Major Research Project on

Statistical study on the impact of Fossil Fuel Subsidy on Greenhouse gas emissions

Submitted By

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CERTIFICATE

This is to certify that **Yuvraj Gosain,** roll number **2K22/DMBA/150** a student at Delhi School of Management, Delhi Technological University has worked on a research project titled "**A Statistical Study on The Impact Of Fossil Fuels Subsidy on Greenhouse Gas Emissions** " in the partial fulfilment of the requirement for the award of the degree of Master in Business Administration program for the academic year 2022-2024.

Signature of Guide	**Signature of HOD**
Dr. Shikha N Khera	**Dr. Saurabh Aggarwal**
Assistant Professor	**Associate Professor**

DECLARATION

I hereby declare that the project work titled " **A Statistical Study on The Impact Of Fossil Fuels Subsidy on Greenhouse Gas Emissions”** submitted to the Delhi School of Management, is a record of an original work done by me under the guidance of Dr Shikha N Khera and this project work is submitted in the partial fulfilment of the requirements for the award of the degree of Master of Business Administration. I declare that this research is my own, unaided work. It has not been submitted before for any other degree, part of a degree or examination at this or any other university.

Yuvraj Gosain

(2K22/DMBA/150)

ACKNOWLEDGEMENT

I want to thank Dr. Shikha N Khera and Ms Komal for allowing me to work directly under their supervision and guidance. I appreciate all their help and support during my major research project. It was an excellent learning opportunity.

I appreciate the unmatched assistance, suggestions, and thinking that enabled me to finish my job with all the correct data.

Finally, I would like to express my gratitude to all the distinguished Delhi School of Management faculty members for sharing their knowledge and experience on this project.

My wholehearted effort has been directed towards ensuring the job is flawlessly finished and executed to the highest standard.

Yuvraj Gosain

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EXECUTIVE SUMMARY

Fossil fuel subsidies harm countries by emitting Greenhouse gases and artificially creating a price that is not a realistic price for their usage. They indirectly block the path for clean energy investments by making fossil fuel consumption more affordable and encouraging their wasteful consumption such as in large cars with lower mileage. Consequently, fossil fuel subsidies lead to climate change which in turn causes water pollution, air pollution, and biodiversity loss. They are also expensive and inefficient because adequate safeguards are not built by countries so that these subsidies go only to the economically weaker section but instead, these benefits go to the wealthy. Fossil fuel subsidy reform can substantially aid the fight for climate change because it will help reduce demand.

Global aid was US$5.9 trillion in 2020, accounting for approximately 6.8% of GDP, and is expected to rise to 7.4% of GDP by 2025. Despite the high cost of fuel subsidies, it is possible to achieve significant results with financial reforms. Removing these subsidies is expected to lead to a reduction in global greenhouse gas emissions of approximately 32% below 2018 levels, in line with limiting world warming to 1.5 degrees Celsius by 2030.

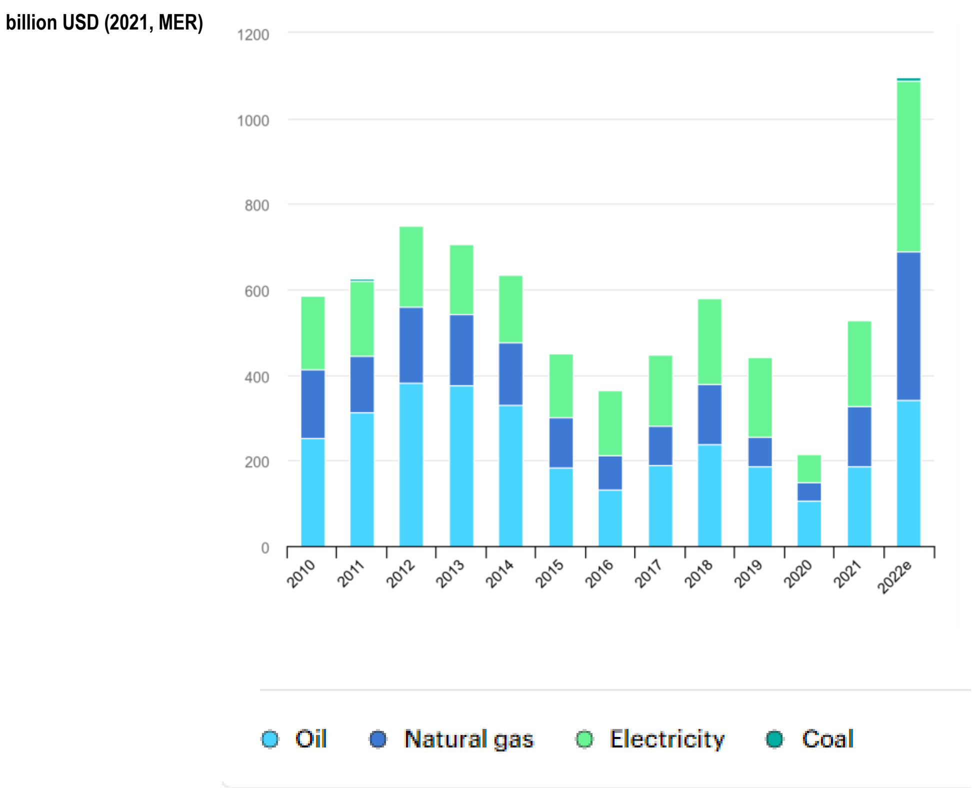
It is widely recognized that countries with high fossil fuel subsidies tend to have significantly higher greenhouse gas (GHG) emissions. Global estimations suggest that nations artificially lowering the cost of fossil fuels emit 11.4% more GHG emissions compared to those that do not adopt such practices. Despite this widely known issue, the overall extent of subsidies continues to remain at elevated levels.

Initial small subsidies aimed at maintaining price stability can evolve into entrenched schemes. These subsidies draw in interest groups that advocate for increasing permanent subsidies, making it challenging to eliminate or redirect them. The issue with energy subsidies lies not in understanding their negative impact but in the complexities of political economy.

The Fossil Fuel Subsidy dataset has the latest data from 3 international databases, including organizations such as the OECD, the IEA, and the IMF. The inputs from the three organizations are based on two different approaches, which allow us to comprehend the output better.

Fossil fuel subsidy 12-year Period By Type Of Fuel.

MER: Market Exchange Rate as a % of GDP



Source :IEA,2022

Fossil Fuel Subsidies crossed $1 trillion in 2022 which showed a substantial increase over the previous years. This increase was largely due to chaos in the supply side of the energy market leading to international fuel prices surpassing actual costs for many countries. The subsidies observed in 2022 were 2X the size of those in 2021, which in turn were nearly 5X more than those allocated in 2020. This rapid escalation was significantly influenced by the global energy market dynamics.

The statistical tests performed by us on the panel dataset of 12 years of data for 10 countries shows that there is a high correlation (almost 50%) between fossil fuel subsidies and greenhouse gas emissions, both in the correlation test and the regression test. The R^2 test and adjusted R^2 test also showed that the explanatory variables of the various fuel types such as petroleum and coal had a higher effect on Greenhouse gases and were statistically also more significant.

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CHAPTER 1

1. Introduction

General Area: The study will focus on the relationship between fossil fuel subsidies and greenhouse gas emissions.

Importance: Climate change, driven by increasing greenhouse gas emissions, poses a significant threat to global sustainability and human well-being. Fossil fuels are the primary contributor to these emissions, and their consumption is often artificially incentivized through government subsidies. Understanding the causal relationship between these subsidies and emissions is crucial for designing effective climate change mitigation strategies

1.1 Background

Previous research has established a connection between fossil fuel subsidies and increased emissions. Existing studies have employed various methodologies, including:

Econometric models: These models estimate the causal impact of subsidy removal on emissions, accounting for other confounding factors. Studies using this approach have found that eliminating fossil fuel subsidies could lead to substantial emission reductions (International Monetary Fund, 2021).

Comparative case studies: Researchers have compared countries with significant fossil fuel subsidies to those with minimal subsidies, highlighting the association between subsidies and higher emissions (IISD, 2022).

Historical analyses: Examining historical data allows for the exploration of the dynamic relationship between subsidy policies and emission trends over time (IEA, 2023).

While existing research provides valuable insights, several gaps remain. Many studies focus on broad regional or global data, lacking a nuanced understanding of how the relationship between subsidies and emissions varies across individual countries and within different economic sectors. Additionally, few studies comprehensively examine the mediating factors influencing this relationship, such as pre-existing energy infrastructure, political context, and public attitudes toward climate change.

1.2 Problem Statement

The purpose of the subsidies is to protect consumers by keeping prices low, but they come with significant costs. Subsidies have significant fiscal consequences and often lead to higher taxes/borrowing or lower spending on public health, and infrastructure etc, promote inefficient allocation of economic resources (impede growth), promote pollution (contribute to climate change and premature deaths from local air pollution), and are not well-targeted. for the poor. Eliminating subsidies and using revenues to better distribute social costs, reduce inefficient taxes, and invest in productive investments can contribute to the SDG goals. Eliminating fossil fuel subsidies would also reduce concerns about the fluctuating nature of the prices of fossil fuels.

1.3 Objectives of the Study

This research will conduct a comprehensive statistical analysis of the impact of fossil fuel subsidies on greenhouse gas emissions, focusing on:

- To explore the relationship at the country level and if data is available also on whether different fuels have different impacts.
- Incorporate economic, political, and social factors alongside subsidy data.
- To examine countries with differing subsidy policies and emission levels.

1.4 Scope of Study

The study will focus on 4 major fossil fuels i.e petroleum, oil, natural gas, and end-use electricity with International Energy Agency data available from multiple sources such as IMF, Asian Development Bank, and Country reports obtained by the IEA for our statistical analysis to build a correlation between greenhouse gas emissions and fossil fuel subsidies.

Using research already done in multiple areas to understand comprehensively whether factors, such as economic development, political stability, and energy infrastructure, influence the relationship between subsidies and emissions.

To understand whether there are significant differences in the impact of subsidies on emissions across different fossil fuel sectors e.g., power generation, transportation etc.

CHAPTER 2

2.0 LITERATURE REVIEW

The main problem with fossil fuel subsidies is their significant contribution to climate change and environmental degradation (Arzaghi and Squalli 2023; Solarin 2020).

