+05  1.538908e+05  1.562154e+05          3731555.0
16  3.813618e+05  4.060833e+05  3.934042e+05  4.247551e+05          9588232.5
17  1.524292e+06  1.609862e+06  1.606048e+06  1.556226e+06         38945265.0
18  8.344230e+04  8.459620e+04  8.394330e+04  8.293700e+04          2070582.5
19  1.703328e+06  1.714466e+06  1.702989e+06  1.553836e+06         38856350.0
20  4.983830e+04  4.999120e+04  4.941410e+04  4.915200e+04          1145967.5
21  4.386620e+05  3.362555e+05  4.121775e+05  3.501365e+05          9118200.0
22  1.365174e+06  1.360552e+06  1.336231e+06  1.318431e+06         34543610.0
23  9.522272e+05  9.590840e+05  9.575896e+05  9.316100e+05         23711950.0
24  2.190123e+07  2.205893e+07  2.202456e+07  2.142703e+07        545374850.0

    tCO2_2016_FAOSTAT  tCO2_2017_FAOSTAT  ...  CO2_abs_percent_diff_2019  \
0        2.733701e+07       2.886328e+07  ...                  57.606797
1        3.156955e+06       3.258072e+06  ...                  99.141295
2        1.349980e+08       1.350032e+08  ...                   7.189945
3        1.376828e+06       1.355810e+06  ...                 127.757634
4        5.969141e+07       6.063226e+07  ...                  56.234955
5        1.139784e+08       1.155198e+08  ...                  47.515394
6        3.275212e+06       2.180840e+06  ...                   1.152675
7        2.950075e+06       2.950075e+06  ...                  83.321649
8        8.160075e+06       8.092508e+06  ...                  31.555853
9        1.147508e+07       1.184363e+07  ...                  23.769728
10       4.088352e+06       3.962243e+06  ...                  14.321600
11       2.390750e+06       2.348518e+06  ...                 136.209544
12       3.043908e+06       2.111408e+06  ...                  18.612972
13       2.630719e+07       2.717574e+07  ...                  14.853751
14       3.080820e+06       3.066408e+06  ...                  14.753544
15       3.568093e+06       4.064365e+06  ...                  29.190154
16       9.534045e+06       1.015208e+07  ...                  42.334367
17       3.810731e+07       4.024656e+07  ...                 125.114417
18       2.086058e+06       2.114905e+06  ...                  15.169422
19       4.258319e+07       4.286164e+07  ...                  17.404685
20       1.245958e+06       1.249780e+06  ...                  58.617135
21       1.096655e+07       8.406388e+06  ...                  69.713577
22       3.412934e+07       3.401379e+07  ...                   3.761740
23       2.380568e+07       2.397710e+07  ...                  47.621862
24       5.475306e+08       5.514733e+08  ...                1095.302835

    CO2_abs_percent_diff_means  CO2_abs_percent_diff_totals  \
0                    63.425917                    63.425917
1                    93.222402                    93.222402
2                     9.421813                     9.421813
3                   124.705066                   124.705066
4                    70.153790                    70.153790
5                    32.086209                    32.086209
6                    13.260902                    13.260902
7                    80.187551                    80.187551
8                    36.874729                    36.874729
9                    14.304565                    14.304565
10                   15.813819                    15.813819
11                  145.627378                   145.627378
12                   27.569003                    27.569003
13                   14.697380                    14.697380
14                   13.043224                    13.043224
15                   50.437328                    50.437328
```

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```
16                   31.154530                   31.154530
17                  121.748165                  121.748165
18                   17.492669                   17.492669
19                   22.551331                   22.551331
20                   52.458032                   52.458032
21                   78.850049                   78.850049
22                    0.902428                    0.902428
23                   49.129925                   49.129925
24                 1129.988279                 1129.988279

    CO2_relative_percent_diff_2015  CO2_relative_percent_diff_2016  \
0                      -107.233570                     -108.340089
1                      -145.498958                     -145.821472
2                       -13.447527                       -8.511442
3                        79.277072                       75.763074
4                        46.691296                       57.149216
5                       -35.798018                      -16.456550
6                        24.674600                       29.927285
7                        56.395576                       58.155426
8                        30.212099                       30.021068
9                       -13.424988                      -24.872761
10                       13.507737                       22.059230
11                       82.482067                       82.260369
12                       37.382189                       16.904226
13                       -6.859731                      -22.666619
14                       13.287137                        9.922595
15                       32.502761                       53.286238
16                      -26.520489                      -55.912882
17                       77.968948                       73.275770
18                      -38.030793                       -9.988016
19                       10.323662                       -4.559627
20                      -71.622589                      -62.307893
21                       55.821215                       63.101978
22                        2.585962                       -8.687738
23                        4.551116                        4.508756
24                      104.675658                      103.701389

    CO2_relative_percent_diff_2017 CO2_relative_percent_diff_2018  \
0                      -81.801753                     -87.073857
1                     -185.841820                    -205.638590
2                      -17.683689                      -2.108366
3                       77.554025                       73.445258
4                       60.353916                       51.073546
5                      -34.791882                      -41.376939
6                      -10.281098                        5.513463
7                       53.868303                       59.165480
8                       16.313490                       51.954183
9                        4.652461                      -16.667610
10                       7.677136                       16.497815
11                      87.565950                       87.883944
12                      30.001182                       18.784377
13                     -10.868129                      -22.665852
14                       9.398001                       14.840462
15                      50.291743                       40.212459
16                     -32.303912                      -15.207139
17                      76.166725                       74.003201
```

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```
18                      -28.310326                      -3.195586
19                       32.066348                      46.173612
20                      -74.143329                     -64.692890
21                       49.895259                      59.792699
22                       -3.372544                       1.405162
23                        3.322003                       6.179080
24                       76.406059                     142.118831

    CO2_relative_percent_diff_2019  CO2_relative_percent_diff_means  \
0                       -80.912284                      -92.881337
1                      -196.594424                     -174.610414
2                        -7.458060                       -9.887609
3                        77.958601                       76.811284
4                        43.893273                       51.936188
5                       -62.321563                      -38.217479
6                         1.146070                       12.436318
7                        58.817707                       57.238482
8                        27.255501                       31.134372
9                       -26.975760                      -15.406481
10                       13.364589                       14.655057
11                       81.026578                       84.268427
12                       17.028241                       24.229137
13                      -16.045425                      -15.863111
14                       13.739977                       12.244674
15                       25.472433                       40.279401
16                      -53.701452                      -36.903009
17                       76.966391                       75.679166
18                      -16.414407                      -19.169278
19                       16.011325                       20.266184
20                      -82.919716                      -71.109302
21                       51.694526                       56.553728
22                        3.692293                       -0.906518
23                       -1.533721                        3.599038
24                      -35.275585                       82.777881

    CO2_relative_percent_diff_totals
0                        -92.881337
1                       -174.610414
2                         -9.887609
3                          76.811284
4                          51.936188
5                         -38.217479
6                          12.436318
7                          57.238482
8                          31.134372
9                         -15.406481
10                         14.655057
11                         84.268427
12                         24.229137
13                        -15.863111
14                         12.244674
15                         40.279401
16                        -36.903009
17                         75.679166
18                        -19.169278
19                         20.266184
```

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```
20                          -71.109302
21                           56.553728
22                           -0.906518
23                            3.599038
24                           82.777881

[25 rows x 73 columns]
```

5.7.9 Merged Data to File

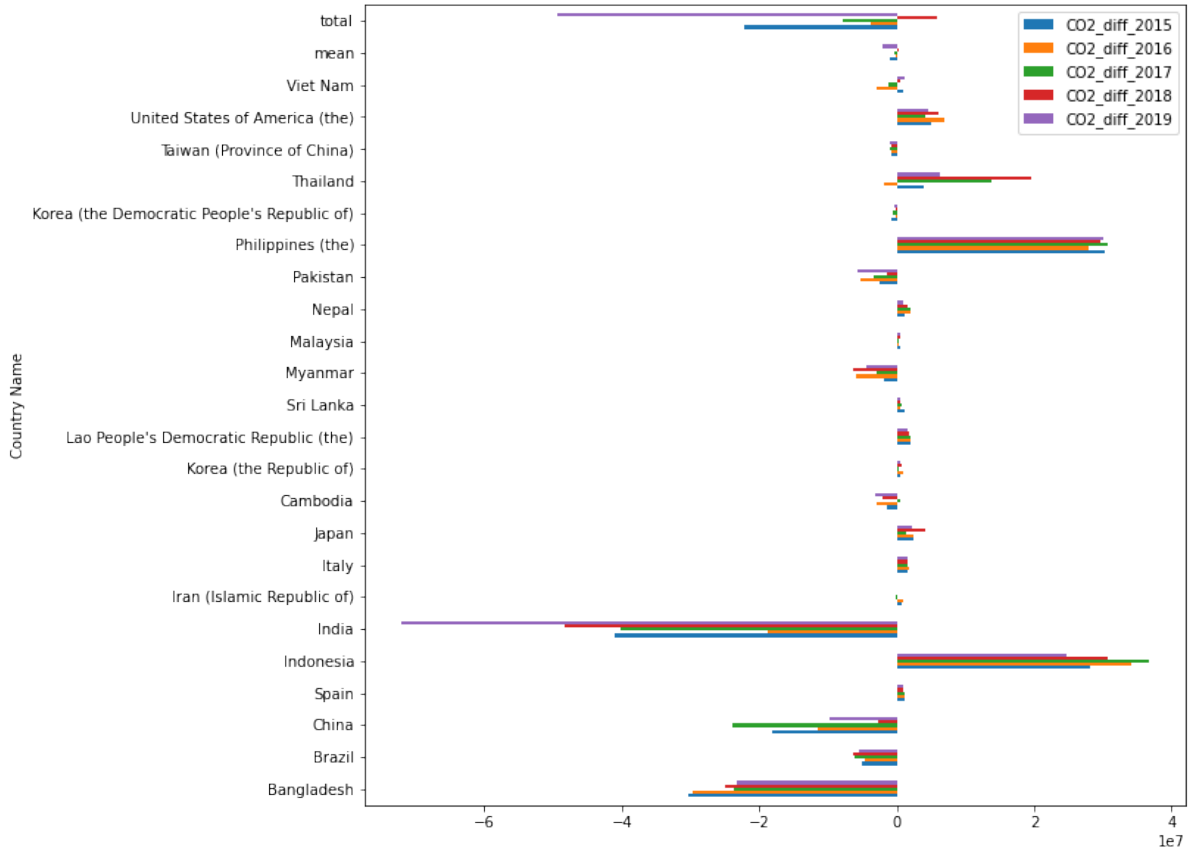
```
outfile = "/Users/jnapolitano/Projects/wattime-takehome/data/MERGED_DATA.csv"

merged_df.to_csv(outfile)
```

