A Data Driven Study of Pollution Control Performance of Select Countries

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Abstract

This report focuses on (*i*) establishing whether the "usual suspects" i.e. India, China, and Russia are the true culprits and (*ii*) finding which countries or group are really working towards a greener future and which aren't. Eight countries (USA, China, Russia, Japan, South Korea, India, Germany, Canada) and the EU28 (UK included) were selected. The report uses Fossil CO_2 emission (absolute, per capita and by GDP) from EDGAR *v5* and energy generation (renewable & non-renewable) from bp Statistical review. The report uses locally weighted smoothed lines in the plot which gives a good idea about the trends. It was observed that Japan and South Korea are heavily reliant on buying carbon credits to ***show*** reduced CO_2 emissions, the EU and US are trying but need to work very hard to reduce CO_2 emission and the Germans have shown exemplary effort.

Motivation

- On July 29th, 2020 POTUS claimed that inter alia, (a) US is doing sufficient work on reversing environmental pollution and (b) countries like "India, Russia, China" are not doing their bit in cleaning "the air and the oceans".[1]

- A controversy erupted and the cognoscenti threw out the **Environmental Performance Index** by Yale University to contradict the POTUS.[2]

- A close study of EPI got me thinking that a study of Fossil CO_2 emission of a select group of countries would go a long way in revealing a truer picture.

- This would help garner worldwide opinion and channel pressure on true culprits – *those that can but won't.*

Datasets

The data in the final presentation is curated from a combination of different sources.

1. Emissions Database for Global Atmospheric Research[3]: Provides global past and present day anthropogenic emissions of greenhouse gases and air pollutants by country and on spatial grid. The report uses version 5 of the database. The following sheets from the excel sheets were used:
   a) Fossil CO_2 emission totals by Country
   b) Fossil CO_2 emissions per capita
   c) Fossil CO_2 emissions per GDP (kUSD)

2. bp Statistical Review of World Energy June 2020[4]: bp Statistical Review of World Energy is an annual report published by bp p.l.c., the data used in the report is also published along with the report.
   a) Nuclear Energy Generation by Country
   b) Hydroelectric Energy Generation by Country
   c) Renewable Energy Generation by Country
   d) Total Energy Generation by Country

Data Preparation and Cleaning

- The aforementioned datasets were combined using a combination of pandas and excel.

- Due to inconsistences in data formatting, specially country names, regular expression searching had to be used to make the final dataset and standardize the country names.

- Once the required datasets were created and properly organized, we checked for null columns and removed unnecessary data.

- Certain null values which could not be removed were replaced with the linear interpolation using pandas.

- Since it was not possible to compare all the 200+ countries, therefore a group of 7 countries and the EU28 were selected.

- Germany was compared separately because their performance is exemplary and stellar.

Research Question(s)

*Q*: Are the "Usual Suspects", i.e., India, China, and Russia the largest polluters globally?

Q: Who amongst the under-study are seriously working to address pollution problem?

Q: Who amongst the under-study show the least commitment?

Methods

- Linear Interpolation for filling non-removable null values.

- **Lo**cally **We**ighted **S**catterplot **S**moothing (**LOWESS**) was used to make trendline for data visualization

- Since the project is insight extraction from the data, no special statistical or machine learning methods were required.