These subsidies reduce the cost of fossil fuels, stimulating increased consumption, which leads to increased greenhouse gases (GHG). This undermines global efforts to combat climate change and the transition to cleaner renewable energy sources. Recent studies have shown that fossil fuel consumption is a decisive factor in increasing carbon dioxide (CO2) emissions (Le Quéré). et al. 2019; Liang, Zhang, and Qiang 2022). Increased levels of fossil fuel subsidies show a positive correlation with increased greenhouse gas emissions (Arzaghi and Squalli 2023; Jewel et al. 2018; Ellis 2010). Countries with significant fossil fuel subsidies emit 11.4% more greenhouse gases than countries with high fossil fuel taxes (Arzaghi and Squalli 2023). Fossil fuel subsidies increase greenhouse gas emissions in two ways: they act as an incentive to consume fossil fuels and they prevent low-carbon energy solutions. Global CO2 emissions have risen to 32 billion tonnes in 2020, and a staggering 90% of those emissions come from the use of fossil energy sources. In addition, fossil fuel subsidies are often criticized as one of the biggest obstacles to the adoption of low-carbon solutions such as renewable energy, energy efficiency (Sovacool 2017; Li and Solaymani 2021) and subsequently increases consumption and emissions of carbon dioxide in all sectors of the economy. In addition to influencing greenhouse gases, fossil fuel subsidies have been criticized for their ineffectiveness (Anbumozhi et al .. 2023; De Bruin and Yakut 2023). Subsidized energy is offered to households and

businesses as low-cost energy with the aim of supporting the poor and increasing the competitiveness of local goods (Lin and Li 2012). However, groups of higher incomes tend to benefit more than groups with low incomes, because members of these groups have bigger houses and cars. Subsidies affect the overall capacity of a nation to invest in public expenditure, reduce spending from other areas such as education or health in some Asian countries.

Subsidies for fossil fuels increased in 2021-2023 due to a sharp rise in energy prices caused by the Russian invasion of Ukraine. However, the effect of subsidies on greenhouse gas emissions (or fossil fuel consumption) is not clear. While some studies show that subsidy reductions bring benefits to the environment (Jewell et al. 2018; Ellis 2010; Arzaghi and Squalli 2023; Chepelievja Mensbrugghe 2020), others show that subsidy reductions have no or even harmful effects on the environment (Greve and May 2023). An increase in the energy price should encourage the reduction of energy consumption and improvement of energy efficiency but sometimes it does not give the desired effects. For e.g., the consumer/industry might shift to relatively cheaper but more polluting fuels (e.g. from electricity to coal or diesel) or the industry may not have the option to switch to low-emission substitutes (such as steel and cement), where renewable electricity cannot replace fossil fuels because high temperatures are needed. Green hydrogen could replace fossil fuels in sectors such as steel and cement in the future, but it is still a less advanced technology (compared to renewable energy) and its current costs are significantly higher than those of fossil fuels. For the above reasons, it is important to study the impact of fossil fuel subsidies on greenhouse gas emissions and find if it is to have policy recommendations for the effective implementation of fossil fuel subsidies or phase-out in the long run.

CHAPTER 3

3. RESEARCH DATA

3.1 Dependent Variable: GHG Emissions

The input data for GHG Emissions has been obtained from the IEA website and a more detailed explanation of inputs included in this variable is given in the table below from the IEA dataset :

Figure3

GHG emissions from fuel combustion (kt of CO_{2eq})

Flow	Short name	Definition
GHG from fuel combustion	GHGFCOMB	*GHG from fuel combustion* presents total greenhouse gas emissions from fuel combustion including CO_2, CH_4 and N_2O. This includes GHG emissions from fuel combustion in IPCC Source/Sink Category 1 A Fuel Combustion Activities and those, which may be reallocated to IPCC Source/Sink Category 2 Industrial Processes and Product Use under the *2006 GLs*. GHGFCOMB = MAINPROD + AUTOPROD + OTHEN + TOTIND +TOTTRANS + RESIDENT+ COMMPUB + AGRICULT + FISHING + ONONSPEC. For the most recent year available, this value is estimated based on provisional data. Please refer to the section *Provisional year estimates* for more information on this methodology.

Source :IEA

3.2 Independent Variables: Fossil Fuel Subsidy

This research has used the Fossil Fuel Subsidy tracker provided as a free-to-use dataset that incorporates inputs from almost all bodies working in the energy sector. The data provides us inputs on all types of fossil fuel subsidies i.e. Oil Subsidy, Natural Gas Subsidy, End Use Electricity Subsidy, and Coal Subsidy.

3.3 Selection of Data Sets

The Fossil Fuel Subsidy dataset has the latest data from 3 international databases which include organizations such as the OECD, the IEA and the IMF. The estimates used in the dataset are based on 2 approaches.

The IEA and the IMF for their calculation of subsidies use the final consumption prices paid by fuel consumers with reference prices (for e.g., import prices of the same fuel). Fossil fuel subsidy dataset follows only the explicit model. The IMF data for certain selected countries also includes indirect subsidies. Indirect subsidies take into account the underestimation of costs on the environment and output taxes and are therefore higher than "explicit" subsidy estimates. The OECD data is based on direct budget subsidies, transmissions, and tax expenditures that favor the production or consumption of fossil fuels over alternatives. It also includes money spent on lowering the prices of fossil fuels by developing private or public institutions and infrastructures that support these fuels in the long run.

3.4 Definition of Fuels in the Fossil Fuel Subsidy Dataset

Fuels covered by the Fossil Fuels Dataset include primary fossil fuels (such as petroleum, natural gas, coal, and peat) and refined or finished products (such as diesel, gasoline, kerosene, and coal briquettes). Primary fuels include fossil fuels derived from crude oil, such as tar sands oil, shale-produced natural gas, or methane produced from coal beds. Electricity: Includes electricity produced from fossil fuels for end users. According to estimates by the OECD and the International Energy Agency, the final support for electricity includes financial aid through the provision of electricity prices below production costs.

Points to Remember in any Decision-Making arising from This Data Set

The OECD dataset is more extensive than the conventional meanings of "endowment". The OECD dataset is wider in its definition because it is used for defining national policies in this domain. The information provided in the Fossil Fuel Subsidies Dataset may be an underestimation of the actual subsidy. This is because the OECD rundown might not have incorporated every strong measure or the actions taken might not have been completely evaluated. Values for certain measurements may not be accessible or may incorporate just fractional information. Along these lines, void cells ought to be treated as values that are not provided but cannot be assumed to be nulls.

3.5 Database used for Greenhouse Gas Emissions: The Greenhouse Gas Emission database contains global annual GHG emissions from fuel combustion including all fossil fuels such as Oil, Natural Gas, End Use Electricity generated using fossil fuels and Coal

Emissions from fuel combustion are calculated using IEA energy balances and the default methods and emission factors given in the IPCC Guidelines.

Method: The study has employed a mixed-methods approach, combining quantitative and qualitative data analysis.

- Quantitative data collection: We have utilized datasets on fossil fuel subsidies, and greenhouse gas emissions from the IEA website which gives datasets that have been downloaded for our statistical analysis.
- Qualitative data collection: We have relied on secondary sources of information that have authenticated data-backed research such as the IMF, IEA, and research published by energy policymakers and industry experts in selected countries to gain deeper insights into the context and factors influencing subsidy policies and their environmental impact.

Techniques & Tools Used:

- Quantitative analysis: We have employed a panel regression model to estimate the causal effect of greenhouse gases with time series data for 10 countries over 12 years from 2010-2021 for performing rigorous tests using " Stata" a statistical data analytics tool. The input data from two different datasets, 1) using the Fossil fuel subsidy tracker and 2) using the GHG Emission Highlights dataset available on the IEA website was downloaded, cleaned and various iterations of regressions were performed to see what would be the best choice of countries to establish whether there exists a correlation between greenhouse gases and fossil fuel subsidies. Additionally, we have used descriptive statistics and correlation analysis to explore relationships between variables. Initially, we faced problems using the numbers given in the fossil fuel subsidies since data had very large numbers and variations which affected the quality of results. In order to do a correct analysis we understood that data required smoothening for a correct picture. In subsequent iterations of regression and datasets we created fresh variables for log outputs from the input fuel variables and greenhouse gases. This model is typically called a double-log model in statistical analysis.
- Qualitative analysis: We studied research papers by industry experts that had done analysis based on other control variables to identify key themes and patterns that could provide context to our quantitative findings and also widen the understanding of linkages with other factors that influence subsidy.