5.7.10 CO2 Difference Plots

```
merged_df.plot(kind = "barh", x = 'country_name_FAOSTAT', y = ["CO2_diff_2015", "CO2_
↪diff_2016",        "CO2_diff_2017", "CO2_diff_2018", "CO2_diff_2019"], xlabel =
↪"Country Name", ylabel = "Tonnes CH4", figsize = (10,10))
```

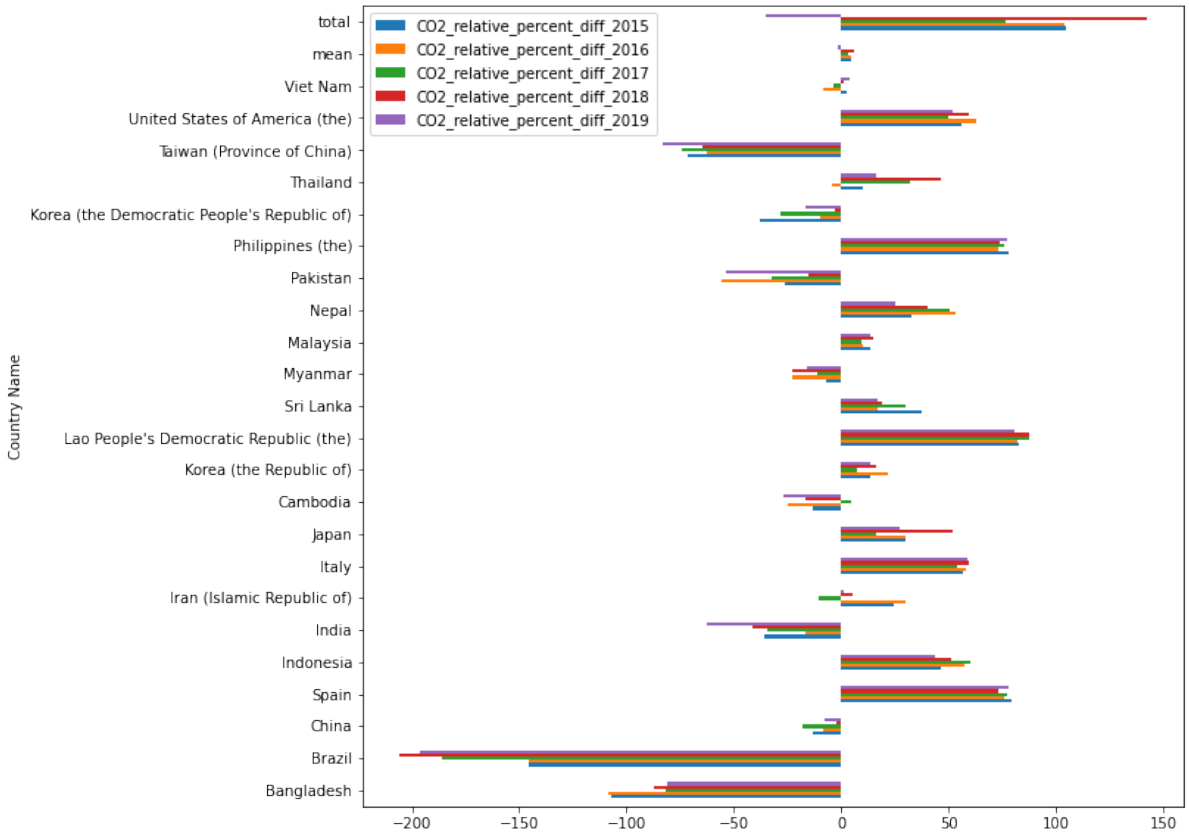
```
<AxesSubplot:ylabel='Country Name'>
```



5.7.11 Percent Difference Plot

```
merged_df.plot(kind = "barh", x = 'country_name_FAOSTAT', y = ["CO2_relative_percent_
↪diff_2015", "CO2_relative_percent_diff_2016",       "CO2_relative_percent_diff_2017
↪", "CO2_relative_percent_diff_2018", "CO2_relative_percent_diff_2019"], xlabel =
↪"Country Name", ylabel = "Tonnes CH4", figsize=(10,10))
```

```
<AxesSubplot:ylabel='Country Name'>
```



5.8 Impressions

5.8.1 Initial

The percent difference and the tonnege difference do not support each other. I need to recalculate the totals section to ensure that we are doing things correctly.

I need to confirm the values, but I'm initially impressed by the fact that the faostat data reports higher values than the malaysia data on average. According to the included paper this shold not be the case.

The quote included below states the problems with the malysia methodology.

"The difference between harvested rice cultivation area from statistical data and remote-sensing estimates can be due to two factors: (i) MODIS data which have moderate spatial resolution lead to mixed pixels, where rice fields and non-rice fields are combined. This can overestimate area, especially in lowland regions and have a low ability to detect small rice field patches in upland regions (Frolking et al 1999, Seto et al 2000); and (ii) political and policy factors (Yan et al., 2019)

such as determination of the amount of subsidies for fertilizers and evaluation of achievement of government programs in the agricultural sector. Other factors that contribute to discrepancy in CH4 emission are from different emission and scale factors that are related to water regime and organic amendment. These values give high uncertainty since the availability of these data are limited and quite variable."

Verified

I calculated differences totals and means per dataframe to ensure accuracy prior to the join. I also dropped precalcuated values when joining to ensure that the aggregation algorithms to not modify the results.

The data is now consistent and supports the findings of the University of Malaysia Paper

CHAPTER

SIX

MERGING TRACE AND FAOSTAT DATA WITH GEOGRAPHIC DATA FOR MAPPING

```
import pandas as pd
import matplotlib.pyplot as plt
import geopandas as gpd
import folium
import contextily as cx
from shapely.geometry import Point, LineString, Polygon
import numpy as np
from scipy.spatial import cKDTree
from geopy.distance import distance
import scipy.stats as stats
```

```
/Users/jnapolitano/venvs/finance/lib/python3.9/site-packages/geopandas/_compat.
 ↪py:111: UserWarning: The Shapely GEOS version (3.10.2-CAPI-1.16.0) is␣
 ↪incompatible with the GEOS version PyGEOS was compiled with (3.10.1-CAPI-1.16.0).
 ↪ Conversions between both will be slow.
  warnings.warn(
```

6.1 Shape Data

```
gisfilepath = "/Users/jnapolitano/Projects/wattime-takehome/data/country_shapefiles/
 ↪World_Countries__Generalized_.shp"


countries_df = gpd.read_file(gisfilepath)

countries_df = countries_df.to_crs(epsg=3857)
```

```
world = gpd.read_file(gpd.datasets.get_path('naturalearth_lowres'))

cities = gpd.read_file(gpd.datasets.get_path('naturalearth_cities'))
```

```
world.rename({"iso_a3" :  'iso3_country'},axis =1,inplace=True)
```

```
world
```

```
       pop_est      continent                      name iso3_country  \
0       920938        Oceania                      Fiji          FJI
1     53950935         Africa                  Tanzania          TZA
2       603253         Africa                 W. Sahara          ESH
3     35623680  North America                    Canada          CAN
4    326625791  North America  United States of America          USA
..         ...            ...                       ...          ...
172    7111024         Europe                    Serbia          SRB
173     642550         Europe                Montenegro          MNE
174    1895250         Europe                    Kosovo          -99
175    1218208  North America       Trinidad and Tobago          TTO
176   13026129         Africa                   S. Sudan          SSD

     gdp_md_est                                           geometry
0        8374.0  MULTIPOLYGON (((180.00000 -16.06713, 180.00000...
1      150600.0  POLYGON ((33.90371 -0.95000, 34.07262 -1.05982...
2         906.5  POLYGON ((-8.66559 27.65643, -8.66512 27.58948...
3     1674000.0  MULTIPOLYGON (((-122.84000 49.00000, -122.9742...
4    18560000.0  MULTIPOLYGON (((-122.84000 49.00000, -120.0000...
..          ...                                                ...
172    101800.0  POLYGON ((18.82982 45.90887, 18.82984 45.90888...
173     10610.0  POLYGON ((20.07070 42.58863, 19.80161 42.50009...
174     18490.0  POLYGON ((20.59025 41.85541, 20.52295 42.21787...
175     43570.0  POLYGON ((-61.68000 10.76000, -61.10500 10.890...
176     20880.0  POLYGON ((30.83385 3.50917, 29.95350 4.17370, ...

[177 rows x 6 columns]
```

6.2 FAOSTAT DATA

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/FAOSTAT_DATA.csv"

faostat_emissions_df = pd.read_csv(filepath)
faostat_emissions_df.drop('Unnamed: 0', axis = 1 , inplace = True)
faostat_emissions_df = faostat_emissions_df[(faostat_emissions_df["country_name"] !=
↪'Total') & (faostat_emissions_df["country_name"] != "mean")]
faostat_emissions_df.dropna(how="any", axis=1, inplace= True)
```