- For clarity in visualization, slides with trend plots have 2 plots each – one all inclusive and the other on the right hand side after removing a few of the higher valued curves.
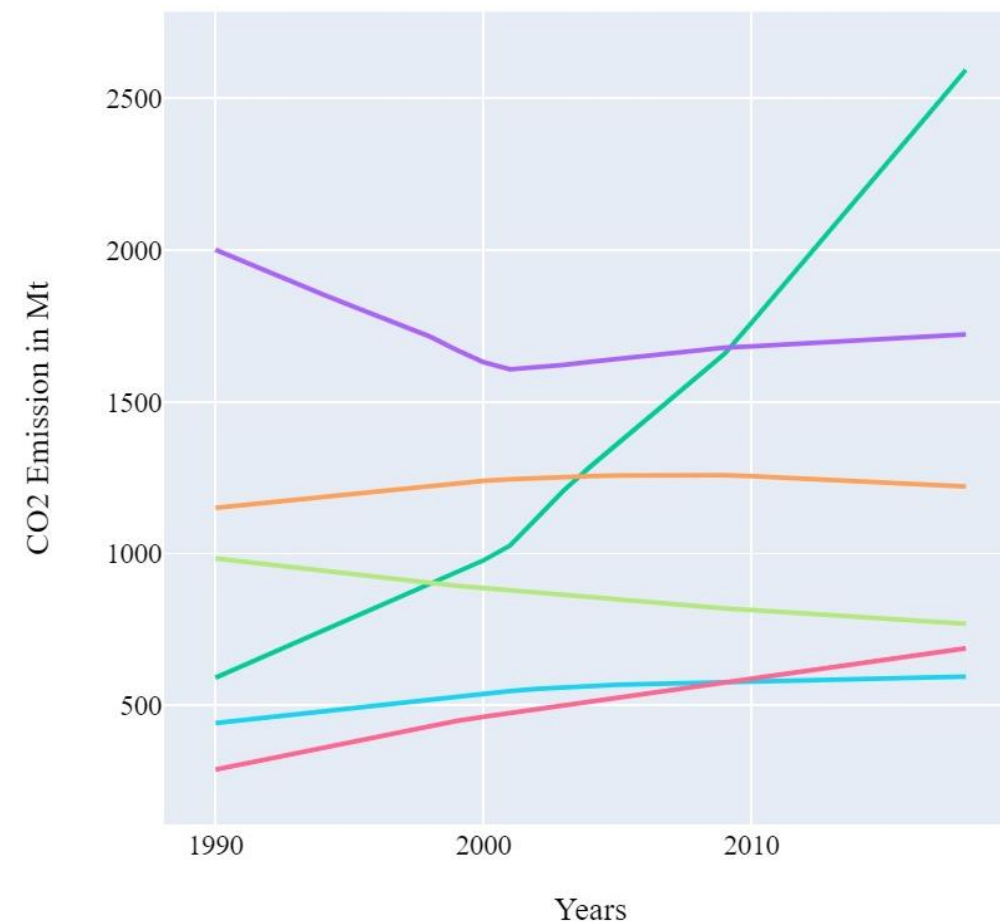