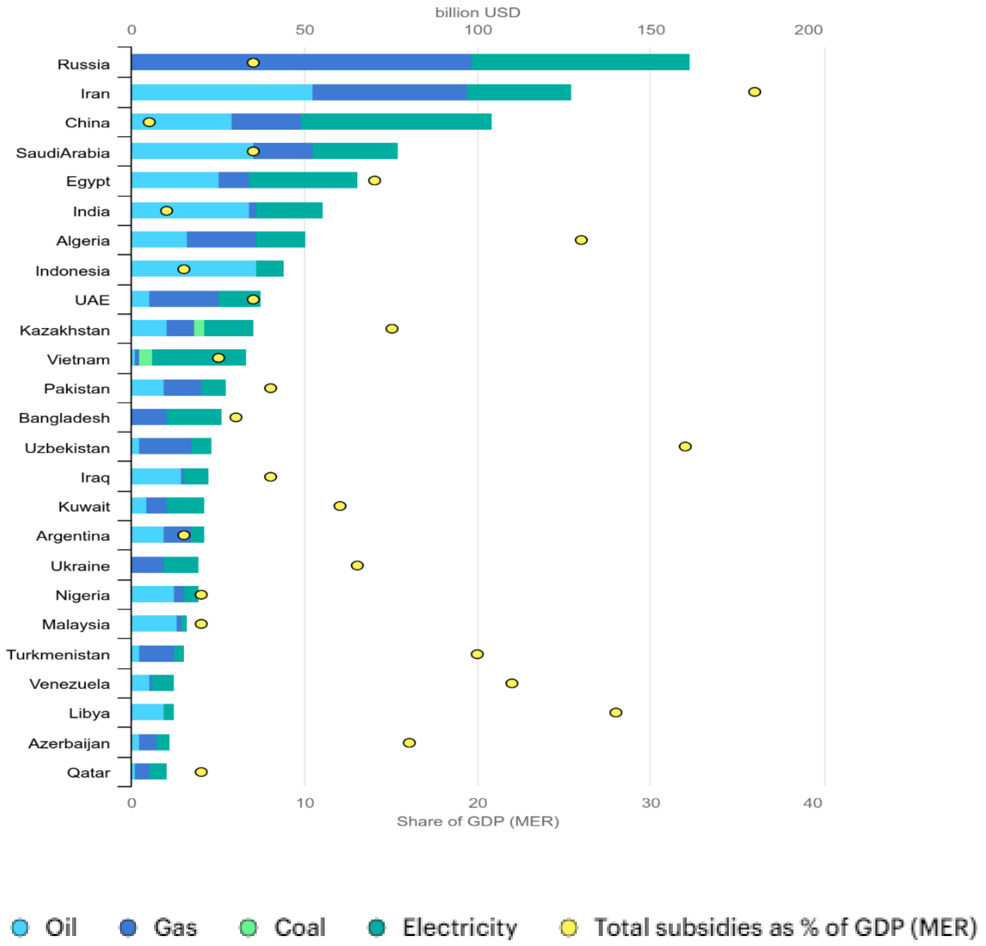
CHAPTER 4

4.0 Major Observations From The Project

The International Energy Agency, or IEA, has long supported eliminating or drastically cutting back on subsidies related to fossil fuels since they distort markets, give consumers incorrect pricing signals, increase subsidies in developing nations, and hinder the development of clean energy sources. The nations' accomplishments over the previous ten years might be undone by this increase in fossil fuel subsidies at a time when they should be falling. Many nations find it difficult to maintain gasoline prices at actual costs since fuel is utilized for nearly all activities by the poorest segments of society, and political and social considerations typically take precedence over basic sense, which dictates that any subsidies should be avoided.

In 2022 Russia, Iran, and China were the three largest subsidy givers.

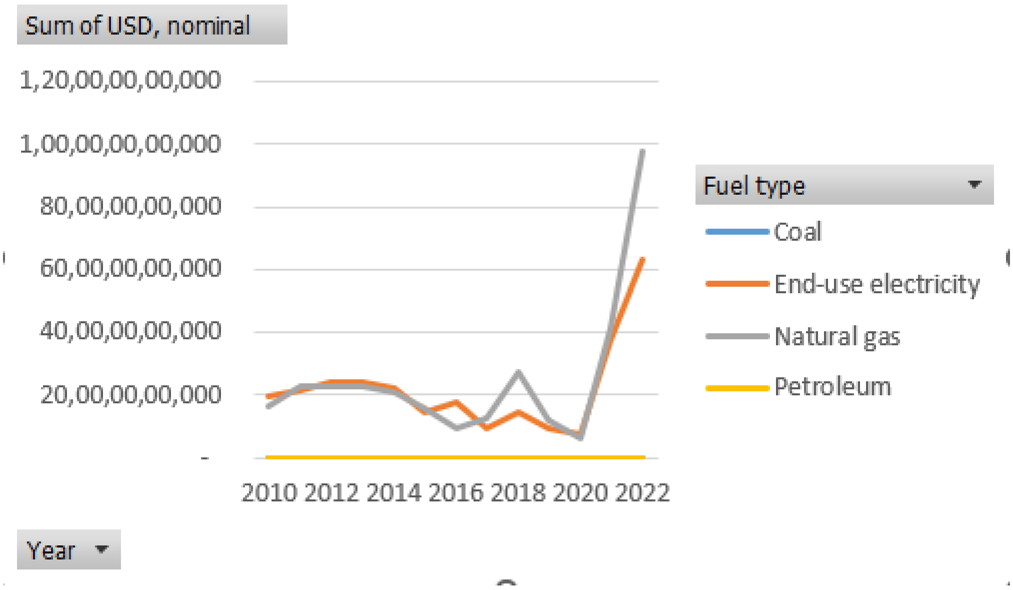
Figure 4.1 Value of fossil-fuel subsidies by fuel in the top 25 countries, 2022



Source : IEA,2022

4.1 Understanding The Country Trends in Fuel Subsidy for top 6 countries giving Fuel Subsidy from 2010-2022

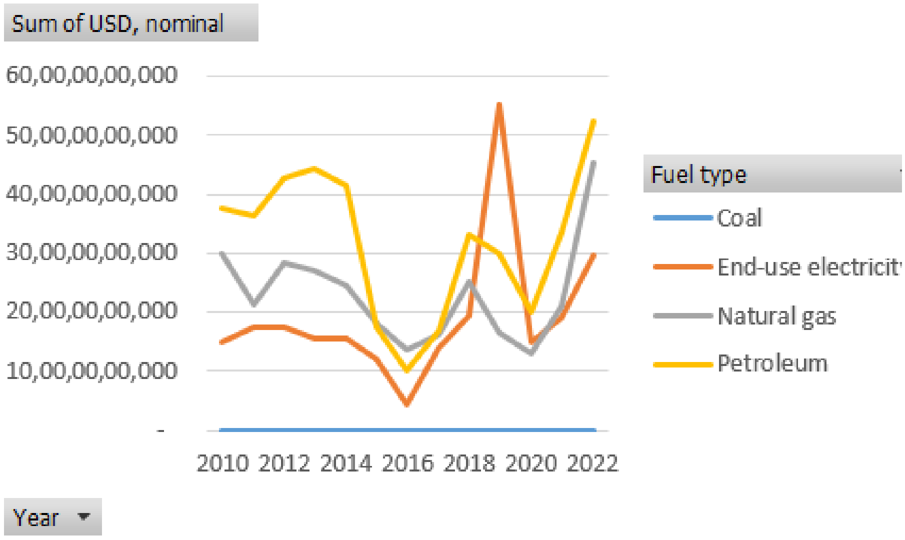
Figure 4.2 Russia Subsidy Trend Fuel Wise (2010-2022)



Source: Author

- **Petroleum:** Russia does not give petroleum subsidies since it is one of the largest petroleum producers in the entire world.
- **Natural gas:** The Natural gas subsidy showed a declining trend from 2010-2016 and then there was an increase from 2016 to 2018, a small decline again, and then a major spike from 2020-2022 which was the after-effect of the Ukraine war.
- **End-use electricity:** The end-use electricity trend for subsidy has been fluctuating between 2010-2020 largely but overall following a declining trend but from 2020 -2022 there has been a spike here also.
- **Coal :** Either there is no subsidy or data has not been reported

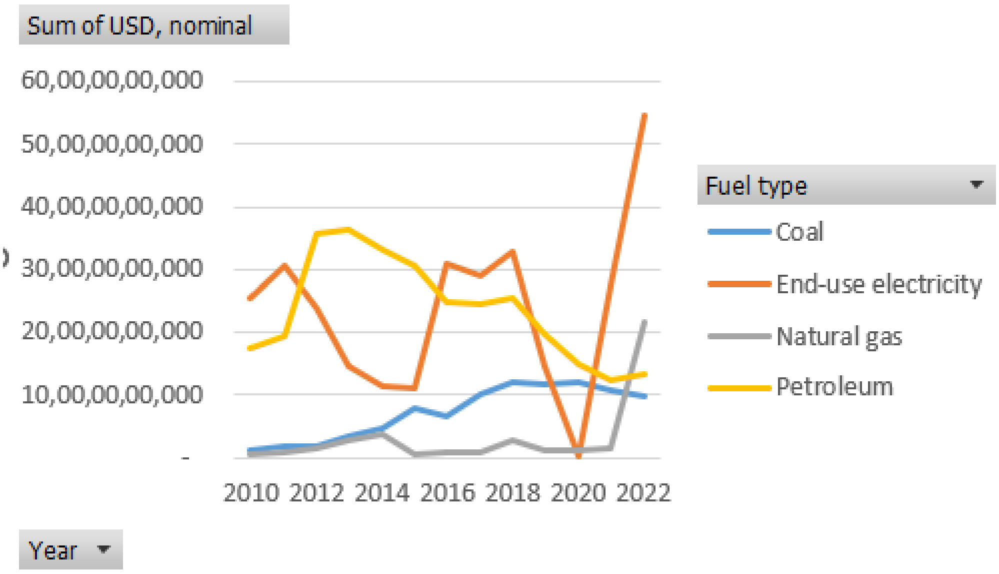
Figure 4.3 Iran Subsidy Trend Fuel Wise (2010-2022)



Source :Author

- **Petroleum:** Iran had a declining trend in fuel subsidy from 2010-2016 and almost a 50% retracement from 2016-2018 on the earlier gains, then again a fall and from 2020-2022 there has only been an increase with a sharp spike.
- **Natural gas:** The Natural gas subsidy trend in Iran has followed a similar trend as petroleum subsidy.
- **End-use electricity:** The end-use electricity trend for subsidy has been declining from 2010-2016. From 2016-2019 there was a sharp spike and then a fall in subsidy in 2020. From 2020-2022 it is again showing a steady upward trend.
- **Coal :** Either there is no subsidy or data has not been reported.

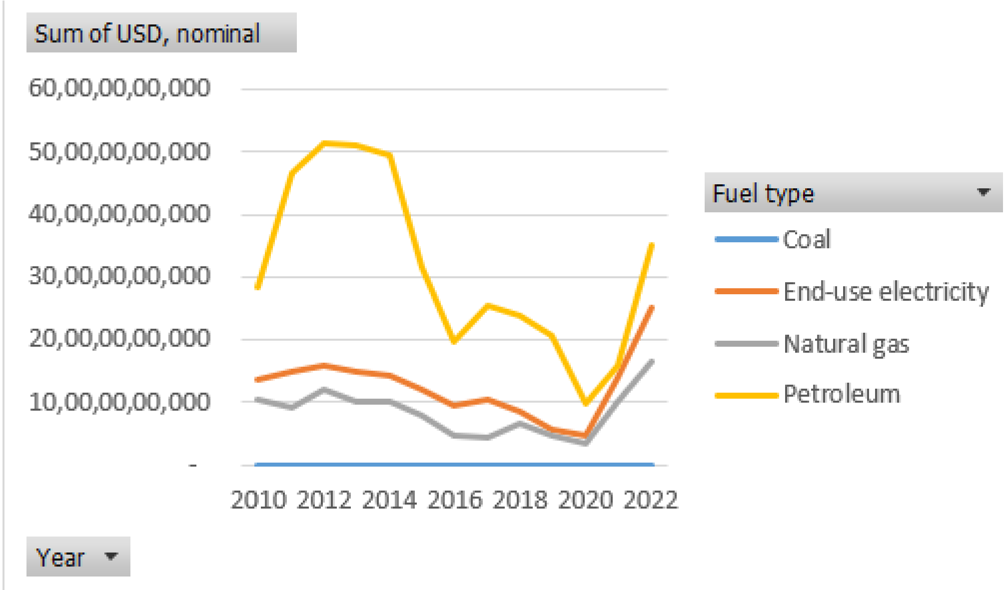
Figure 4.4 China Subsidy Trend Fuel Wise (2010-2022)



Source:Author

- **Petroleum:** China had a increase in petroleum subsidies from 2010 to 2013 but has shown a downward trend since then till 2022.
- **Natural gas:** The Natural gas subsidy trend in China was consistent from 2010 to 2020 but has shown a upward trend (20 times of previous year) in 2022.
- **End-use electricity:** In China the end use electricity trend for subsidy has been declining from 2011-2015.In 2016 there was a sharp spike which was maintained till 2018.In 2019 and 2020 there was a sharp decline which can be attributed largely to Covid since China was affected very badly. In 2021 consumption came back to normal and hence subsidy jumped almost double. and in 2022 it has double again from the previous year.
- **Coal:** China had a upward trend in coal subsidy from 2010 -2020 and has registered a small decline from 2020-2022.