```
faostat_emissions_df
```

```
   iso3_country                                country_name       2015  \
0           BGD                                  Bangladesh  1131293.4
1           BRA                                      Brazil   138910.3
2           CHN                                       China  5406593.9
3           ESP                                       Spain    55082.2
4           IDN                                   Indonesia  2407953.5
5           IND                                       India  4580248.4
6           IRN                   Iran (Islamic Republic of)   116486.7
7           ITA                                       Italy   114574.8
8           JPN                                       Japan   330353.1
9           KHM                                    Cambodia   436826.0
10          KOR                      Korea (the Republic of)   167862.2
```

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```
11          LAO       Lao People's Democratic Republic (the)    94826.8
12          LKA                                    Sri Lanka   132640.0
13          MMR                                      Myanmar  1059409.6
14          MYS                                    Malaysia   121942.6
15          NPL                                       Nepal   149262.2
16          PAK                                    Pakistan   383529.3
17          PHL                              Philippines (the)  1557810.6
18          PRK  Korea (the Democratic People's Republic of)    82823.3
19          THA                                    Thailand  1554254.0
20          TWN                  Taiwan (Province of China)    45838.7
21          USA               United States of America (the)   364728.0
22          VNM                                    Viet Nam  1381744.4

         2016       2017       2018       2019    tCO2_2015    tCO2_2016  \
0   1093480.4  1154531.0  1144591.0  1144745.4   28282335.0   27337010.0
1    126278.2   130322.9   121615.2   111084.8    3472757.5    3156955.0
2   5399920.0  5400129.0  5302173.1  5214454.7  135164847.5  134998000.0
3     55073.1    54232.4    52925.0    52098.5    1377055.0    1376827.5
4   2387656.4  2425290.6  2405613.8  2257604.3   60198837.5   59691410.0
5   4559136.4  4620790.8  4661154.9  4621416.8  114506210.0  113978410.0
6    131008.5    87233.6    93936.6    96103.4    2912167.5    3275212.5
7    118003.0   118003.0   109463.8   110895.1    2864370.0    2950075.0
8    326403.0   323700.3   322245.0   320581.8    8258827.5    8160075.0
9    459003.1   473745.3   479362.7   468378.9   10920650.0   11475077.5
10   163534.1   158489.7   154911.3   153260.9    4196555.0    4088352.5
11    95630.0    93940.7    83333.6    77005.5    2370670.0    2390750.0
12   121756.3    84456.3   111049.0   102156.3    3316000.0    3043907.5
13  1052287.7  1087029.5  1118850.0  1083100.3   26485240.0   26307192.5
14   123232.8   122656.3   125238.5   122453.8    3048565.0    3080820.0
15   142723.7   162574.6   153890.8   156215.4    3731555.0    3568092.5
16   381361.8   406083.3   393404.2   424755.1    9588232.5    9534045.0
17  1524292.5  1609862.5  1606047.8  1556225.8   38945265.0   38107312.5
18    83442.3    84596.2    83943.3    82937.0    2070582.5    2086057.5
19  1703327.7  1714465.6  1702989.1  1553835.5   38856350.0   42583192.5
20    49838.3    49991.2    49414.1    49152.0    1145967.5    1245957.5
21   438662.0   336255.5   412177.5   350136.5    9118200.0   10966550.0
22  1365173.8  1360551.6  1336231.2  1318431.1   34543610.0   34129345.0

      tCO2_2017    tCO2_2018    tCO2_2019    Mean_CH4   Total_CH4  \
0    28863275.0   28614775.0   28618635.0  1133728.24   5668641.2
1     3258072.5    3040380.0    2777120.0   125642.28    628211.4
2   135003225.0  132554327.5  130361367.5  5344654.14  26723270.7
3     1355810.0    1323125.0    1302462.5    53882.24    269411.2
4    60632265.0   60140345.0   56440107.5  2376823.72  11884118.6
5   115519770.0  116528872.5  115535420.0  4608549.46  23042747.3
6     2180840.0    2348415.0    2402585.0   104953.76    524768.8
7     2950075.0    2736595.0    2772377.5   114187.94    570939.7
8     8092507.5    8056125.0    8014545.0   324656.64   1623283.2
9    11843632.5   11984067.5   11709472.5   463463.20   2317316.0
10    3962242.5    3872782.5    3831522.5   159611.64    798058.2
11    2348517.5    2083340.0    1925137.5    88947.32    444736.6
12    2111407.5    2776225.0    2553907.5   110411.58    552057.9
13   27175737.5   27971250.0   27077507.5  1080135.42   5400677.1
14    3066407.5    3130962.5    3061345.0   123104.80    615524.0
15    4064365.0    3847270.0    3905385.0   152933.34    764666.7
16   10152082.5    9835105.0   10618877.5   397826.74   1989133.7
```

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```
17   40246562.5   40151195.0   38905645.0  1570847.84   7854239.2
18    2114905.0    2098582.5    2073425.0    83548.42    417742.1
19   42861640.0   42574727.5   38845887.5  1645774.38   8228871.9
20    1249780.0    1235352.5    1228800.0    48846.86    244234.3
21    8406387.5   10304437.5    8753412.5   380391.90   1901959.5
22   34013790.0   33405780.0   32960777.5  1352426.42   6762132.1

       Mean_CO2    Total_CO2
0    28343206.0  141716030.0
1     3141057.0   15705285.0
2   133616353.5  668081767.5
3     1347056.0    6735280.0
4    59420593.0  297102965.0
5   115213736.5  576068682.5
6     2623844.0   13119220.0
7     2854698.5   14273492.5
8     8116416.0   40582080.0
9    11586580.0   57932900.0
10    3990291.0   19951455.0
11    2223683.0   11118415.0
12    2760289.5   13801447.5
13   27003385.5  135016927.5
14    3077620.0   15388100.0
15    3823333.5   19116667.5
16    9945668.5   49728342.5
17   39271196.0  196355980.0
18    2088710.5   10443552.5
19   41144359.5  205721797.5
20    1221171.5    6105857.5
21    9509797.5   47548987.5
22   33810660.5  169053302.5
```

6.2.1 FAOSTAT Country Merge

```
faostat_merged_df = world.merge(faostat_emissions_df, on='iso3_country', how='right',␣
↪sort=True)
```

```
faostat_merged_df
#trace_merged_df.dropna(axis=1, how='any')
```

```
       pop_est      continent                      name iso3_country  \
0    157826578           Asia                Bangladesh          BGD
1    207353391  South America                    Brazil          BRA
2   1379302771           Asia                     China          CHN
3     48958159         Europe                     Spain          ESP
4    260580739           Asia                 Indonesia          IDN
5   1281935911           Asia                     India          IND
6     82021564           Asia                      Iran          IRN
7     62137802         Europe                     Italy          ITA
8    126451398           Asia                     Japan          JPN
9     16204486           Asia                  Cambodia          KHM
10    51181299           Asia               South Korea          KOR
```

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```
11     7126706           Asia                       Laos          LAO
12    22409381           Asia                  Sri Lanka          LKA
13    55123814           Asia                    Myanmar          MMR
14    31381992           Asia                   Malaysia          MYS
15    29384297           Asia                      Nepal          NPL
16   204924861           Asia                   Pakistan          PAK
17   104256076           Asia                Philippines          PHL
18    25248140           Asia                North Korea          PRK
19    68414135           Asia                   Thailand          THA
20    23508428           Asia                     Taiwan          TWN
21   326625791  North America  United States of America          USA
22    96160163           Asia                    Vietnam          VNM

    gdp_md_est                                           geometry  \
0     628400.0  POLYGON ((92.67272 22.04124, 92.65226 21.32405...
1    3081000.0  POLYGON ((-53.37366 -33.76838, -53.65054 -33.2...
2   21140000.0  MULTIPOLYGON (((109.47521 18.19770, 108.65521 ...
3    1690000.0  POLYGON ((-7.45373 37.09779, -7.53711 37.42890...
4    3028000.0  MULTIPOLYGON (((141.00021 -2.60015, 141.01706 ...
5    8721000.0  POLYGON ((97.32711 28.26158, 97.40256 27.88254...
6    1459000.0  POLYGON ((48.56797 29.92678, 48.01457 30.45246...
7    2221000.0  MULTIPOLYGON (((10.44270 46.89355, 11.04856 46...
8    4932000.0  MULTIPOLYGON (((141.88460 39.18086, 140.95949 ...
9      58940.0  POLYGON ((102.58493 12.18659, 102.34810 13.394...
10   1929000.0  POLYGON ((126.17476 37.74969, 126.23734 37.840...
11     40960.0  POLYGON ((107.38273 14.20244, 106.49637 14.570...
12    236700.0  POLYGON ((81.78796 7.52306, 81.63732 6.48178, ...
13    311100.0  POLYGON ((100.11599 20.41785, 99.54331 20.1866...
14    863000.0  MULTIPOLYGON (((100.08576 6.46449, 100.25960 6...
15     71520.0  POLYGON ((88.12044 27.87654, 88.04313 27.44582...
16    988200.0  POLYGON ((77.83745 35.49401, 76.87172 34.65354...
17    801900.0  MULTIPOLYGON (((120.83390 12.70450, 120.32344 ...
18     40000.0  MULTIPOLYGON (((130.78000 42.22001, 130.78000 ...
19   1161000.0  POLYGON ((105.21878 14.27321, 104.28142 14.416...
20   1127000.0  POLYGON ((121.77782 24.39427, 121.17563 22.790...
21  18560000.0  MULTIPOLYGON (((-122.84000 49.00000, -120.0000...
22    594900.0  POLYGON ((104.33433 10.48654, 105.19991 10.889...

                                  country_name       2015       2016  \
0                                   Bangladesh  1131293.4  1093480.4
1                                       Brazil   138910.3   126278.2
2                                        China  5406593.9  5399920.0
3                                        Spain    55082.2    55073.1
4                                    Indonesia  2407953.5  2387656.4
5                                        India  4580248.4  4559136.4
6                  Iran (Islamic Republic of)   116486.7   131008.5
7                                        Italy   114574.8   118003.0
8                                        Japan   330353.1   326403.0
9                                     Cambodia   436826.0   459003.1
10                 Korea (the Republic of)   167862.2   163534.1
11  Lao People's Democratic Republic (the)    94826.8    95630.0
12                                  Sri Lanka   132640.0   121756.3
13                                    Myanmar  1059409.6  1052287.7
14                                   Malaysia   121942.6   123232.8
15                                      Nepal   149262.2   142723.7
16                                   Pakistan   383529.3   381361.8
```