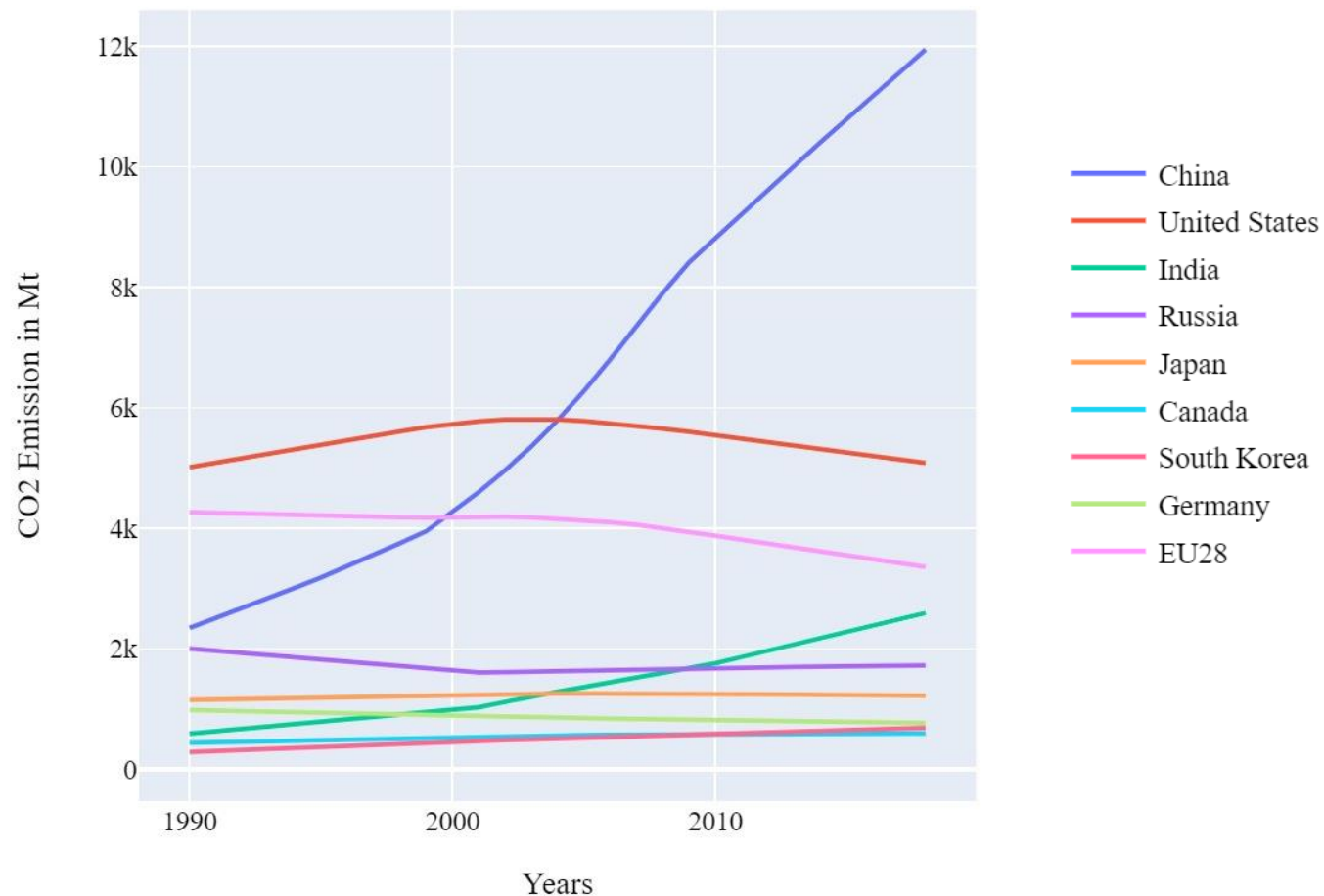
Why we selected these countries only?
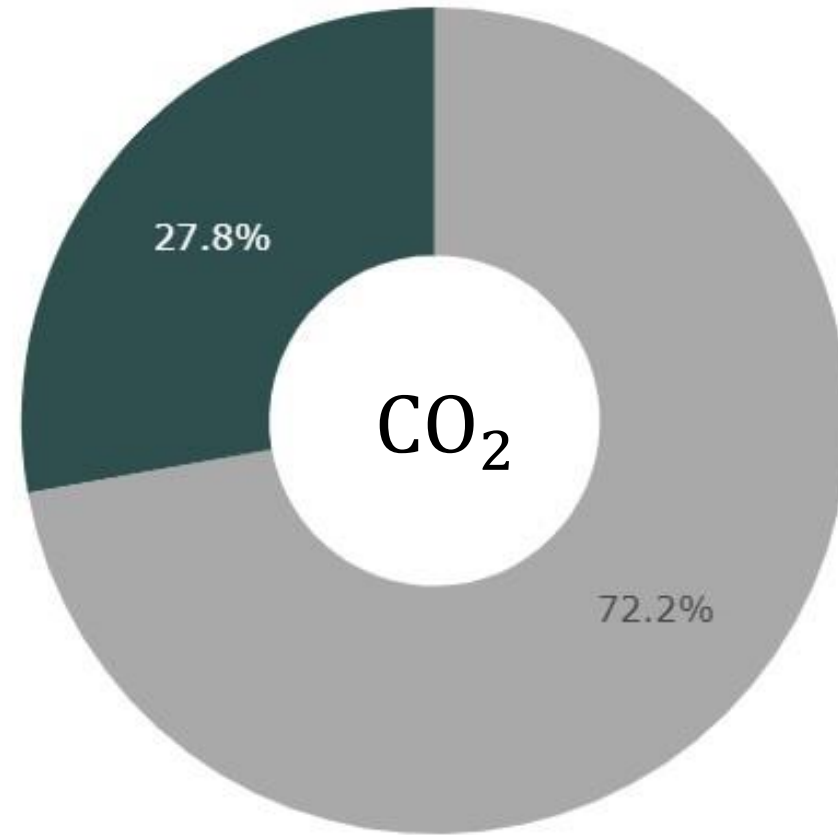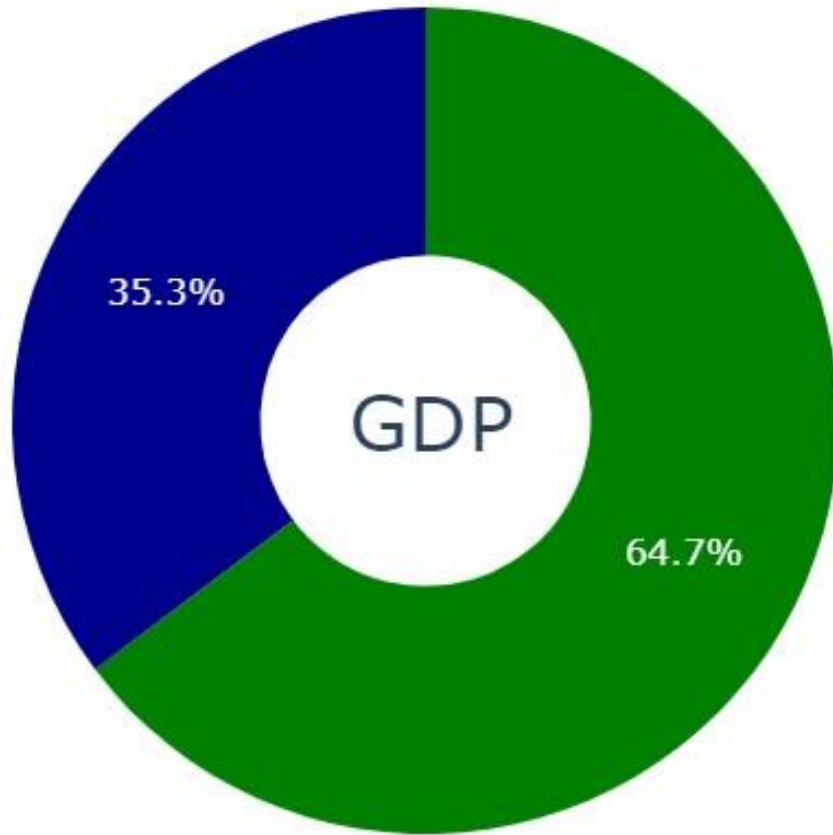
The selected countries together contribute 64.7% to