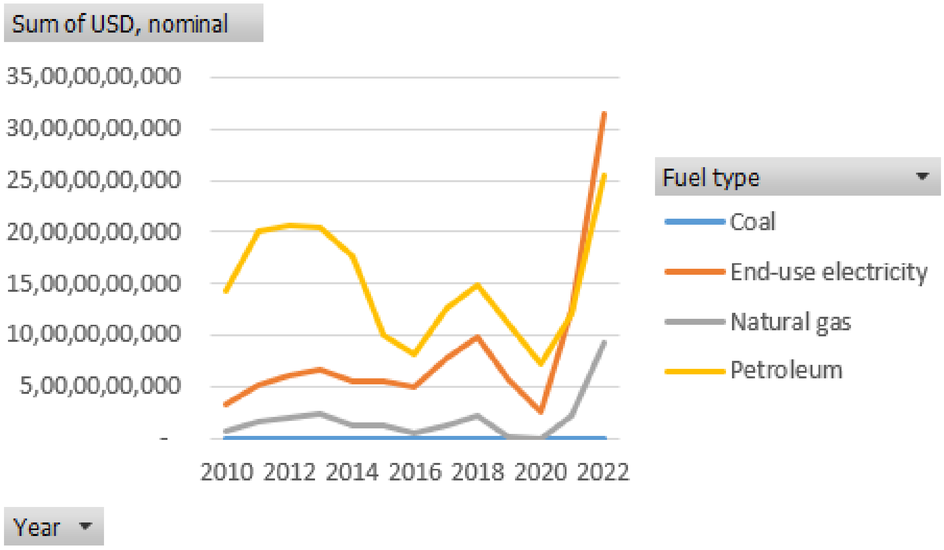
Figure 4.5 Saudi Arabia Subsidy Trend Fuel Wise (2010-2022)



Source :Author

- **Petroleum:** Saudi Arabia had a increase in petroleum subsidies from 2010 to 2014 (almost doubled) but has shown a downward trend from 2014 -2016. In 2017 it showed a gradual increase .to 2019 and then a decline in 2020 as per the trend worldwide. From 2020 to 2022 it has steadily increased back to 2015 level giving up almost all gains.
- **Natural gas:** The Natural gas subsidy trend in Saudi Arabia was consistent from 2010 to 2014 and then a downward trend till 2020 but has shown a upward trend from 2020-2022 and in 2022 surpassed the level of 2010.
- **End-use electricity:** In Saudi Arabia the end-use electricity trend for the subsidy has been declining from 2010-2020 and then an increase from 2020-2022.
- **Coal:** No reported subsidy to IEA.

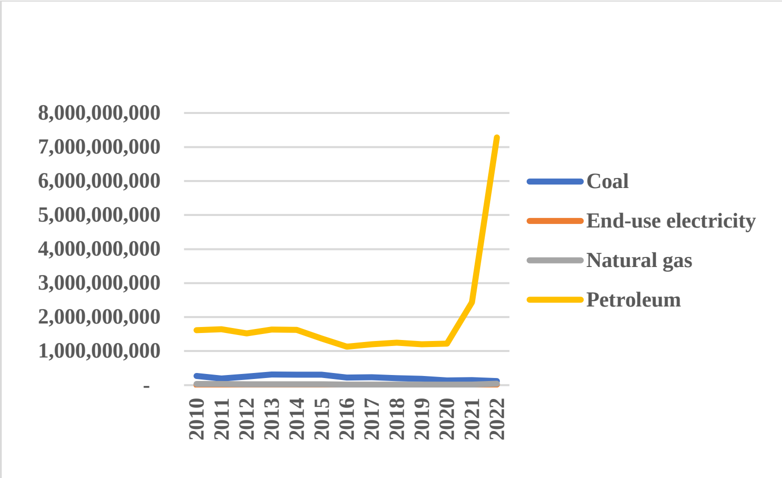
Figure 4.6 Egypt Subsidy Trend Fuel Wise (2010-2022)



Source :Author

- **Petroleum:** Egypt had an increase in petroleum subsidy from 2010 - 2013.From 2014-2016 it was able to reduce the petroleum subsidy and in 2017and 2018 it registered an upward increase again. From 2018 to 2021 it kept fluctuating whereas in 2022 it registered a spike again as was the trend globally due to the worldwide shock on crude prices.
- **Natural gas:** The Natural gas subsidy trend in Egypt followed the yearly trends as the petroleum cycle although the quantum of subsidy on this fuel was much lower.
- **End-use electricity:** The end use electricity subsidy trend in Egypt increased from 2010-2013 and then nearly plateaued between 2014-2016. From 2016 t-2018 it showed an increase, and then from 2018 to 2022 it showed a substantial fall following the worldwide trends for this. From 2021 and 2022 Egypt has also showed a substantial hike in subsidy trends and reached its highest levels since 2010.
- **Coal:** No reported subsidy to IEA.

Figure 4.7 India Subsidy Trend Fuel Wise (2010-2022)



Source :Author

- **Petroleum:** India had an increase in petroleum subsidy from 2010 -2013.From 2014-2016 it was able to reduce the petroleum subsidy and in 2017and 2018 it registered an upward increase again. From 2018 to 2020 it showed a downward trend whereas in 2021 and 2022 it registered a spike again as was the trend globally due to the worldwide shock on crude prices.
- **Natural gas:** The Natural gas subsidy trend in India increased form 2010-2014, then fell from 2015-2017, again rose in 2018.From 2018-2020 the subsidy level fell again, and in 2021 and 2022 it seems to have risen following the worldwide trend for these years but has not risen beyond 2018 levels.
- **End-use electricity:** The end-use electricity subsidy trend in India increased from 2010-2016 with 2 falls in between. and then nearly plateaued between 2014-2016. From 2016 -2020 it kept fluctuating with an increase as well as a decrease in these years. From 2020 to 2022 India has almost trebled its subsidy levels and shown a substantial jump in this category.
- **Coal:** No reported subsidy to IEA.

4.2 Statistical Analysis

Criterion Used for Selection of Countries in Panel Data Statistical Analysis

The countries that have been selected from the larger IEA dataset are based on the logic that those countries that have a higher subsidization rate should be included in the data set to statistically also check whether what has been found in scientific studies worldwide is also getting established from the live data received by the IEA regarding the subsidy amounts spent by them in the past 10 years from 2010 -2021. We have not been able to incorporate the data for 2022 because all the top 10 countries that provide the subsidies have not provided the GHG emissions data for 2022.

The panel data has data for 10 countries over 12 years with data for greenhouse gas emissions between 2010 and 2021 and fuel subsidies for the same time periods. Since it had cross-sectional data for 10 countries based on various types of fuel subsidy and the time periods the statistical analysis had to be done using panel data analysis techniques.

Figure 4.8 Descriptive Statistics for Panel Data of 10 Countries

```
. summarize
```

Variable	Obs	Mean	Std. Dev.	Min	Max
CountryID	119	5.537815	2.866492	1	10
Year	119	2015.546	3.443855	2010	2021
GHGEmissions	119	1539.308	2747.294	96.45212	10795.99
CoalSub	119	1.18e+09	2.63e+09	0	1.22e+10
EndUElecSub	119	9.70e+09	9.04e+09	4.66e+07	5.53e+10
NatGasSub	119	6.53e+09	8.19e+09	2.20e+07	4.11e+10
PetrSub	119	1.64e+10	1.39e+10	0	5.15e+10
GrTotSub	119	3.38e+10	2.29e+10	3.00e+09	1.02e+11
logGHGEmis~s	119	6.344816	1.29081	4.569046	9.28693
logCoalSub	48	20.7577	1.854347	15.41833	23.224
logEndUEle~b	119	22.49786	1.17859	17.65769	24.73536
logNatGasSub	119	21.77856	1.403238	16.90615	24.44023
logPetrSub	108	23.10617	1.311947	18.78339	24.66444

Source :Author

The dependent variable is GHG emissions (in million tonnes of Co2 equivalent) and the independent variables are the fossil fuel subsidies country-wise for 12 years based on 4 different types of fuel subsidy ie Petroleum subsidy, Natural gas subsidy, End Use Electricity subsidy and Coal Subsidy.

The data above gives the mean values for GHG emissions, Standard Deviation for Different Fuel subsidies across Fuel Categories, and minimum and maximum values of fuel subsidy based on the sample data chosen by us.

Figure 4.9 Correlation Statistics Between GHG Emissions and Various Subsidies

```
. pwcorr logGHGEmissions logCoalSub logEndUElecSub logNatGasSub logPetrSub
```

	logGHG~s	logCoa~b	logEnd~b	logNat~b	logPet~b
logGHGEmis~s	1.0000				
logCoalSub	0.1112	1.0000			
logEndUEle~b	0.4952	0.0123	1.0000		
logNatGasSub	0.0018	-0.2138	0.3605	1.0000	
logPetrSub	0.4998	-0.1810	0.7012	0.0951	1.0000

Source:Author

Interpretations:

Correlations ranges from -1.00 to 1.00, with larger absolute values indicating a greater relationship.