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```
17                            Philippines (the)  1557810.6  1524292.5
18  Korea (the Democratic People's Republic of)    82823.3    83442.3
19                                    Thailand  1554254.0  1703327.7
20                  Taiwan (Province of China)    45838.7    49838.3
21               United States of America (the)   364728.0   438662.0
22                                    Viet Nam  1381744.4  1365173.8

        2017  ...       2019    tCO2_2015    tCO2_2016    tCO2_2017  \
0   1154531.0  ...  1144745.4   28282335.0   27337010.0   28863275.0
1    130322.9  ...   111084.8    3472757.5    3156955.0    3258072.5
2   5400129.0  ...  5214454.7  135164847.5  134998000.0  135003225.0
3     54232.4  ...    52098.5    1377055.0    1376827.5    1355810.0
4   2425290.6  ...  2257604.3   60198837.5   59691410.0   60632265.0
5   4620790.8  ...  4621416.8  114506210.0  113978410.0  115519770.0
6     87233.6  ...    96103.4    2912167.5    3275212.5    2180840.0
7    118003.0  ...   110895.1    2864370.0    2950075.0    2950075.0
8    323700.3  ...   320581.8    8258827.5    8160075.0    8092507.5
9    473745.3  ...   468378.9   10920650.0   11475077.5   11843632.5
10   158489.7  ...   153260.9    4196555.0    4088352.5    3962242.5
11    93940.7  ...    77005.5    2370670.0    2390750.0    2348517.5
12    84456.3  ...   102156.3    3316000.0    3043907.5    2111407.5
13  1087029.5  ...  1083100.3   26485240.0   26307192.5   27175737.5
14   122656.3  ...   122453.8    3048565.0    3080820.0    3066407.5
15   162574.6  ...   156215.4    3731555.0    3568092.5    4064365.0
16   406083.3  ...   424755.1    9588232.5    9534045.0   10152082.5
17  1609862.5  ...  1556225.8   38945265.0   38107312.5   40246562.5
18    84596.2  ...    82937.0    2070582.5    2086057.5    2114905.0
19  1714465.6  ...  1553835.5   38856350.0   42583192.5   42861640.0
20    49991.2  ...    49152.0    1145967.5    1245957.5    1249780.0
21   336255.5  ...   350136.5    9118200.0   10966550.0    8406387.5
22  1360551.6  ...  1318431.1   34543610.0   34129345.0   34013790.0

      tCO2_2018    tCO2_2019    Mean_CH4   Total_CH4     Mean_CO2    Total_CO2
0    28614775.0   28618635.0  1133728.24   5668641.2   28343206.0  141716030.0
1     3040380.0    2777120.0   125642.28    628211.4    3141057.0   15705285.0
2   132554327.5  130361367.5  5344654.14  26723270.7  133616353.5  668081767.5
3     1323125.0    1302462.5    53882.24    269411.2    1347056.0    6735280.0
4    60140345.0   56440107.5  2376823.72  11884118.6   59420593.0  297102965.0
5   116528872.5  115535420.0  4608549.46  23042747.3  115213736.5  576068682.5
6     2348415.0    2402585.0   104953.76    524768.8    2623844.0   13119220.0
7     2736595.0    2772377.5   114187.94    570939.7    2854698.5   14273492.5
8     8056125.0    8014545.0   324656.64   1623283.2    8116416.0   40582080.0
9    11984067.5   11709472.5   463463.20   2317316.0   11586580.0   57932900.0
10    3872782.5    3831522.5   159611.64    798058.2    3990291.0   19951455.0
11    2083340.0    1925137.5    88947.32    444736.6    2223683.0   11118415.0
12    2776225.0    2553907.5   110411.58    552057.9    2760289.5   13801447.5
13   27971250.0   27077507.5  1080135.42   5400677.1   27003385.5  135016927.5
14    3130962.5    3061345.0   123104.80    615524.0    3077620.0   15388100.0
15    3847270.0    3905385.0   152933.34    764666.7    3823333.5   19116667.5
16    9835105.0   10618877.5   397826.74   1989133.7    9945668.5   49728342.5
17   40151195.0   38905645.0  1570847.84   7854239.2   39271196.0  196355980.0
18    2098582.5    2073425.0    83548.42    417742.1    2088710.5   10443552.5
19   42574727.5   38845887.5  1645774.38   8228871.9   41144359.5  205721797.5
20    1235352.5    1228800.0    48846.86    244234.3    1221171.5    6105857.5
21   10304437.5    8753412.5   380391.90   1901959.5    9509797.5   47548987.5
22   33405780.0   32960777.5  1352426.42   6762132.1   33810660.5  169053302.5
```

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```
[23 rows x 21 columns]
```

```
faostat_merged_df = faostat_merged_df[faostat_merged_df['continent'] != 'Antarctica'].
↪copy()
```

6.2.2 FAOSTAT Merge to File

```
gisout = "/Users/jnapolitano/Projects/wattime-takehome/data/FAOSTAT_GEO.geojson"
faostat_merged_df.to_file(gisout, driver="GeoJSON")
```

```
/Users/jnapolitano/venvs/finance/lib/python3.9/site-packages/geopandas/io/file.
↪py:362: FutureWarning: pandas.Int64Index is deprecated and will be removed from␣
↪pandas in a future version. Use pandas.Index with the appropriate dtype instead.
  pd.Int64Index,
```

6.3 TRACE Data

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/TRACE_DATA.csv"

trace_emissions_df = pd.read_csv(filepath)
trace_emissions_df.drop('Unnamed: 0', axis = 1 , inplace = True)
trace_emissions_df = trace_emissions_df[(trace_emissions_df["country_name"] != 'Total
↪') & (trace_emissions_df["country_name"] != "mean")]
```

```
trace_emissions_df
```

```
   iso3_country                                country_name     tCH4_2015  \
0           BGD                                  Bangladesh  2.344420e+06
1           BRA                                      Brazil  3.410233e+05
2           CHN                                       China  6.133647e+06
3           ESP                                       Spain  1.141464e+04
4           IDN                                   Indonesia  1.283649e+06
5           IND                                       India  6.219887e+06
6           IRN                    Iran (Islamic Republic of)  8.774407e+04
7           ITA                                       Italy  4.995968e+04
8           JPN                                       Japan  2.305465e+05
9           KHM                                    Cambodia  4.954698e+05
10          KOR                      Korea (the Republic of)  1.451878e+05
11          LAO       Lao People's Democratic Republic (the)  1.661169e+04
12          LKA                                   Sri Lanka  8.305626e+04
13          MMR                                     Myanmar  1.132082e+06
14          MYS                                    Malaysia  1.057399e+05
15          NPL                                       Nepal  1.007479e+05
16          PAK                                    Pakistan  4.852431e+05
17          PHL                                Philippines (the)  3.432021e+05
18          PRK  Korea (the Democratic People's Republic of)  1.143217e+05
```

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```
19          THA                                    Thailand  1.393798e+06
20          TWN                 Taiwan (Province of China)  7.866956e+04
21          USA               United States of America (the)  1.611324e+05
22          VNM                                   Viet Nam  1.346013e+06

      tCH4_2016     tCH4_2017     tCH4_2018     tCH4_2019     tCH4_2020  \
0   2.278158e+06  2.098958e+06  2.141231e+06  2.070985e+06  2.106781e+06
1   3.104189e+05  3.725173e+05  3.717030e+05  3.294713e+05  4.902874e+05
2   5.859531e+06  6.355071e+06  5.413962e+06  5.603352e+06  6.402353e+06
3   1.334803e+04  1.217299e+04  1.405410e+04  1.148324e+04  1.305461e+04
4   1.023129e+06  9.615327e+05  1.176982e+06  1.266668e+06  1.188195e+06
5   5.309413e+06  6.228451e+06  6.589798e+06  7.501556e+06  7.599764e+06
6   9.180121e+04  9.620217e+04  8.875744e+04  9.500199e+04  9.600254e+04
7   4.937785e+04  5.443679e+04  4.469902e+04  4.566914e+04  5.101547e+04
8   2.284133e+05  2.708935e+05  1.548252e+05  2.332056e+05  2.835167e+05
9   5.731698e+05  4.517045e+05  5.592610e+05  5.947277e+05  6.412802e+05
10  1.274597e+05  1.463222e+05  1.293543e+05  1.327782e+05  1.165467e+05
11  1.696441e+04  1.168063e+04  1.009675e+04  1.461058e+04  2.136270e+04
12  1.011743e+05  5.911841e+04  9.018914e+04  8.476088e+04  9.248238e+04
13  1.290806e+06  1.205169e+06  1.372447e+06  1.256888e+06  1.221904e+06
14  1.110049e+05  1.111291e+05  1.066525e+05  1.056287e+05  1.127141e+05
15  6.667161e+04  8.081300e+04  9.200752e+04  1.164235e+05  7.168401e+04
16  5.945922e+05  5.372641e+05  4.532297e+05  6.528548e+05  6.401201e+05
17  4.073554e+05  3.836830e+05  4.175210e+05  3.584550e+05  4.462836e+05
18  9.177653e+04  1.085457e+05  8.662578e+04  9.655062e+04  8.581038e+04
19  1.780993e+06  1.164699e+06  9.166575e+05  1.305046e+06  1.520788e+06
20  8.089149e+04  8.705634e+04  8.138151e+04  8.990870e+04  8.333327e+04
21  1.618576e+05  1.684799e+05  1.657254e+05  1.691351e+05  1.941455e+05
22  1.483777e+06  1.406437e+06  1.317455e+06  1.269751e+06  1.374450e+06

      tCH4_2021     tCO2_2015     tCO2_2016     tCO2_2017     tCO2_2018  \
0   1.983974e+06  5.861049e+07  5.695395e+07  5.247394e+07  5.353076e+07
1   4.544874e+05  8.525583e+06  7.760473e+06  9.312934e+06  9.292575e+06
2   6.068210e+06  1.533412e+08  1.464883e+08  1.588768e+08  1.353491e+08
3   8.531579e+03  2.853661e+05  3.337007e+05  3.043248e+05  3.513524e+05
4   1.009936e+06  3.209122e+07  2.557824e+07  2.403832e+07  2.942454e+07
5   6.567960e+06  1.554972e+08  1.327353e+08  1.557113e+08  1.647450e+08
6   9.053525e+04  2.193602e+06  2.295030e+06  2.405054e+06  2.218936e+06
7   5.089759e+04  1.248992e+06  1.234446e+06  1.360920e+06  1.117475e+06
8   1.574007e+05  5.763662e+06  5.710333e+06  6.772337e+06  3.870631e+06
9   5.644891e+05  1.238675e+07  1.432925e+07  1.129261e+07  1.398153e+07
10  1.013006e+05  3.629695e+06  3.186493e+06  3.658056e+06  3.233858e+06
11  1.475014e+04  4.152924e+05  4.241102e+05  2.920158e+05  2.524186e+05
12  8.466966e+04  2.076407e+06  2.529358e+06  1.477960e+06  2.254728e+06
13  1.289837e+06  2.830206e+07  3.227014e+07  3.012923e+07  3.431117e+07
14  1.069696e+05  2.643498e+06  2.775123e+06  2.778227e+06  2.666313e+06
15  4.811408e+04  2.518697e+06  1.666790e+06  2.020325e+06  2.300188e+06
16  4.849205e+05  1.213108e+07  1.486480e+07  1.343160e+07  1.133074e+07
17  4.383270e+05  8.580052e+06  1.018389e+07  9.592074e+06  1.043803e+07
18  7.735988e+04  2.858041e+06  2.294413e+06  2.713641e+06  2.165645e+06
19  8.528673e+05  3.484495e+07  4.452483e+07  2.911748e+07  2.291644e+07
20  6.619861e+04  1.966739e+06  2.022287e+06  2.176408e+06  2.034538e+06
21  1.634842e+05  4.028310e+06  4.046440e+06  4.211999e+06  4.143136e+06
22  1.502787e+06  3.365033e+07  3.709441e+07  3.516092e+07  3.293637e+07

      tCO2_2019      Mean_CH4     Total_CH4      Mean_CO2     Total_CO2
```