global GDP (the green slice of GDP doughnut) and a whopping 72.2% to global fossil CO_2 emissions (the sooty grey of CO_2 doughnut).
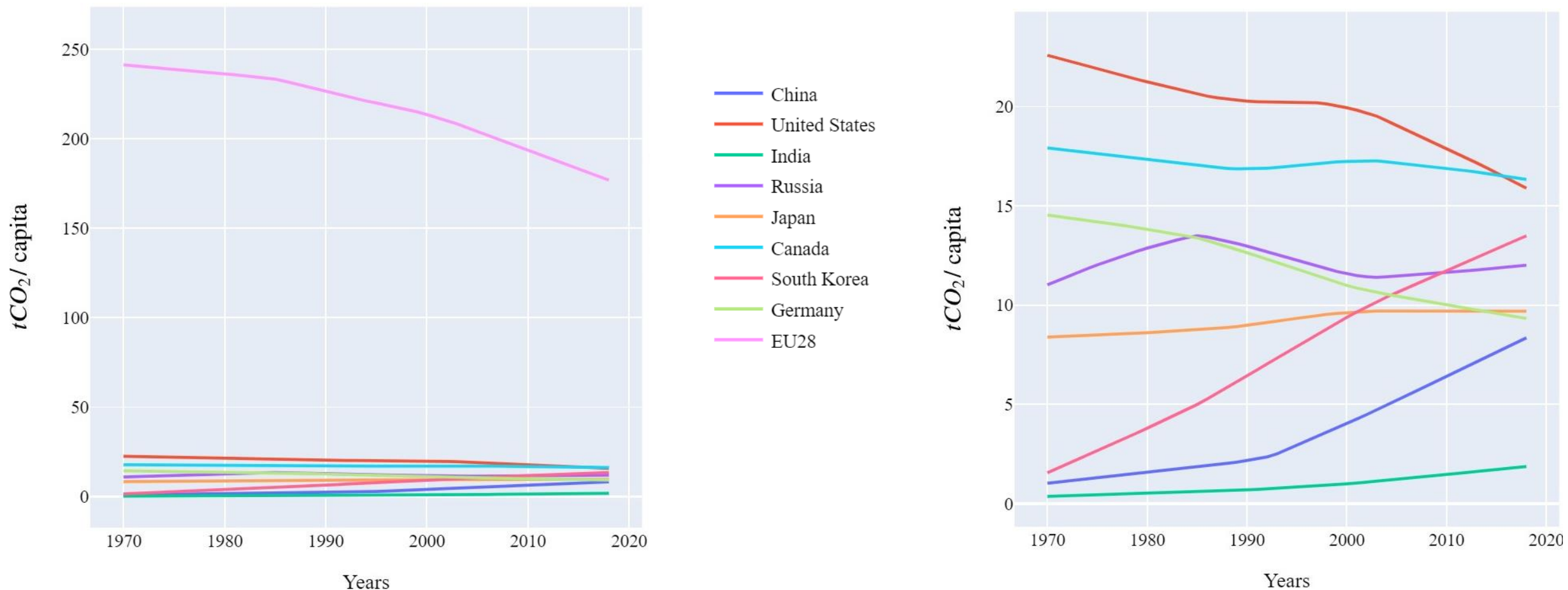
Country-wise Fossil CO_2 Emission in Mt