1. From the above data it can be interpreted that there is a direct correlation between GHG emissions and Petroleum Subsidy to the tune of 49.98%.

2. Similarly GHG emissions and Natural Gas subsidies are positively correlated to the extent of 1.8%.

3.GHG emissions and End Use Electricity subsidy are also positively correlated with a correlation of 49.52 % which supports the widely held belief that a lot of End Use Electricity subsidy is ultimately landing up as subsidy to Coal plants because a large number of power producing plants in almost all countries are still based on coal.

4. GHG Emissions and Coal Subsidy are showing a lower correlation because coal subsidy data has not been provided by 6 countries in the sample out of 10 countries, hence 11.12% correlation is justifiable.

Figure 4.10 Regression Results of GHG Emissions and Various Subsidies

```
. reg logGHGEmissions logCoalSub logEndUElecSub logNatGasSub logPetrSub
```

Source	SS	df	MS			
				Number of obs	=	48
				F(4, 43)	=	16.63
Model	60.8479594	4	15.2119899	Prob > F	=	0.0000
Residual	39.3449902	43	.914999772	R-squared	=	0.6073
				Adj R-squared	=	0.5708
Total	100.19295	47	2.13176489	Root MSE	=	.95656

logGHGEmissi~s	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
logCoalSub	.203108	.0789623	2.57	0.014	.0438654	.3623506
logEndUElecSub	.1650946	.1470413	1.12	0.268	-.1314424	.4616316
logNatGasSub	.4708273	.2476839	1.90	0.064	-.0286748	.9703294
logPetrSub	.7675836	.1771938	4.33	0.000	.4102384	1.124929
_cons	-28.42076	5.680182	-5.00	0.000	-39.87593	-16.96558

Source:Author

Interpretations:

R squared values show the proportion of total variation in GHG emissions explained by the above independent variables used in this analysis which are the 4 types of Fuel subsidies. The R^2 Model typically tries to build a linear model by analyzing the explained and unexplained variation in the relationship. **Adjusted R^2** tries to consider the effect of adding even more variables to the data set. In the result for our regression since the R^2 and adjusted R^2 values are 60.73% and 57.08% which is a very high correlation between the 4 types of fuel subsidies and GHG Emissions.

This results from these 2 metrics would have been even better had we eliminated the outlier years of 2019 and 2020.

RMSE metric shows the standard deviation of the residuals or how far the residuals are from the
regression line data points. A good RMSE value would typically lie between .2 and .5 but here it is .95 due to inclusion of outlier years.

The F test in linear regression is the test statistic for the analysis of variance (ANOVA) approach to test the significance of the model or the components in the model. As a thumb rule if the F statistic >2.5 the correlation between independent variables and dependent variables is statistically significant. In this case the F statistic is 16.63 which makes it highly significant.

The T statistic is a measure of the difference between the mean of a dataset and the hypothesized population mean. It is used in hypothesis testing to determine whether the difference between sample means is statistically significant. The T statistic magnitude measures the size of the difference relative to the variations in the fossil fuel subsidies. It has a strong correlation if the magnitude of the T statistic is >2 which is the case here for the 3 Fuel subsidies including Petroleum subsidy (4.33), Natural Gas Subsidy (1.9) and Coal Subsidy (2.57) .

The P Statistic: In regression analysis, the P value for each fossil fuel will test the null hypothesis that this variable is not correlated with GHG Emissions. A p-value however is a probabilistic measure of the likelihood that the observed correlation that has shown up is by chance. A low P value of less than .05 (5% level of significance) assures us that the null hypothesis is not true. In our results again 3 out of the 4 fuel subsidies have P values which are very close or < .05. Only.

End-Use Electricity subsidy is .264 which is higher than .05 but we must always remember that P values can sometimes be an inaccurate analysis because they only reflect probabilities.

The p-value of the intercept in the regression shows the % of samples that will have a coefficient far away 0 if one draws multiple samples from our population.

An intercept value of "0" Is supposed to be a very good outcome indicating that even a larger sample will not help more in the model as a probability.