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(continued from previous page)

0	5.177463e+07	2.186750e+06	1.093375e+07	5.466875e+07	2.733438e+08
1	8.236783e+06	3.450268e+05	1.725134e+06	8.625670e+06	4.312835e+07
2	1.400838e+08	5.873113e+06	2.936556e+07	1.468278e+08	7.341391e+08
3	2.870810e+05	1.249460e+04	6.247300e+04	3.123650e+05	1.561825e+06
4	3.166670e+07	1.142392e+06	5.711960e+06	2.855980e+07	1.427990e+08
5	1.875389e+08	6.369821e+06	3.184910e+07	1.592455e+08	7.962276e+08
6	2.375050e+06	9.190138e+04	4.595069e+05	2.297534e+06	1.148767e+07
7	1.141729e+06	4.882850e+04	2.441425e+05	1.220712e+06	6.103562e+06
8	5.830141e+06	2.235768e+05	1.117884e+06	5.589421e+06	2.794710e+07
9	1.486819e+07	5.348666e+05	2.674333e+06	1.337166e+07	6.685832e+07
10	3.319455e+06	1.362205e+05	6.811023e+05	3.405512e+06	1.702756e+07
11	3.652645e+05	1.399281e+04	6.996406e+04	3.498203e+05	1.749102e+06
12	2.119022e+06	8.365981e+04	4.182990e+05	2.091495e+06	1.045748e+07
13	3.142221e+07	1.251478e+06	6.257392e+06	3.128696e+07	1.564348e+08
14	2.640717e+06	1.080310e+05	5.401551e+05	2.700775e+06	1.350388e+07
15	2.910588e+06	9.133271e+04	4.566635e+05	2.283318e+06	1.141659e+07
16	1.632137e+07	5.446368e+05	2.723184e+06	1.361592e+07	6.807960e+07
17	8.961374e+06	3.820433e+05	1.910216e+06	9.551082e+06	4.775541e+07
18	2.413765e+06	9.956405e+04	4.978202e+05	2.489101e+06	1.244551e+07
19	3.262615e+07	1.312239e+06	6.561194e+06	3.280597e+07	1.640298e+08
20	2.247717e+06	8.358152e+04	4.179076e+05	2.089538e+06	1.044769e+07
21	4.228377e+06	1.652661e+05	8.263305e+05	4.131652e+06	2.065826e+07
22	3.174377e+07	1.364686e+06	6.823432e+06	3.411716e+07	1.705858e+08

6.3.1 TRACE Country Merge

```
trace_merged_df = world.merge(trace_emissions_df, on='iso3_country', how='right',␣
↪sort=True)
```

```
trace_merged_df
```

	pop_est	continent	name	iso3_country	\
0	157826578	Asia	Bangladesh	BGD	
1	207353391	South America	Brazil	BRA	
2	1379302771	Asia	China	CHN	
3	48958159	Europe	Spain	ESP	
4	260580739	Asia	Indonesia	IDN	
5	1281935911	Asia	India	IND	
6	82021564	Asia	Iran	IRN	
7	62137802	Europe	Italy	ITA	
8	126451398	Asia	Japan	JPN	
9	16204486	Asia	Cambodia	KHM	
10	51181299	Asia	South Korea	KOR	
11	7126706	Asia	Laos	LAO	
12	22409381	Asia	Sri Lanka	LKA	
13	55123814	Asia	Myanmar	MMR	
14	31381992	Asia	Malaysia	MYS	
15	29384297	Asia	Nepal	NPL	
16	204924861	Asia	Pakistan	PAK	
17	104256076	Asia	Philippines	PHL	
18	25248140	Asia	North Korea	PRK	
19	68414135	Asia	Thailand	THA	

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```
20    23508428           Asia                      Taiwan          TWN
21   326625791  North America  United States of America          USA
22    96160163           Asia                     Vietnam          VNM

    gdp_md_est                                           geometry  \
0     628400.0  POLYGON ((92.67272 22.04124, 92.65226 21.32405...
1    3081000.0  POLYGON ((-53.37366 -33.76838, -53.65054 -33.2...
2   21140000.0  MULTIPOLYGON (((109.47521 18.19770, 108.65521 ...
3    1690000.0  POLYGON ((-7.45373 37.09779, -7.53711 37.42890...
4    3028000.0  MULTIPOLYGON (((141.00021 -2.60015, 141.01706 ...
5    8721000.0  POLYGON ((97.32711 28.26158, 97.40256 27.88254...
6    1459000.0  POLYGON ((48.56797 29.92678, 48.01457 30.45246...
7    2221000.0  MULTIPOLYGON (((10.44270 46.89355, 11.04856 46...
8    4932000.0  MULTIPOLYGON (((141.88460 39.18086, 140.95949 ...
9      58940.0  POLYGON ((102.58493 12.18659, 102.34810 13.394...
10   1929000.0  POLYGON ((126.17476 37.74969, 126.23734 37.840...
11     40960.0  POLYGON ((107.38273 14.20244, 106.49637 14.570...
12    236700.0  POLYGON ((81.78796 7.52306, 81.63732 6.48178, ...
13    311100.0  POLYGON ((100.11599 20.41785, 99.54331 20.1866...
14    863000.0  MULTIPOLYGON (((100.08576 6.46449, 100.25960 6...
15     71520.0  POLYGON ((88.12044 27.87654, 88.04313 27.44582...
16    988200.0  POLYGON ((77.83745 35.49401, 76.87172 34.65354...
17    801900.0  MULTIPOLYGON (((120.83390 12.70450, 120.32344 ...
18     40000.0  MULTIPOLYGON (((130.78000 42.22001, 130.78000 ...
19   1161000.0  POLYGON ((105.21878 14.27321, 104.28142 14.416...
20   1127000.0  POLYGON ((121.77782 24.39427, 121.17563 22.790...
21  18560000.0  MULTIPOLYGON (((-122.84000 49.00000, -120.0000...
22    594900.0  POLYGON ((104.33433 10.48654, 105.19991 10.889...