Observations:
- China has a steep continued rise.
- US started with much higher levels, plateaued around 2005 and then started declining.
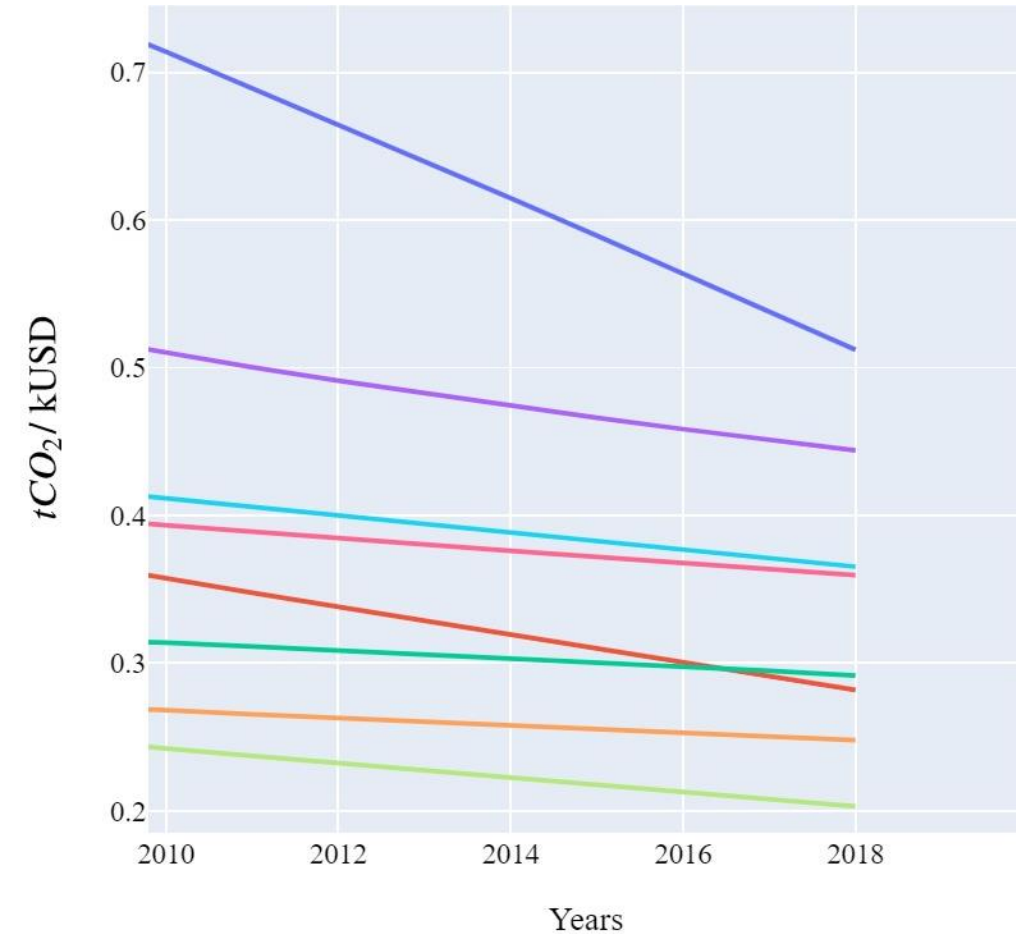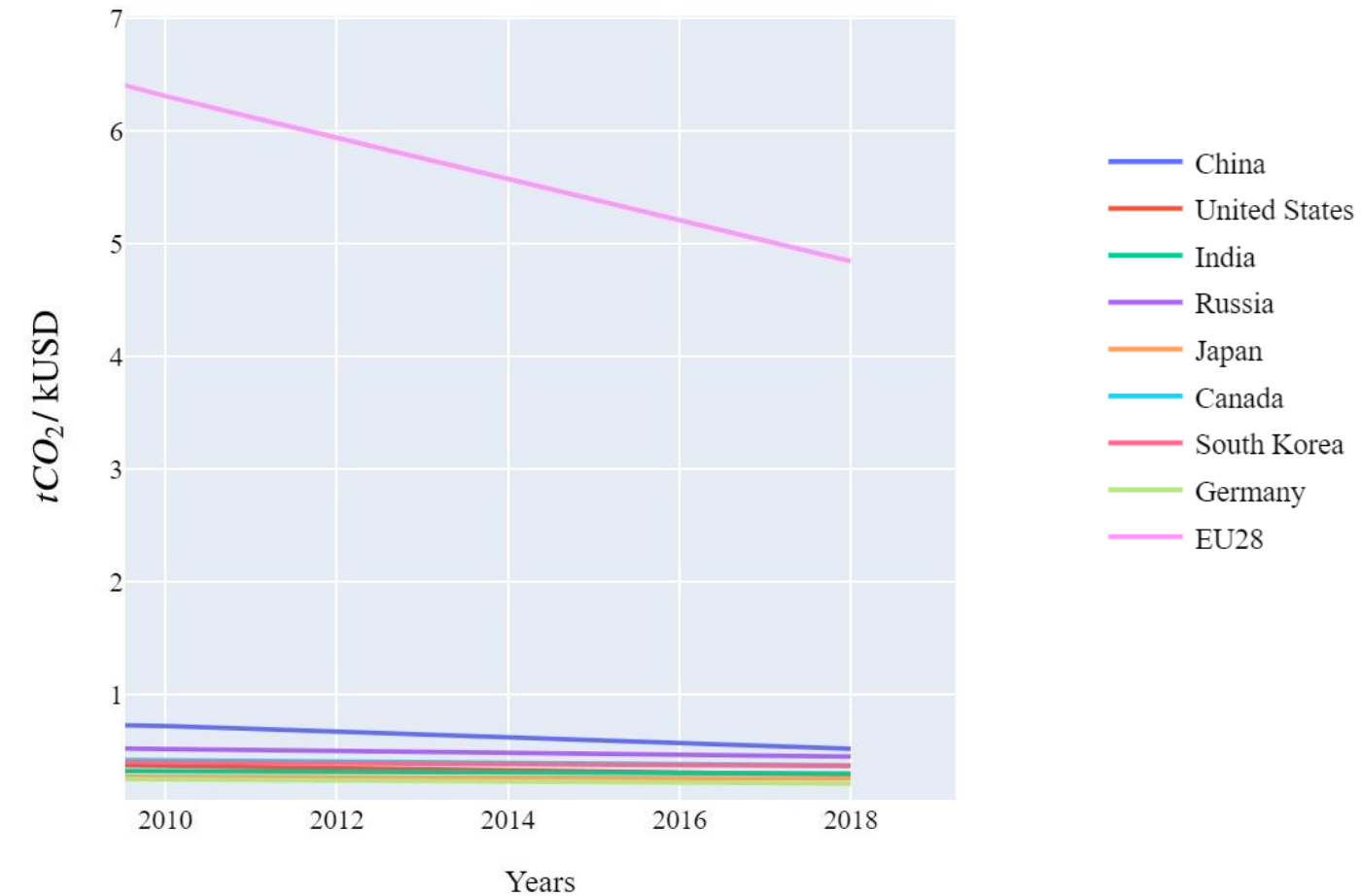- India has uncontrolled emission problems.