Figure 4.11 Fixed Effects Within Group Model Estimation Test Results

```
. xtreg logGHGEmissions logCoalSub logEndUElecSub logNatGasSub logPetrSub

Random-effects GLS regression                   Number of obs      =        48
Group variable: CountryID                       Number of groups   =         4

R-sq:                                           Obs per group:
     within  = 0.0562                                         min =        12
     between = 0.7611                                         avg =      12.0
     overall = 0.6073                                         max =        12

                                                Wald chi2(4)       =     66.50
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

logGHGEmissi~s	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
logCoalSub	.203108	.0789623	2.57	0.010	.0483448	.3578712
logEndUElecSub	.1650946	.1470413	1.12	0.262	-.123101	.4532902
logNatGasSub	.4708273	.2476839	1.90	0.057	-.0146241	.9562788
logPetrSub	.7675836	.1771938	4.33	0.000	.4202903	1.114877
_cons	-28.42076	5.680182	-5.00	0.000	-39.55371	-17.2878
sigma_u	0					
sigma_e	.0908747					
rho	0	(fraction of variance due to u_i)				

Source: Author

Interpretations

1. We use the Fixed effects within group model when the number of entities or time periods is large. One of the ways to estimate a pooled regression is to eliminate the fixed effects in the population is by expressing the values of the dependent and independent variables for each country as deviations from their respective means. For each country we then obtain the demeaned values in the sample and then pool all the panel data and run an OLS regression.
2. In our case we ran the same using Stata which made 4 groups with a sample of 48 observations instead of the complete population. The R^2 overall is still 60.73 % which shows a high degree of correlation between GHG emissions and fossil fuel subsidies. The Z parameter within the independent variable indicates the

mean value from the groups constructed. The P value of the test indicates the least value of α (Type 1 error) at which the null hypothesis can be rejected.

3. If the Wald Chi-square statistics of the estimates are greater than 3.84, it means the Chi-square test for each estimate is significant. In our case, the observed value is 66.50 for this test which indicates that the independent variables are statistically significant.
4. sigma_u: Error due to differences between units. sigma_e: Error due to differences within units. Rho: Proportion of variance due to unit effects

Limitations of This Study

1. It should however be kept in mind that the statistical results would vary greatly based on the sample size and the countries included in the statistical analysis.

2. It should also be kept in mind that the results can easily be bettered by removing the outliers from the data i.e the years of 2019 and 2020 because those were Covid years and there was a significant decline in fuel subsidies in almost all countries because worldwide economic activity had fallen drastically and hence consumption of fossil fuels was also lowered resulting in much lower subsidies. The choice was between omitting this data or keeping this data in order to make the report with the latest years as far as possible and we decided to go with the latest data.

3. The main limitations of this study are due to limited data availability. Data on fossil fuel subsidies are estimated by the IEA using the price-gap methodology, which uses a reference price for estimating subsidies rather than the actual subsidies, as the data on actual subsidies is highly limited and most subsidies are off-budget (implicit) because they are made through regulating the energy price.

4.3 Latest Trends Based on Qualitative Research

Global Coal Consumption headed towards a new record in 2023

Coal is the largest source of human-caused carbon dioxide (CO2) emissions, and controlling consumption is essential to achieving global climate goals. Coal is responsible for 1/3rd of the global electricity generation and countries are trying to gradually replace it with alternative fuels and technologies. It will continue to play a crucial role in iron and steel production until newer technologies are available.

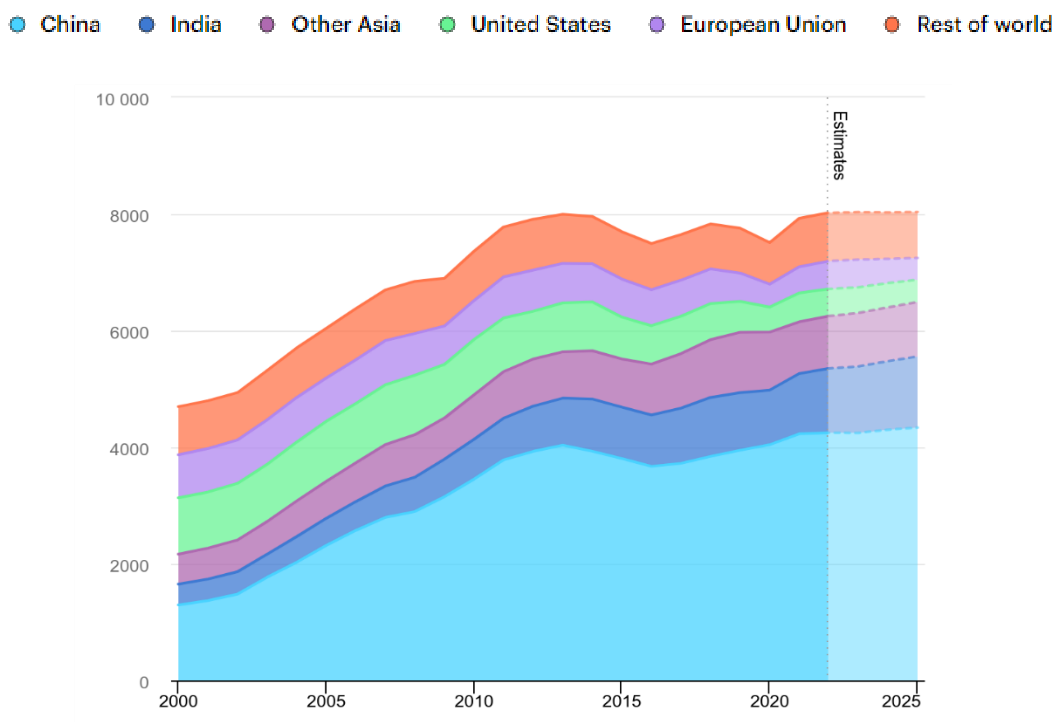
In 2022, coal demand reached a new peak of 8,415 million tons. India and China have significant contributions to this growth. High natural gas prices and declines in electricity and nuclear energy have also increased demand for coal-fired power generation. Electricity production demand increased by 4% to 5,687 million tons. Coal demand in other industries increased by 3.7% to 2,728 million tons. China is the world's largest coal consumer and its total coal demand increased by 4.6% to 4,520 million tons, out of which coal was used for more than 60% of electricity production. India is the second largest consumer of coal, accounting for 14% of the world's coal demand which will reach 1,162 million tons by 2023. World coal demand is now slowing and has risen by only 1.4% to 8,536 million tons.

Coal demand growth was slower due to a rise in global temperatures in 2022 but seems to be shifting towards China, India, and ASEAN countries. These Asian countries consume three-quarters of global demand. The biggest losses are expected in the European Union (down 107 million tons or 23%) and the United States (down 95 million tons or 21%), mainly due to lower demand. The figure for Russia, currently the fourth largest energy consumer, is difficult to assess due to the ongoing war against Ukraine.

IEA Forecasts that global coal demand will fall from 2024 and this trend will continue till 2026. Energy demand growth in India and ASEAN countries will balance the decrease in the European Union and the United States. China will continue to be a key player in determining the world's coal needs.

Growth in renewable energy is faster than growth in total demand for electricity which is likely to lead to a reduction in global coal consumption.

Figure 4.12 Global Coal Consumption,2000-2025



Source:IEA,2022

Steps That Are Being Taken and Need Further Strengthening In Coal Sector

- G7 countries recognize the need to completely stop adding any newer coal-based power plants.
- Global CO2 emissions are at an elevated level and substantial efforts will be required to align with net-zero goals.
- Policymakers and private sector entities need to be incentivized to use

technologies that ensure grid stability but reduce emissions.

- Support for carbon capture, utilization, and storage (CCUS) deployment in the power sector through a time-based push for changes in the plants is necessary.

Global Gas Markets Rebalanced in 2023 Following Russian Invasion

In 2022, global gas-fired generation remained relatively steady at just over 20% of global electricity generation.

While there were declines in gas-fired generation in countries like China and India, an increase in natural gas production in the US, certain countries in Europe and Asia , and the Middle East balanced out the overall trend.