                                  country_name     tCH4_2015     tCH4_2016  \
0                                   Bangladesh  2.344420e+06  2.278158e+06
1                                       Brazil  3.410233e+05  3.104189e+05
2                                        China  6.133647e+06  5.859531e+06
3                                        Spain  1.141464e+04  1.334803e+04
4                                    Indonesia  1.283649e+06  1.023129e+06
5                                        India  6.219887e+06  5.309413e+06
6                  Iran (Islamic Republic of)  8.774407e+04  9.180121e+04
7                                        Italy  4.995968e+04  4.937785e+04
8                                        Japan  2.305465e+05  2.284133e+05
9                                     Cambodia  4.954698e+05  5.731698e+05
10                   Korea (the Republic of)  1.451878e+05  1.274597e+05
11      Lao People's Democratic Republic (the)  1.661169e+04  1.696441e+04
12                                   Sri Lanka  8.305626e+04  1.011743e+05
13                                     Myanmar  1.132082e+06  1.290806e+06
14                                    Malaysia  1.057399e+05  1.110049e+05
15                                       Nepal  1.007479e+05  6.667161e+04
16                                    Pakistan  4.852431e+05  5.945922e+05
17                           Philippines (the)  3.432021e+05  4.073554e+05
18  Korea (the Democratic People's Republic of)  1.143217e+05  9.177653e+04
19                                    Thailand  1.393798e+06  1.780993e+06
20                 Taiwan (Province of China)  7.866956e+04  8.089149e+04
21              United States of America (the)  1.611324e+05  1.618576e+05
22                                    Viet Nam  1.346013e+06  1.483777e+06

      tCH4_2017  ...     tCH4_2021     tCO2_2015     tCO2_2016     tCO2_2017  \
0  2.098958e+06  ...  1.983974e+06  5.861049e+07  5.695395e+07  5.247394e+07
```

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```
1   3.725173e+05  ...  4.544874e+05  8.525583e+06  7.760473e+06  9.312934e+06
2   6.355071e+06  ...  6.068210e+06  1.533412e+08  1.464883e+08  1.588768e+08
3   1.217299e+04  ...  8.531579e+03  2.853661e+05  3.337007e+05  3.043248e+05
4   9.615327e+05  ...  1.009936e+06  3.209122e+07  2.557824e+07  2.403832e+07
5   6.228451e+06  ...  6.567960e+06  1.554972e+08  1.327353e+08  1.557113e+08
6   9.620217e+04  ...  9.053525e+04  2.193602e+06  2.295030e+06  2.405054e+06
7   5.443679e+04  ...  5.089759e+04  1.248992e+06  1.234446e+06  1.360920e+06
8   2.708935e+05  ...  1.574007e+05  5.763662e+06  5.710333e+06  6.772337e+06
9   4.517045e+05  ...  5.644891e+05  1.238675e+07  1.432925e+07  1.129261e+07
10  1.463222e+05  ...  1.013006e+05  3.629695e+06  3.186493e+06  3.658056e+06
11  1.168063e+04  ...  1.475014e+04  4.152924e+05  4.241102e+05  2.920158e+05
12  5.911841e+04  ...  8.466966e+04  2.076407e+06  2.529358e+06  1.477960e+06
13  1.205169e+06  ...  1.289837e+06  2.830206e+07  3.227014e+07  3.012923e+07
14  1.111291e+05  ...  1.069696e+05  2.643498e+06  2.775123e+06  2.778227e+06
15  8.081300e+04  ...  4.811408e+04  2.518697e+06  1.666790e+06  2.020325e+06
16  5.372641e+05  ...  4.849205e+05  1.213108e+07  1.486480e+07  1.343160e+07
17  3.836830e+05  ...  4.383270e+05  8.580052e+06  1.018389e+07  9.592074e+06
18  1.085457e+05  ...  7.735988e+04  2.858041e+06  2.294413e+06  2.713641e+06
19  1.164699e+06  ...  8.528673e+05  3.484495e+07  4.452483e+07  2.911748e+07
20  8.705634e+04  ...  6.619861e+04  1.966739e+06  2.022287e+06  2.176408e+06
21  1.684799e+05  ...  1.634842e+05  4.028310e+06  4.046440e+06  4.211999e+06
22  1.406437e+06  ...  1.502787e+06  3.365033e+07  3.709441e+07  3.516092e+07

      tCO2_2018     tCO2_2019      Mean_CH4     Total_CH4      Mean_CO2  \
0   5.353076e+07  5.177463e+07  2.186750e+06  1.093375e+07  5.466875e+07
1   9.292575e+06  8.236783e+06  3.450268e+05  1.725134e+06  8.625670e+06
2   1.353491e+08  1.400838e+08  5.873113e+06  2.936556e+07  1.468278e+08
3   3.513524e+05  2.870810e+05  1.249460e+04  6.247300e+04  3.123650e+05
4   2.942454e+07  3.166670e+07  1.142392e+06  5.711960e+06  2.855980e+07
5   1.647450e+08  1.875389e+08  6.369821e+06  3.184910e+07  1.592455e+08
6   2.218936e+06  2.375050e+06  9.190138e+04  4.595069e+05  2.297534e+06
7   1.117475e+06  1.141729e+06  4.882850e+04  2.441425e+05  1.220712e+06
8   3.870631e+06  5.830141e+06  2.235768e+05  1.117884e+06  5.589421e+06
9   1.398153e+07  1.486819e+07  5.348666e+05  2.674333e+06  1.337166e+07
10  3.233858e+06  3.319455e+06  1.362205e+05  6.811023e+05  3.405512e+06
11  2.524186e+05  3.652645e+05  1.399281e+04  6.996406e+04  3.498203e+05
12  2.254728e+06  2.119022e+06  8.365981e+04  4.182990e+05  2.091495e+06
13  3.431117e+07  3.142221e+07  1.251478e+06  6.257392e+06  3.128696e+07
14  2.666313e+06  2.640717e+06  1.080310e+05  5.401551e+05  2.700775e+06
15  2.300188e+06  2.910588e+06  9.133271e+04  4.566635e+05  2.283318e+06
16  1.133074e+07  1.632137e+07  5.446368e+05  2.723184e+06  1.361592e+07
17  1.043803e+07  8.961374e+06  3.820433e+05  1.910216e+06  9.551082e+06
18  2.165645e+06  2.413765e+06  9.956405e+04  4.978202e+05  2.489101e+06
19  2.291644e+07  3.262615e+07  1.312239e+06  6.561194e+06  3.280597e+07
20  2.034538e+06  2.247717e+06  8.358152e+04  4.179076e+05  2.089538e+06
21  4.143136e+06  4.228377e+06  1.652661e+05  8.263305e+05  4.131652e+06
22  3.293637e+07  3.174377e+07  1.364686e+06  6.823432e+06  3.411716e+07

      Total_CO2
0   2.733438e+08
1   4.312835e+07
2   7.341391e+08
3   1.561825e+06
4   1.427990e+08
5   7.962276e+08
6   1.148767e+07
```

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```
7   6.103562e+06
8   2.794710e+07
9   6.685832e+07
10  1.702756e+07
11  1.749102e+06
12  1.045748e+07
13  1.564348e+08
14  1.350388e+07
15  1.141659e+07
16  6.807960e+07
17  4.775541e+07
18  1.244551e+07
19  1.640298e+08
20  1.044769e+07
21  2.065826e+07
22  1.705858e+08

[23 rows x 23 columns]
```

```
trace_merged_df = trace_merged_df[trace_merged_df['continent'] != 'Antarctica'].copy()
```

```
trace_merged_df
#trace_merged_df.dropna(axis=1, how='any')
```

```
       pop_est      continent                      name iso3_country  \
0    157826578           Asia                Bangladesh          BGD
1    207353391  South America                    Brazil          BRA
2   1379302771           Asia                     China          CHN
3     48958159         Europe                     Spain          ESP
4    260580739           Asia                 Indonesia          IDN
5   1281935911           Asia                     India          IND
6     82021564           Asia                      Iran          IRN
7     62137802         Europe                     Italy          ITA
8    126451398           Asia                     Japan          JPN
9     16204486           Asia                  Cambodia          KHM
10    51181299           Asia               South Korea          KOR
11     7126706           Asia                      Laos          LAO
12    22409381           Asia                 Sri Lanka          LKA
13    55123814           Asia                   Myanmar          MMR
14    31381992           Asia                  Malaysia          MYS
15    29384297           Asia                     Nepal          NPL
16   204924861           Asia                  Pakistan          PAK
17   104256076           Asia               Philippines          PHL
18    25248140           Asia               North Korea          PRK
19    68414135           Asia                  Thailand          THA
20    23508428           Asia                    Taiwan          TWN
21   326625791  North America  United States of America          USA
22    96160163           Asia                   Vietnam          VNM

    gdp_md_est                                           geometry  \
0     628400.0  POLYGON ((92.67272 22.04124, 92.65226 21.32405...
1    3081000.0  POLYGON ((-53.37366 -33.76838, -53.65054 -33.2...
2   21140000.0  MULTIPOLYGON (((109.47521 18.19770, 108.65521 ...
3    1690000.0  POLYGON ((-7.45373 37.09779, -7.53711 37.42890...
```

(continues on next page)

(continued from previous page)

```
4    3028000.0  MULTIPOLYGON (((141.00021 -2.60015, 141.01706 ...
5    8721000.0  POLYGON ((97.32711 28.26158, 97.40256 27.88254...
6    1459000.0  POLYGON ((48.56797 29.92678, 48.01457 30.45246...
7    2221000.0  MULTIPOLYGON (((10.44270 46.89355, 11.04856 46...
8    4932000.0  MULTIPOLYGON (((141.88460 39.18086, 140.95949 ...
9      58940.0  POLYGON ((102.58493 12.18659, 102.34810 13.394...
10   1929000.0  POLYGON ((126.17476 37.74969, 126.23734 37.840...
11     40960.0  POLYGON ((107.38273 14.20244, 106.49637 14.570...
12    236700.0  POLYGON ((81.78796 7.52306, 81.63732 6.48178, ...
13    311100.0  POLYGON ((100.11599 20.41785, 99.54331 20.1866...
14    863000.0  MULTIPOLYGON (((100.08576 6.46449, 100.25960 6...
15     71520.0  POLYGON ((88.12044 27.87654, 88.04313 27.44582...
16    988200.0  POLYGON ((77.83745 35.49401, 76.87172 34.65354...
17    801900.0  MULTIPOLYGON (((120.83390 12.70450, 120.32344 ...
18     40000.0  MULTIPOLYGON (((130.78000 42.22001, 130.78000 ...
19   1161000.0  POLYGON ((105.21878 14.27321, 104.28142 14.416...
20   1127000.0  POLYGON ((121.77782 24.39427, 121.17563 22.790...
21  18560000.0  MULTIPOLYGON (((-122.84000 49.00000, -120.0000...
22    594900.0  POLYGON ((104.33433 10.48654, 105.19991 10.889...