Per Capita Fossil CO$_2$ Emission

Observations:
- EU28 – exceedingly high emission levels, decline over the years, specially after 2000 – 2005
- South Korea's steep rise is reaching steeply declining US levels.
- Steeply rising levels of China nearly equaling declining German levels.

Fossil CO_2 emission tCO_2 per kUSD of GDP

Observation:
- This brings out the huge "Environmental Cost" of development.
- EU28 has the highest levels followed by China, Russia, Canada, and South Korea (nearing Canada)
- Germany has the lowest levels and US is 3rd from bottom.

Annual Energy Generation from Renewable Resources
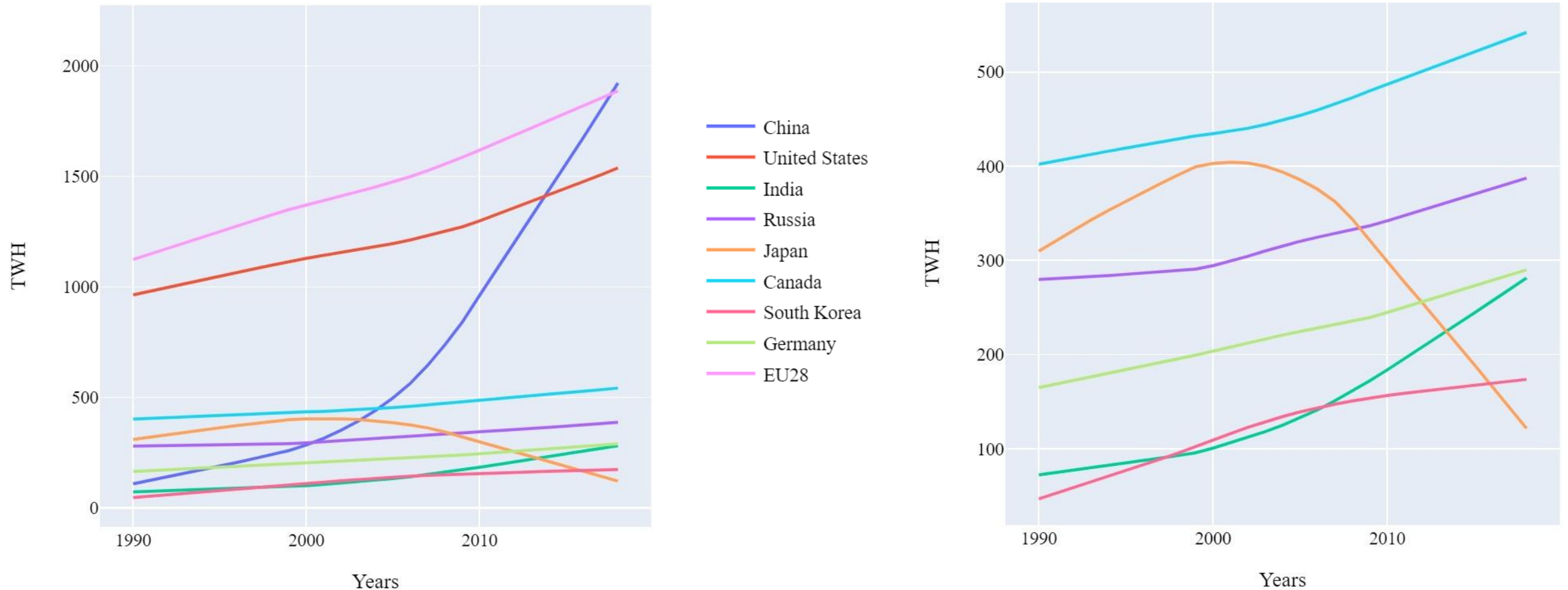
Observations:
- Any increase in energy from renewable resources is a good news for the environment.
- China's remarkable rise is noteworthy (*are their numbers reliable?*)
- Steep decline of Japan is due to unfortunate natural events in 2011 – 2012.
- South Korea's lack of concern is notable.