The European Union experienced a spike in natural gas prices due to supply shocks from Russia's invasion of Ukraine, but despite this, gas-fired output in the EU remained stable compared to 2021.

The Net Zero Scenario predicts a gradual decline in gas-fired generation by an average of around 2% per year leading up to 2030.

The United States' six upcoming power projects which are natural gas-based will be equipped with carbon capture, utilization, and storage (CCUS) technology.

The United Kingdom's Net Zero Teesside Power project, expected to be operational by 2027, is poised to be one of the first commercial-scale gas-fired power stations with CCUS, with investment negotiations underway following a government announcement in March 2023.

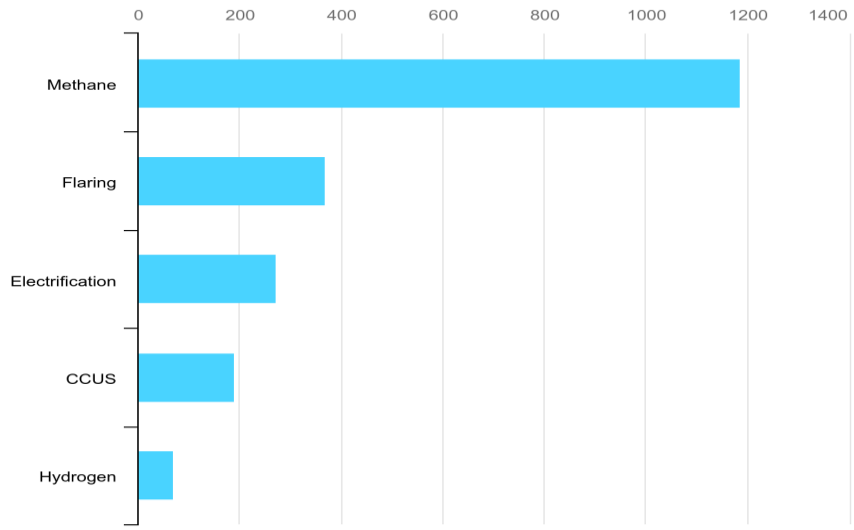
Nigeria has become the first African country and Colombia the first South American country to regulate methane emissions from the oil and gas industry, signaling global progress in tackling methane emissions.

Limiting Methane Emissions in Oil and Gas operations Holds the Key

Oil and gas operations account for nearly 15% of energy-related greenhouse gas emissions today and the industry has the ability and resources to cut them quickly and cost-effectively

Methane contributes to about 30 percent of the warming of the world. Combating methane emissions produced during oil and gas operations is one of the most effective ways to fight emissions. Using leak detection and repair programs can reduce methane emissions by 75% in the oil and gas sector. In the coal sector, we can cut methane emissions by 50% by either flaring or oxidation or using it at the site itself. Using these simple measures and improving/scaling up Carbon Capture, Utilization, and Storage, and increasing the usage of low-emission hydrogen can greatly aid the process of energy transition to mech cleaner outputs .

Figure 4.13 Emissions reductions in the Net Zero Scenario, 2030



Source:IEA,2023

Gas and oil sectors produced 5.1 billion tonnes (Gt) of CO_2 equivalent which contributed to around 15% of the world's greenhouse gas emissions from the energy sector. Methane generated during these activities and flaring was responsible for around 50% of these emissions. The oil and Gas sector needs to make a much larger contribution towards reduction as the world now seeks a voluntary effort by governments and private investments in enterprises to understand the seriousness of the issue. A much more serious approach is required to bring the oil and gas sector into compliance with the Net Zero.

More commitments are required to achieve the Net Zero Outflows by 2050 (NZE) Situation. Methane must be switched over completely to CO_2-equivalent given the 100-year global warming potential detailed by the IPCC.

Oil Markets

Worldwide oil demand is estimated to increase by 1.7 mb/d in the first quarter of 2024 because of US economic growth better than anticipated and increased fuel inventories. Projections show that in 2024 oil demand will be 110 mb/d report but the speed of growth is slower than in 2023 as demand comes back to normal levels the increased adoption of electric vehicles worldwide helps in reducing the pace of growth.

Major oil producers are ramping up production capacity even when demand is slowing. In the period from 2022-2028, oil demand is expected to slow down but there are risks in this assumption. OPEC+ decisions and China's policy could substantially influence this trend. As the world transits towards clean energy after the shocks from the Ukraine war, increases in oil stock and air travel are also leading to increased consumption. Oil demand growth is expected to fall from 2.4Mb/d in 2023 to 400 Kb/d in 2028.
LPG, Ethane, and Naphtha are the derivatives of Petroleum that account for more than 50% of the demand growth between 2022 and 2028.

A Future Roadmap for Net Zero Emissions by 2050

The IEA aims to achieve net zero CO_2 emissions by 2050 for which it has drawn up a roadmap for the participating countries. This roadmap aims to make energy access easier for those countries who are deficient in energy and also improve air quality.
The IEA monitors this progress worldwide and provides recommendations for the same on technologies, infrastructure, sectors and subsectors.

How are the countries doing currently?

3 components out of 50 suggested pathways by IEA are fully on track i.e. solar-based PV, electric vehicles, and lighting. Solar PV was upgraded as it is already on track in 2022 at a growth rate of 26% to be in the Net Zero situation by 2030 if it compounds @26% from here onwards.

Progress on clean energy innovation has been quite fast in 2022 although all countries are not at the same adaption level.

Some Key Highlights:

1. Electric vehicle Sales grew by 55%, arriving at a record high in excess of 10 million. Currently, the electric vehicle batteries production is adequate to satisfy expected demand in 2030 in the NZE Situation.

2. Nuclear Capacity has been added by 40 % growth with 8 GW of newly installed plants. Good progress has been made in this sector.

3. Heat Pumps grew at 11% growth rates which is close to the 15% growth rate required in this category to achieve Net Zero Status by 2030.

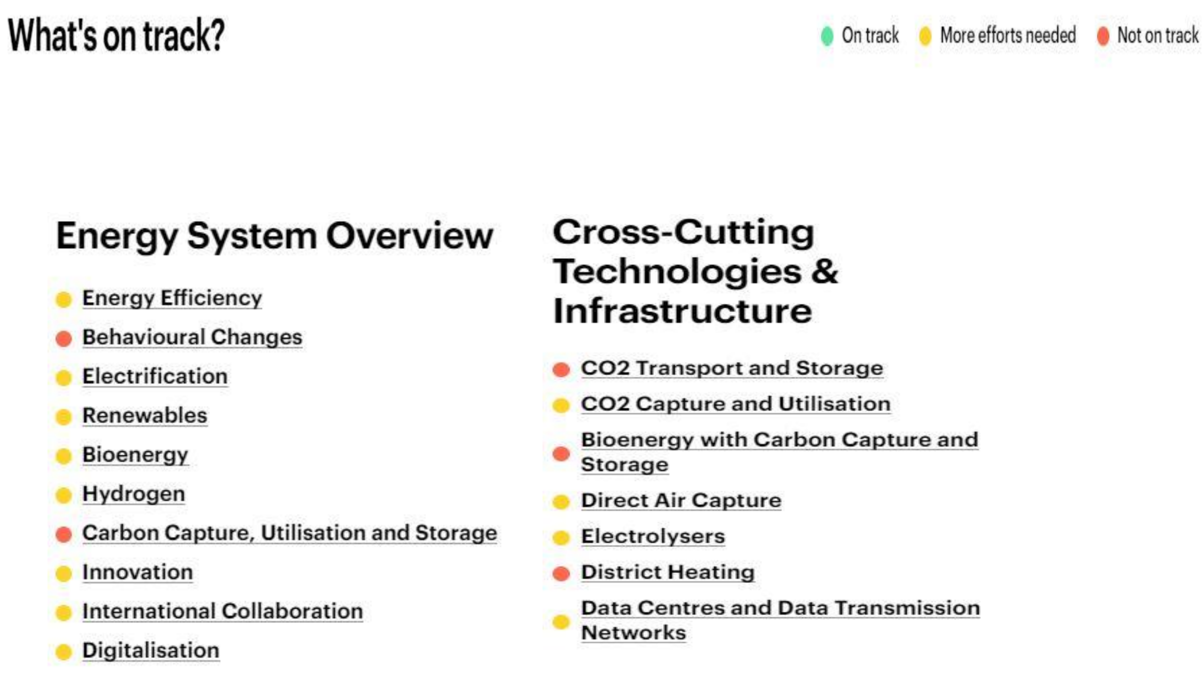
4. Electrolyser installed capacity grew by 20% whereas manufacturing capacity grew by 25% and is expected to have reached 3 GW capacity by 2023 which would be a 4-fold increase over 2022.

5. Energy proficiency in several economies grew by over two times the level in the previous year.

More progress has been observed in electricity generation and passenger cars where clean technology is easily accessible and costs have fallen. Heavy industry and long-distance transport are the tougher areas for complete de-carbonization and much more innovation will be required.

The change is additionally happening at various velocities across locales and areas. For instance, almost 95% of electric vehicle sales in 2022 happened in China, the US, and Europe. Almost 75% of carbon capture capacity is in North America and Europe. Developing economies and emerging markets have not contributed much in this area and we need to push much harder in these countries to achieve the Net Zero emissions goal.

Figure 4.14 Industry Trends in Achieving Net Zero Emissions



Source : IEA,2023

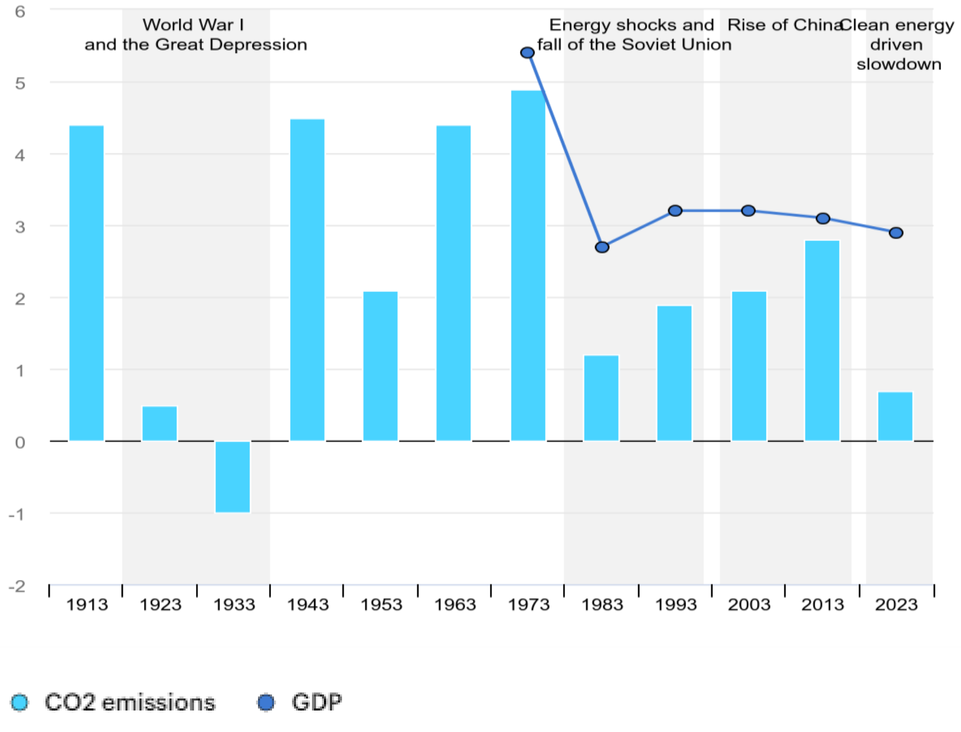
Emission Trends for Carbon Dioxide in 2023

Clean Energy Market Share is Growing

CO_2 emissions reached 37.4 Gt in 2023 which was in the opposite direction of goals set out in the Paris Agreement. This IEA estimate is based on a regional analysis of national energy data with other supplementary data on economic and weather patterns. A growth of 1.1% in greenhouse gas emissions was slower than the 3% global GDP growth.2020 had a positive impact on GHG emissions due to decreased economic activity but in 2021 and 2022 it has rebounded to almost 2019 levels. In the period between 2013-2023 global CO_2 emissions have increased by .5% per year.

Emission growth rate seen between 2010-2020 was slower than the emission growth rate in 1970-1980, or the 2 disruptions of 1973-1974 and 1979-1980 and a disruption caused by the breakdown of the Soviet Union. CO2 emissions around the world are seeing a slowdown.