                                    country_name     tCH4_2015     tCH4_2016  \
0                                     Bangladesh  2.344420e+06  2.278158e+06
1                                         Brazil  3.410233e+05  3.104189e+05
2                                          China  6.133647e+06  5.859531e+06
3                                          Spain  1.141464e+04  1.334803e+04
4                                      Indonesia  1.283649e+06  1.023129e+06
5                                          India  6.219887e+06  5.309413e+06
6                    Iran (Islamic Republic of)  8.774407e+04  9.180121e+04
7                                          Italy  4.995968e+04  4.937785e+04
8                                          Japan  2.305465e+05  2.284133e+05
9                                       Cambodia  4.954698e+05  5.731698e+05
10                     Korea (the Republic of)  1.451878e+05  1.274597e+05
11       Lao People's Democratic Republic (the)  1.661169e+04  1.696441e+04
12                                    Sri Lanka  8.305626e+04  1.011743e+05
13                                      Myanmar  1.132082e+06  1.290806e+06
14                                     Malaysia  1.057399e+05  1.110049e+05
15                                        Nepal  1.007479e+05  6.667161e+04
16                                     Pakistan  4.852431e+05  5.945922e+05
17                           Philippines (the)  3.432021e+05  4.073554e+05
18  Korea (the Democratic People's Republic of)  1.143217e+05  9.177653e+04
19                                     Thailand  1.393798e+06  1.780993e+06
20                   Taiwan (Province of China)  7.866956e+04  8.089149e+04
21               United States of America (the)  1.611324e+05  1.618576e+05
22                                     Viet Nam  1.346013e+06  1.483777e+06

      tCH4_2017  ...     tCH4_2021     tCO2_2015     tCO2_2016     tCO2_2017  \
0  2.098958e+06  ...  1.983974e+06  5.861049e+07  5.695395e+07  5.247394e+07
1  3.725173e+05  ...  4.544874e+05  8.525583e+06  7.760473e+06  9.312934e+06
2  6.355071e+06  ...  6.068210e+06  1.533412e+08  1.464883e+08  1.588768e+08
3  1.217299e+04  ...  8.531579e+03  2.853661e+05  3.337007e+05  3.043248e+05
4  9.615327e+05  ...  1.009936e+06  3.209122e+07  2.557824e+07  2.403832e+07
5  6.228451e+06  ...  6.567960e+06  1.554972e+08  1.327353e+08  1.557113e+08
6  9.620217e+04  ...  9.053525e+04  2.193602e+06  2.295030e+06  2.405054e+06
7  5.443679e+04  ...  5.089759e+04  1.248992e+06  1.234446e+06  1.360920e+06
8  2.708935e+05  ...  1.574007e+05  5.763662e+06  5.710333e+06  6.772337e+06
9  4.517045e+05  ...  5.644891e+05  1.238675e+07  1.432925e+07  1.129261e+07
```

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```
10  1.463222e+05  ...  1.013006e+05  3.629695e+06  3.186493e+06  3.658056e+06
11  1.168063e+04  ...  1.475014e+04  4.152924e+05  4.241102e+05  2.920158e+05
12  5.911841e+04  ...  8.466966e+04  2.076407e+06  2.529358e+06  1.477960e+06
13  1.205169e+06  ...  1.289837e+06  2.830206e+07  3.227014e+07  3.012923e+07
14  1.111291e+05  ...  1.069696e+05  2.643498e+06  2.775123e+06  2.778227e+06
15  8.081300e+04  ...  4.811408e+04  2.518697e+06  1.666790e+06  2.020325e+06
16  5.372641e+05  ...  4.849205e+05  1.213108e+07  1.486480e+07  1.343160e+07
17  3.836830e+05  ...  4.383270e+05  8.580052e+06  1.018389e+07  9.592074e+06
18  1.085457e+05  ...  7.735988e+04  2.858041e+06  2.294413e+06  2.713641e+06
19  1.164699e+06  ...  8.528673e+05  3.484495e+07  4.452483e+07  2.911748e+07
20  8.705634e+04  ...  6.619861e+04  1.966739e+06  2.022287e+06  2.176408e+06
21  1.684799e+05  ...  1.634842e+05  4.028310e+06  4.046440e+06  4.211999e+06
22  1.406437e+06  ...  1.502787e+06  3.365033e+07  3.709441e+07  3.516092e+07

       tCO2_2018     tCO2_2019      Mean_CH4     Total_CH4      Mean_CO2  \
0   5.353076e+07  5.177463e+07  2.186750e+06  1.093375e+07  5.466875e+07
1   9.292575e+06  8.236783e+06  3.450268e+05  1.725134e+06  8.625670e+06
2   1.353491e+08  1.400838e+08  5.873113e+06  2.936556e+07  1.468278e+08
3   3.513524e+05  2.870810e+05  1.249460e+04  6.247300e+04  3.123650e+05
4   2.942454e+07  3.166670e+07  1.142392e+06  5.711960e+06  2.855980e+07
5   1.647450e+08  1.875389e+08  6.369821e+06  3.184910e+07  1.592455e+08
6   2.218936e+06  2.375050e+06  9.190138e+04  4.595069e+05  2.297534e+06
7   1.117475e+06  1.141729e+06  4.882850e+04  2.441425e+05  1.220712e+06
8   3.870631e+06  5.830141e+06  2.235768e+05  1.117884e+06  5.589421e+06
9   1.398153e+07  1.486819e+07  5.348666e+05  2.674333e+06  1.337166e+07
10  3.233858e+06  3.319455e+06  1.362205e+05  6.811023e+05  3.405512e+06
11  2.524186e+05  3.652645e+05  1.399281e+04  6.996406e+04  3.498203e+05
12  2.254728e+06  2.119022e+06  8.365981e+04  4.182990e+05  2.091495e+06
13  3.431117e+07  3.142221e+07  1.251478e+06  6.257392e+06  3.128696e+07
14  2.666313e+06  2.640717e+06  1.080310e+05  5.401551e+05  2.700775e+06
15  2.300188e+06  2.910588e+06  9.133271e+04  4.566635e+05  2.283318e+06
16  1.133074e+07  1.632137e+07  5.446368e+05  2.723184e+06  1.361592e+07
17  1.043803e+07  8.961374e+06  3.820433e+05  1.910216e+06  9.551082e+06
18  2.165645e+06  2.413765e+06  9.956405e+04  4.978202e+05  2.489101e+06
19  2.291644e+07  3.262615e+07  1.312239e+06  6.561194e+06  3.280597e+07
20  2.034538e+06  2.247717e+06  8.358152e+04  4.179076e+05  2.089538e+06
21  4.143136e+06  4.228377e+06  1.652661e+05  8.263305e+05  4.131652e+06
22  3.293637e+07  3.174377e+07  1.364686e+06  6.823432e+06  3.411716e+07

       Total_CO2
0   2.733438e+08
1   4.312835e+07
2   7.341391e+08
3   1.561825e+06
4   1.427990e+08
5   7.962276e+08
6   1.148767e+07
7   6.103562e+06
8   2.794710e+07
9   6.685832e+07
10  1.702756e+07
11  1.749102e+06
12  1.045748e+07
13  1.564348e+08
14  1.350388e+07
15  1.141659e+07
```

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```
16  6.807960e+07
17  4.775541e+07
18  1.244551e+07
19  1.640298e+08
20  1.044769e+07
21  2.065826e+07
22  1.705858e+08

[23 rows x 23 columns]
```

6.3.2 Trace Merge to File

```
gisout = "/Users/jnapolitano/Projects/wattime-takehome/data/TRACE_DATA_GEO.geojson"
trace_merged_df.to_file(gisout, driver="GeoJSON")
```

```
/Users/jnapolitano/venvs/finance/lib/python3.9/site-packages/geopandas/io/file.
↪py:362: FutureWarning: pandas.Int64Index is deprecated and will be removed from␣
↪pandas in a future version. Use pandas.Index with the appropriate dtype instead.
  pd.Int64Index,
```

6.4 Merge GEO DATA

```
filepath = "/Users/jnapolitano/Projects/wattime-takehome/data/MERGED_DATA.csv"

merged_data = pd.read_csv(filepath)

merged_data.drop('Unnamed: 0', axis = 1 , inplace = True)
```

```
merged_countries = world.merge(merged_data, on='iso3_country', how='right', sort=True)
```