Percentage of Total Energy Generated using Renewable Resources
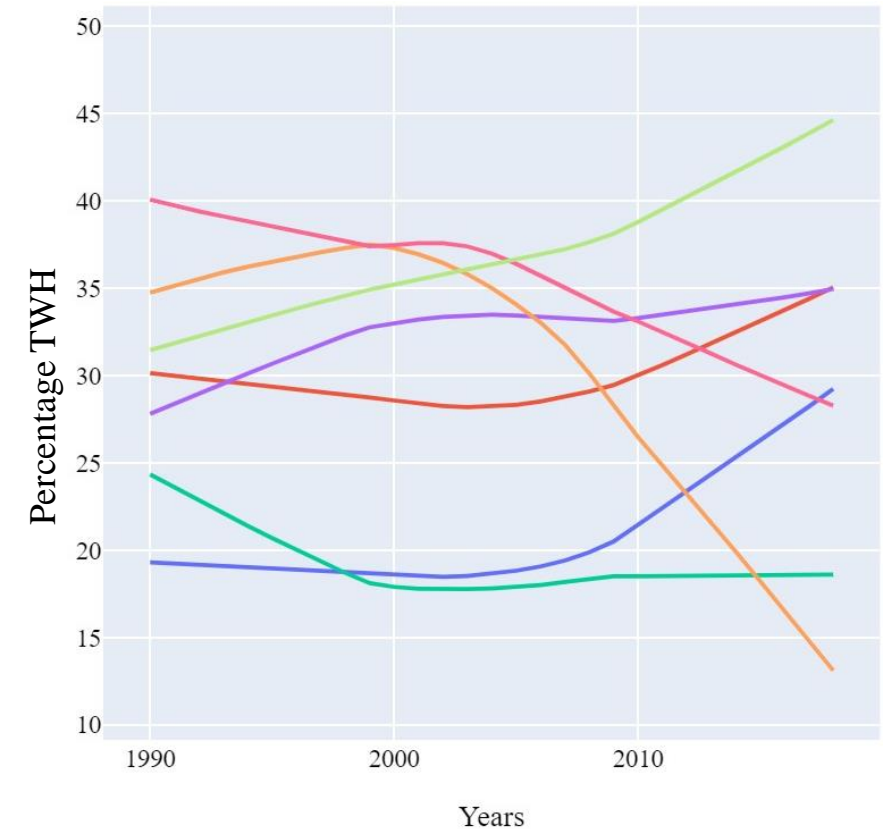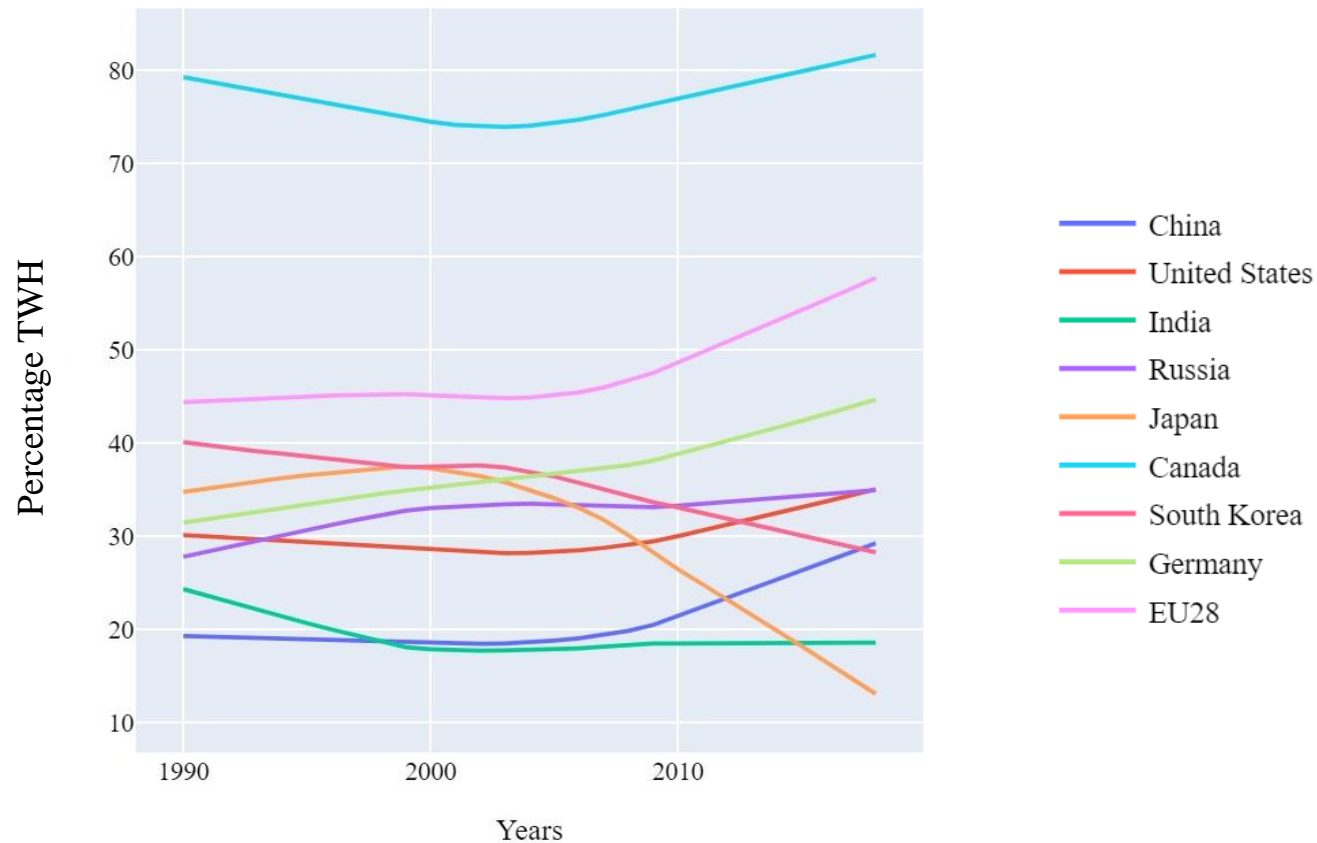
Observations:
- Any change in the energy mix of a country towards renewable resources is a huge plus for the environment.
- Since the plots represent percent contribution of renewable resources to total energy generated, and since the latter amount differs widely, therefore the graphs be used only to observe movement in energy mix and not comparing total renewable resources.
- South Korea have dropped from 48% in 1990 to 27% in 2018.
- Germans, on the other hand, have gone up from 30% in 1990 to 46% in 2018

Findings: United Stated of America

a) USA, in absolute fossil CO_2 emission terms, is second only to China and thus is a major contributor to global GHG concentrations.

b) United States has shown significant reduction in fossil CO_2 emission per capita to bring it below the levels of Canada. It does need to do a lot of hard work to be any-where near "Usual Suspects".

c) On fossil CO_2 emission on GDP basis (tCO_2 per kUSD of GDP) front, one of the largest economies of the world has led a trailblazing path having achieved better results than China, Canada, Russia, South Korea and India.

d) On annual energy generation from renewable resources front, the country continues to invest steadily and was second only EU until being overtaken by China.

e) From a low in 2007 (27%) energy mix has gone up to 35.6% in 2018.