```
merged_countries
```

```
         pop_est      continent                     name iso3_country  \
0   1.578266e+08           Asia               Bangladesh          BGD
1   2.073534e+08  South America                   Brazil          BRA
2   1.379303e+09           Asia                    China          CHN
3   4.895816e+07         Europe                    Spain          ESP
4   2.605807e+08           Asia                Indonesia          IDN
5   1.281936e+09           Asia                    India          IND
6   8.202156e+07           Asia                     Iran          IRN
7   6.213780e+07         Europe                    Italy          ITA
8   1.264514e+08           Asia                    Japan          JPN
9   1.620449e+07           Asia                 Cambodia          KHM
10  5.118130e+07           Asia              South Korea          KOR
11  7.126706e+06           Asia                     Laos          LAO
12  2.240938e+07           Asia                Sri Lanka          LKA
13  5.512381e+07           Asia                  Myanmar          MMR
```

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```
14  3.138199e+07           Asia                   Malaysia          MYS
15  2.938430e+07           Asia                      Nepal          NPL
16  2.049249e+08           Asia                   Pakistan          PAK
17  1.042561e+08           Asia                Philippines          PHL
18  2.524814e+07           Asia                North Korea          PRK
19  6.841414e+07           Asia                   Thailand          THA
20  2.350843e+07           Asia                     Taiwan          TWN
21  3.266258e+08  North America  United States of America          USA
22  9.616016e+07           Asia                    Vietnam          VNM
23           NaN            NaN                        NaN          NaN
24           NaN            NaN                        NaN          NaN

    gdp_md_est                                           geometry  \
0     628400.0  POLYGON ((92.67272 22.04124, 92.65226 21.32405...
1    3081000.0  POLYGON ((-53.37366 -33.76838, -53.65054 -33.2...
2   21140000.0  MULTIPOLYGON (((109.47521 18.19770, 108.65521 ...
3    1690000.0  POLYGON ((-7.45373 37.09779, -7.53711 37.42890...
4    3028000.0  MULTIPOLYGON (((141.00021 -2.60015, 141.01706 ...
5    8721000.0  POLYGON ((97.32711 28.26158, 97.40256 27.88254...
6    1459000.0  POLYGON ((48.56797 29.92678, 48.01457 30.45246...
7    2221000.0  MULTIPOLYGON (((10.44270 46.89355, 11.04856 46...
8    4932000.0  MULTIPOLYGON (((141.88460 39.18086, 140.95949 ...
9      58940.0  POLYGON ((102.58493 12.18659, 102.34810 13.394...
10   1929000.0  POLYGON ((126.17476 37.74969, 126.23734 37.840...
11     40960.0  POLYGON ((107.38273 14.20244, 106.49637 14.570...
12    236700.0  POLYGON ((81.78796 7.52306, 81.63732 6.48178, ...
13    311100.0  POLYGON ((100.11599 20.41785, 99.54331 20.1866...
14    863000.0  MULTIPOLYGON (((100.08576 6.46449, 100.25960 6...
15     71520.0  POLYGON ((88.12044 27.87654, 88.04313 27.44582...
16    988200.0  POLYGON ((77.83745 35.49401, 76.87172 34.65354...
17    801900.0  MULTIPOLYGON (((120.83390 12.70450, 120.32344 ...
18     40000.0  MULTIPOLYGON (((130.78000 42.22001, 130.78000 ...
19   1161000.0  POLYGON ((105.21878 14.27321, 104.28142 14.416...
20   1127000.0  POLYGON ((121.77782 24.39427, 121.17563 22.790...
21  18560000.0  MULTIPOLYGON (((-122.84000 49.00000, -120.0000...
22    594900.0  POLYGON ((104.33433 10.48654, 105.19991 10.889...
23         NaN                                               None
24         NaN                                               None

                          country_name_FAOSTAT        2015          2016  \
0                                   Bangladesh   1131293.4  1.093480e+06
1                                       Brazil    138910.3  1.262782e+05
2                                        China   5406593.9  5.399920e+06
3                                        Spain     55082.2  5.507310e+04
4                                    Indonesia   2407953.5  2.387656e+06
5                                        India   4580248.4  4.559136e+06
6                  Iran (Islamic Republic of)    116486.7  1.310085e+05
7                                        Italy    114574.8  1.180030e+05
8                                        Japan    330353.1  3.264030e+05
9                                     Cambodia    436826.0  4.590031e+05
10                 Korea (the Republic of)    167862.2  1.635341e+05
11    Lao People's Democratic Republic (the)     94826.8  9.563000e+04
12                                  Sri Lanka    132640.0  1.217563e+05
13                                    Myanmar   1059409.6  1.052288e+06
14                                   Malaysia    121942.6  1.232328e+05
15                                      Nepal    149262.2  1.427237e+05
```

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```
16                                    Pakistan    383529.3  3.813618e+05
17                                Philippines (the)   1557810.6  1.524292e+06
18  Korea (the Democratic People's Republic of)     82823.3  8.344230e+04
19                                    Thailand   1554254.0  1.703328e+06
20                     Taiwan (Province of China)     45838.7  4.983830e+04
21                 United States of America (the)    364728.0  4.386620e+05
22                                    Viet Nam   1381744.4  1.365174e+06
23                                        mean    948478.0  9.522272e+05
24                                       total  21814994.0  2.190123e+07

             2017  ...  CO2_abs_percent_diff_2019  CO2_abs_percent_diff_means  \
0   1.154531e+06  ...                  57.606797                   63.425917
1   1.303229e+05  ...                  99.141295                   93.222402
2   5.400129e+06  ...                   7.189945                    9.421813
3   5.423240e+04  ...                 127.757634                  124.705066
4   2.425291e+06  ...                  56.234955                   70.153790
5   4.620791e+06  ...                  47.515394                   32.086209
6   8.723360e+04  ...                   1.152675                   13.260902
7   1.180030e+05  ...                  83.321649                   80.187551
8   3.237003e+05  ...                  31.555853                   36.874729
9   4.737453e+05  ...                  23.769728                   14.304565
10  1.584897e+05  ...                  14.321600                   15.813819
11  9.394070e+04  ...                 136.209544                  145.627378
12  8.445630e+04  ...                  18.612972                   27.569003
13  1.087030e+06  ...                  14.853751                   14.697380
14  1.226563e+05  ...                  14.753544                   13.043224
15  1.625746e+05  ...                  29.190154                   50.437328
16  4.060833e+05  ...                  42.334367                   31.154530
17  1.609862e+06  ...                 125.114417                  121.748165
18  8.459620e+04  ...                  15.169422                   17.492669
19  1.714466e+06  ...                  17.404685                   22.551331
20  4.999120e+04  ...                  58.617135                   52.458032
21  3.362555e+05  ...                  69.713577                   78.850049
22  1.360552e+06  ...                   3.761740                    0.902428
23  9.590840e+05  ...                  47.621862                   49.129925
24  2.205893e+07  ...                1095.302835                 1129.988279

    CO2_abs_percent_diff_totals  CO2_relative_percent_diff_2015  \
0                     63.425917                     -107.233570
1                     93.222402                     -145.498958
2                      9.421813                      -13.447527
3                    124.705066                       79.277072
4                     70.153790                       46.691296
5                     32.086209                      -35.798018
6                     13.260902                       24.674600
7                     80.187551                       56.395576
8                     36.874729                       30.212099
9                     14.304565                      -13.424988
10                    15.813819                       13.507737
11                   145.627378                       82.482067
12                    27.569003                       37.382189
13                    14.697380                       -6.859731
14                    13.043224                       13.287137
15                    50.437328                       32.502761
16                    31.154530                      -26.520489
17                   121.748165                       77.968948
```

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```
18                    17.492669                    -38.030793
19                    22.551331                     10.323662
20                    52.458032                    -71.622589
21                    78.850049                     55.821215
22                     0.902428                      2.585962
23                    49.129925                      4.551116
24                  1129.988279                    104.675658

    CO2_relative_percent_diff_2016  CO2_relative_percent_diff_2017  \
0                      -108.340089                     -81.801753
1                      -145.821472                    -185.841820
2                        -8.511442                     -17.683689
3                        75.763074                      77.554025
4                        57.149216                      60.353916
5                       -16.456550                     -34.791882
6                        29.927285                     -10.281098
7                        58.155426                      53.868303
8                        30.021068                      16.313490
9                       -24.872761                       4.652461
10                       22.059230                       7.677136
11                       82.260369                      87.565950
12                       16.904226                      30.001182
13                      -22.666619                     -10.868129
14                        9.922595                       9.398001
15                       53.286238                      50.291743
16                      -55.912882                     -32.303912
17                       73.275770                      76.166725
18                       -9.988016                     -28.310326
19                       -4.559627                      32.066348
20                      -62.307893                     -74.143329
21                       63.101978                      49.895259
22                       -8.687738                      -3.372544
23                        4.508756                       3.322003
24                      103.701389                      76.406059

    CO2_relative_percent_diff_2018  CO2_relative_percent_diff_2019  \
0                      -87.073857                     -80.912284
1                     -205.638590                    -196.594424
2                       -2.108366                      -7.458060
3                       73.445258                      77.958601
4                       51.073546                      43.893273
5                      -41.376939                     -62.321563
6                        5.513463                       1.146070
7                       59.165480                      58.817707
8                       51.954183                      27.255501
9                      -16.667610                     -26.975760
10                      16.497815                      13.364589
11                      87.883944                      81.026578
12                      18.784377                      17.028241
13                     -22.665852                     -16.045425
14                      14.840462                      13.739977
15                      40.212459                      25.472433
16                     -15.207139                     -53.701452
17                      74.003201                      76.966391
18                      -3.195586                     -16.414407
19                      46.173612                      16.011325
```

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```
20                       -64.692890                       -82.919716
21                        59.792699                        51.694526
22                         1.405162                         3.692293
23                         6.179080                        -1.533721
24                       142.118831                       -35.275585

    CO2_relative_percent_diff_means  CO2_relative_percent_diff_totals
0                        -92.881337                       -92.881337
1                       -174.610414                      -174.610414
2                         -9.887609                        -9.887609
3                         76.811284                        76.811284
4                         51.936188                        51.936188
5                        -38.217479                       -38.217479
6                         12.436318                        12.436318
7                         57.238482                        57.238482
8                         31.134372                        31.134372
9                        -15.406481                       -15.406481
10                        14.655057                        14.655057
11                        84.268427                        84.268427
12                        24.229137                        24.229137
13                       -15.863111                       -15.863111
14                        12.244674                        12.244674
15                        40.279401                        40.279401
16                       -36.903009                       -36.903009
17                        75.679166                        75.679166
18                       -19.169278                       -19.169278
19                        20.266184                        20.266184
20                       -71.109302                       -71.109302
21                        56.553728                        56.553728
22                        -0.906518                        -0.906518
23                         3.599038                         3.599038
24                        82.777881                        82.777881

[25 rows x 78 columns]
```

6.4.1 Merged Countries to File

```
gisout = "/Users/jnapolitano/Projects/wattime-takehome/data/MERGE_DATA_GEO.geojson"
merged_countries.to_file(gisout, driver="GeoJSON")
```

```
/Users/jnapolitano/venvs/finance/lib/python3.9/site-packages/geopandas/io/file.
↪py:362: FutureWarning: pandas.Int64Index is deprecated and will be removed from␣
↪pandas in a future version. Use pandas.Index with the appropriate dtype instead.
  pd.Int64Index,
```