Findings: China

a) Fossil CO_2 emission have risen to the pole position registering a sharp rise after 2005.
b) Rising population has helped maintain per capita fossil CO_2 emission levels.
c) On fossil CO_2 emission on GDP basis (tCO_2 per kUSD of GDP) front, China appears to have worked hard to achieve a steep decline.
d) Annual energy generation from renewable resources have seen exponential growth after 2005.
e) China's energy mix has gone up from 19% in 2007 to 29% in 2018.

Findings: Russia

a) On energy mix front (Percentage of Total Energy Generated using Renewable Resources), Russia are inching towards US levels (about 35.7% from renewable resources).
b) The country has a large tract of boreal forests that helps balance its total carbon footprint.
c) Their performance on almost all fronts has been flat and lackluster; they seem to be over-dependent on their boreal forest reserve to mitigate emissions.

Findings: European Union

a) The European Union member countries, most vocal about GHG emission, are just below USA and China in total fossil CO_2 emission.

b) After 2005 EU countries have shown commitment and registered an 18% decline in absolute fossil CO_2 emission by year 2018.

c) On annual energy generation from renewable resources front, the group has shown leadership.

d) Their per capita fossil CO_2 emission vastly outdistances other countries under study although it has shown a steady decline specially after year 2000.

e) The development of Europe has huge environmental cost; they have done and achieved far less in fossil CO_2 emission on GDP basis (tCO_2 per kUSD of GDP) compared to other economies.

f) On energy mix front, (Percentage of Total Energy Generated using Renewable Resources) this group has shown excellent commitment of moving towards a non-polluting future.

Findings: Germany

a) They have shown a steady decline in their already quite low absolute fossil CO_2 emission levels throughout our study period.

b) Even in per capita fossil CO_2 emission criteria Germany has shown exemplary commitment towards a cleaner environment.

c) On fossil CO_2 emission on GDP basis (tCO_2 per kUSD of GDP) front their achievement is exemplary being the lowest amongst the selected group.

d) Germany has steadily improved upon it's energy mix inching towards 50% mark. (46.7% in 2018)

Findings: Japan

a) Despite its smaller size, the country is a heavy polluter showing little concern towards employing low pollution production methods.

b) On fossil CO_2 emission on GDP basis (tCO_2 per kUSD of GDP) front, Japan continues to show indifference.

c) On annual energy generation from renewable resources front, Japan has shown a reverse trend due to unfortunate natural events in 2011 – 2012 leading to a sharp decline in *the LOWESS trendline*.

d) A reading from their INDC[5] reveals that they are focused on purchasing carbon credits from the market to mitigate their non-performance on emissions front.

Findings: South Korea

a) The Country has shown a steep increase in per capita fossil CO_2 emission levels to almost reach the levels of a decreasing USA.

b) On fossil CO_2 emission on GDP basis (tCO_2 per kUSD of GDP) front the country exhibits lack of commitment.

c) Despite its smaller size, the country is a heavy polluter showing little concern towards employing low pollution production methods.

d) On annual energy generation from renewable resources front, South Korea are clearly the laggards of the group (discounting Japan).

e) South Korea surprisingly have shown a negative movement in renewable energy mix – from 48.6% in 1990 to 27.1% in 2018.

f) As is evident from INDC[6], they are focused on purchasing carbon credits from the market to mitigate their rather lackluster performance on emissions front.

Findings: India

a) India were quite low down the "roll of honor" of absolute fossil CO_2 emission in the year 1990 have registered sharp increase after 2001 and by 2018 they have reached levels just below EU28.

b) India have the lowest per capita fossil CO_2 emission levels; it obviously has a direct link to the low growth levels and high population.

c) Indian investments in yearly energy generation from renewable resources has picked up around 2005 and is nearing German levels despite being a weaker economy.

d) The percentage energy mix curve of India fell from 25% in 1990 to 16.80 % in 2000 and has flatlined around 19% in 2018.

Limitations

- Environment is a vast topic, it is not possible to do justice to such a subject in a couple of lines. It is important for the report to be meaningful and correctly interpreted by everyone and we did not want to make the report like United Nation's Energy Statistics Pocketbook (specially graphs on page 25 and 26)[6].

- Data about total greenhouse gas emission of the selected countries had several missing values and therefore the report only explores Fossil CO_2 emission.

- For every graph we had to dedicate two different slides, a **general slide** which had a graph with **all the countries** and a **focused slide** with countries **clustered at the bottom** of the graph. This was necessary because of the difference between the leaders and the laggards.

Conclusions

1. The most vocal about environment, are also the most polluting – EU28 are (i) number three on total emissions, (ii) highest on per capita basis, & (iii) highest GDP basis.

2. USA is (i) 2nd in total emissions, (ii) 2nd in per capita emission, (iii) 5th on GDP basis, & (iv) 6/7th on energy mix basis. It has shown good progress on almost all fronts post 2005.

3. The Germans have shown excellent commitment to environment on most of the parameters.

4. The Russians are totally dependent on their boreal forest reserves to mitigate poor performance on emissions front.

5. South Korea and Japan have surprised by their inability/unwillingness to adopt low pollution production methods. Both the countries are dependent on buying carbon credits. This amounts to "dumping their garbage elsewhere". Given their strong economy shouldn't they be responsible for developing low pollution production methods and disseminating the technology to the disadvantaged.

6. India and China have consistently taken advantage of "developing country" tag to avoid serious work on environmental front.

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