Figure 4.15 Co2 Emissions,1913-2023 Relative to Worldwide GDP



Source : IEA,2023

In the last 5 years greenhouse gas emissions increased by 900Mt. approx. Clean Technologies such as solar, wind, nuclear power, heat pumps, and electric cars greatly helped to step down the rate of increase. Without these technologies, the increase in emissions would have been 3 times greater.

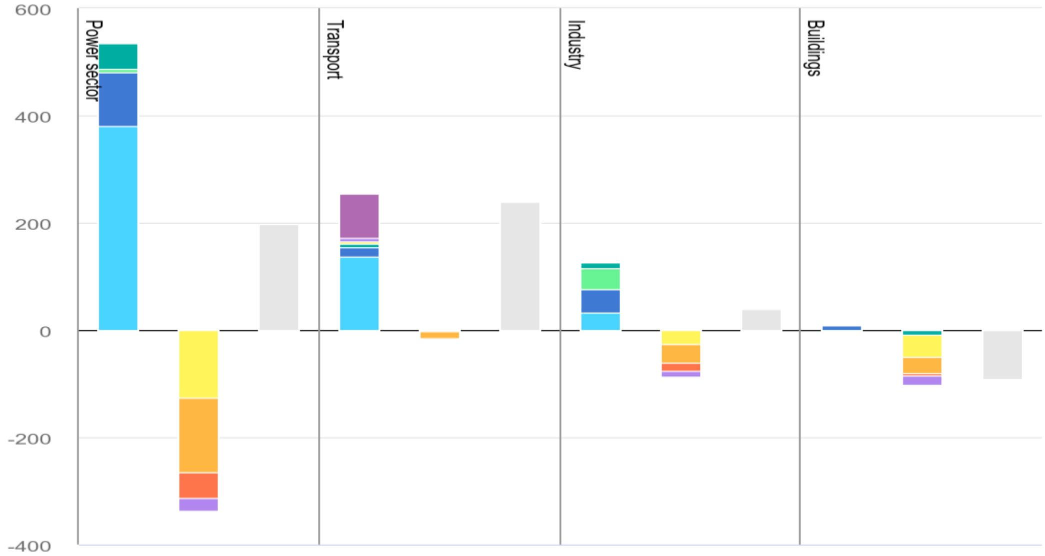
Global air traffic has grown by 35% in the previous year but is still overall 6% below pre-COVID-19 levels. This recovery in global aviation has contributed 140 million tons of emissions in 2023. China relaxed restrictions in early 2023 on air travel which led to a boost in demand. Total Gasoline consumption in China increased 10% in 2023. China's re-opening contributed 50 Mt of additional emissions to the world total.

Coal Related Emissions Were Maximum Contributors

Coal has contributed the most to the increment of worldwide CO2 emissions in the period after 2020. Worldwide outflows from fossil fuel emissions have expanded by around 850 Mt beginning around 2019; those from coal have developed by 900 Mt, Natural gas emissions have expanded with a small quantum , and oil emissions are still somewhat beneath their 2019 level. Coal represented around 70% of the expansion in worldwide emissions from fuel combustion in 2023 (+270 Mt). China and India saw significant increases in coal combustion based emissions which was just offset by the decreases in advanced countries. Oil emissions increased due to opening up of China and global aviation sector , expanding by around 95 Mt at the global level.

Sectoral Trends in Greenhouse Gas Emissions

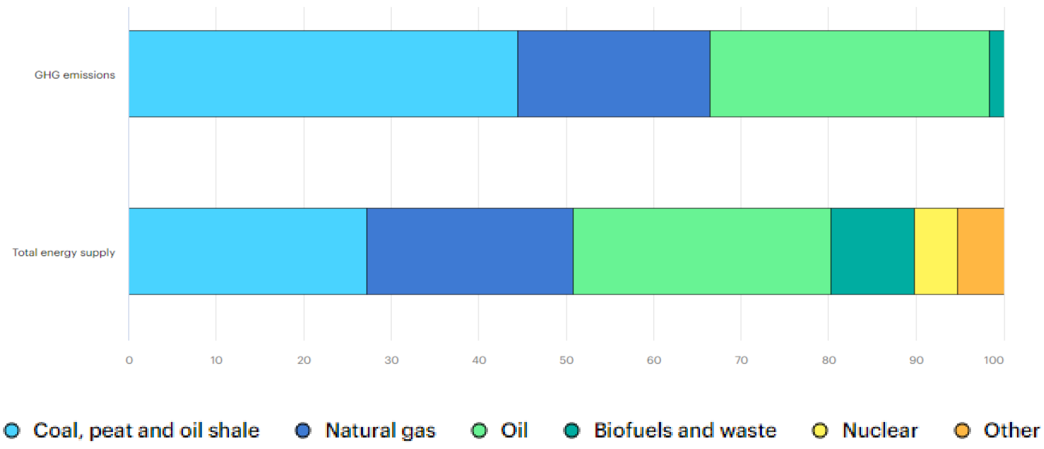
Figure 4.16 Sectoral Trends In Co2 Emissions in 2023



Source :IEA,2023

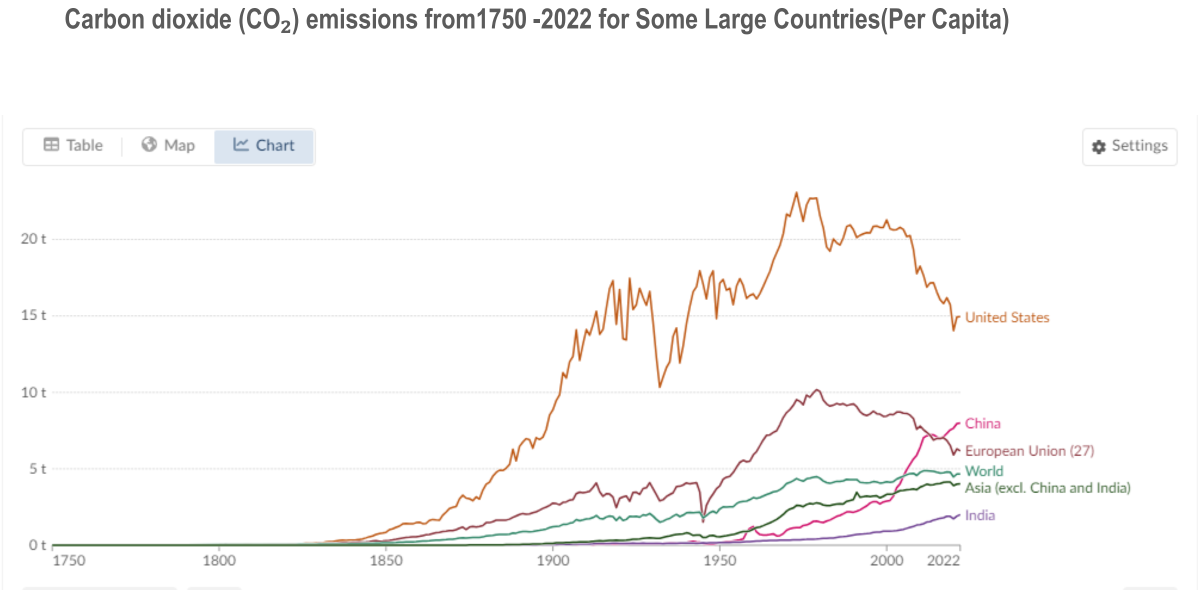
The transport sector had the largest growth in greenhouse gas emissions and grew by 240Mt globally. The power sector was the second largest contributor to emissions but also shows large and regional disparity as emissions in developed countries showed a decline due to the usage of clean technologies to produce power whereas the developing and emerging markets are still struggling to find the necessary investments needed in this sector to make their power sector cleaner. The industries sector emissions saw a modest increase as various factors were playing here. This sector saw some efficiency gains, fuel switching to cleaner fuels in developed countries and also weaker industrial outputs as world struggled with growth but the emerging and developing markets offset these gains .Buildings sector was the only sector to see emissions fall which was largely due to lower temperatures in 2023.

Figure 4.17 Share of GHG emissions and total energy supply by product, World, 2021



Source :IEA (2023),

Figure 4.18 Per capita CO_2 emissions in Major World Countries -2022



Source: Our world in data,2022

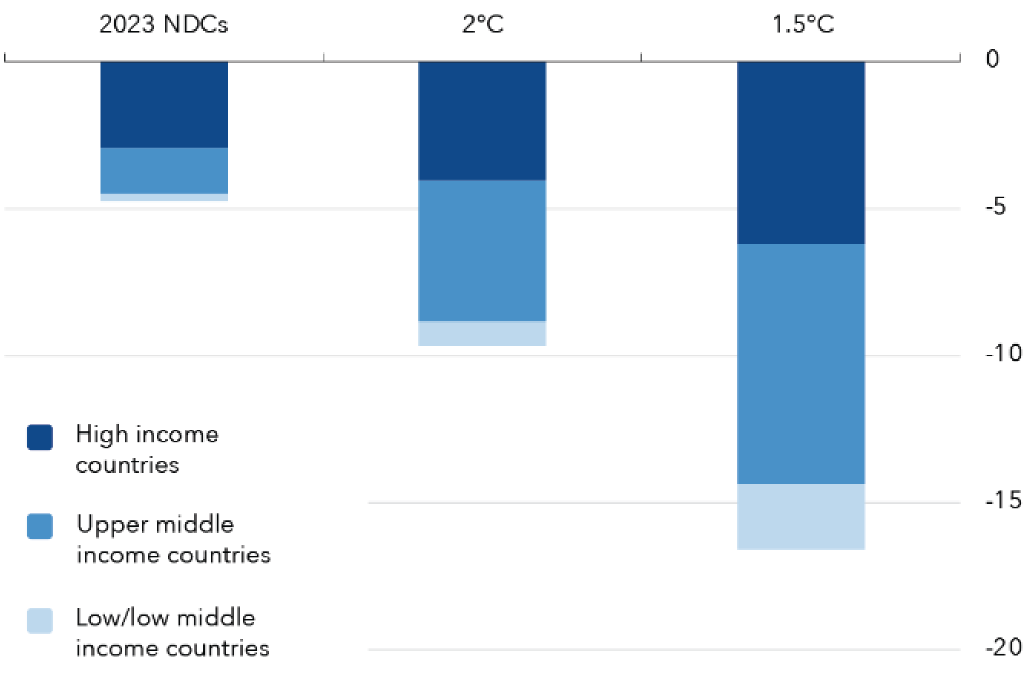
CHAPTER 5

5.0 CONCLUSIONS AND RECOMMENDATIONS

International Cooperation is a Must for Achieving Climate Change Goals

Eight years after the Paris Agreement the policies being framed in various countries are not enough to achieve the SDG goal of limiting Global warming to Net Zero Emissions by 2050. Almost all countries are falling short on financing, investments technology transitions and innovation needed to achieve this goal. The latest analysis shows that the current global commitments reflected in nationally determined contributions would reduce emissions by just 11 percent by 2030 whereas what is required is to cut carbon dioxide and other greenhouse gases by 25 percent to 50 percent by 2030 compared with 2019. A fair approach is for countries to target cuts in emissions in line with per capita incomes.

Figure 5.1 Illustrative Scenarios of Emission Reduction Needed to reach 2030 Goal (billion tons of CO2) NDC : Nationally Determined Contributions

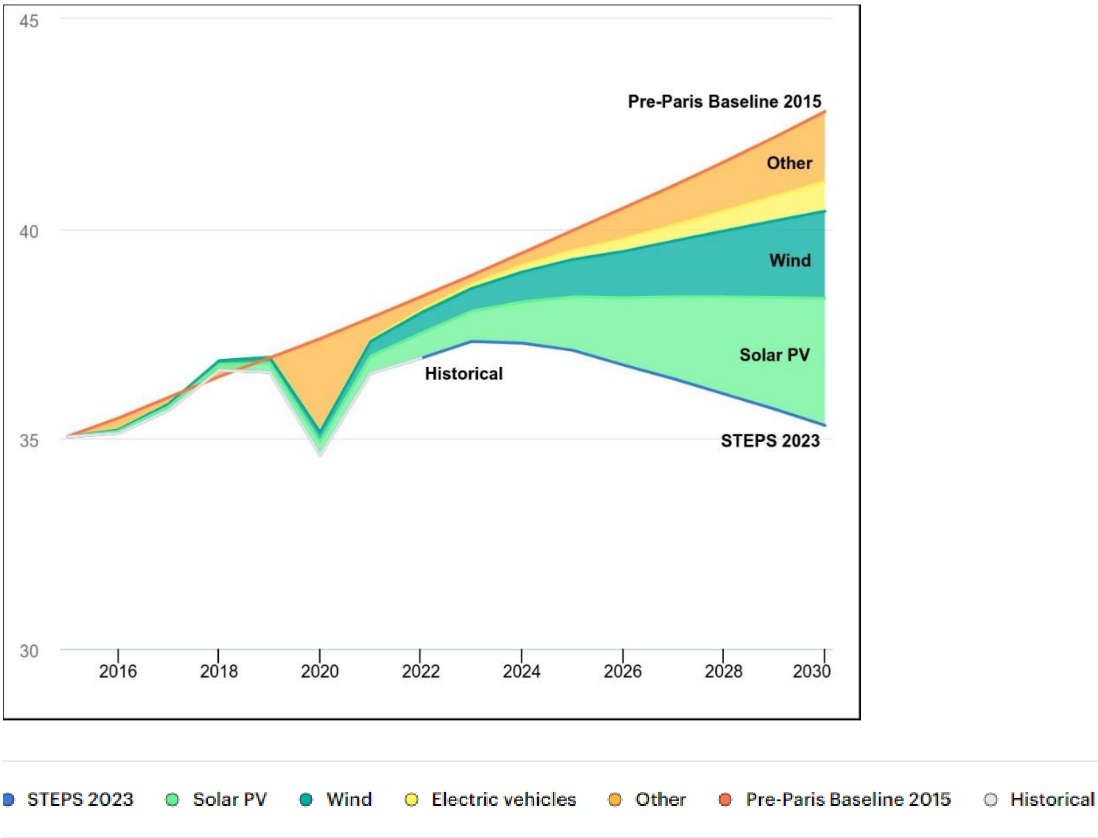


Source: IMF

Here an agreement that could be reached between China, India, the European Union, United States could cover 60% of global greenhouse gas emissions and could set a directional strategic retracement to the increase that we have witnessed in the last 2-3 years which is taking us in the wrong direction.

"Energy sector CO_2 emissions remain worryingly high, reaching a new record of 37 gigatonnes (Gt) in 2022. Instead of starting to fall as envisaged in the 2021 report, demand for fossil fuels has increased – spurred by the energy crisis of 2022 after Russia's invasion of Ukraine – and so have investments in supply. Progress on energy access has stalled while millions of people still lack access to electricity and clean cooking, notably in sub-Saharan Africa." Source: IEA

Figure 5.2 Global Co2 Emissions Comparison Pre Paris Agreement and SPS by 2030



Source : IEA,2023

Clean energy technologies are being helped by falling costs and a seriousness which is now evident in the adoption of these even in the Middle East and Central Asia which are themselves producers of fossil fuels. Fossil Fuel subsidy reforms are happening in Jordan and solar projects are being implemented in UAE and Qatar. "In the Stated

Policies Scenario, emissions are now projected to be 7.5 Gt lower in 2030 than in our 2015 Pre-Paris Baseline Scenario, of which policy-driven expansions of solar PV and wind account for 5 Gt and electric vehicles for nearly 1 Gt. This shift in the outlook means that the projected warming of 2.4 °C in 2100 under current policy settings, though still worryingly high, is now 1 °C lower than before the Paris Agreement in 2015." Source: IEA(2023). A lot more needs to be done to meet the 2030 target for Net Zero pledges. All countries must strengthen their policy frameworks and devise mechanisms to reach these goals faster.

Subsidy Reform Strategies Vary Across Countries Due to Diverse Economies

Communication with diverse stakeholders about the costs of existing subsidies and the opportunities for reform can be a central element of effective energy subsidy reform. Although every case is different, the most difficult tasks for reformers have come in two varieties, depending on who has benefited most from subsidies: (a) mitigating opposition from special interest groups, or (b) credibly compensating the broader public for the reduction or removal of subsidies. Therefore, successful reforms begin with an understanding of which political economy problem the reformers must solve.

Suggestions for Fossil Fuel Subsidy Reform (FFSR):

1. We can look at various models for the FFSR by incorporating 20% of the annual subsidy savings from FFSR to be invested in energy efficiency and 10% in renewable energy and by this process we can easily start increasing the infrastructure which has less impact on the environment and additional reduction in emissions can be achieved. These investments would reduce the emission intensity either by lowering energy consumption or substituting polluting fossil fuels with a low-carbon alternative.

2. Subsidy changes will have an impact on the energy sector and therefore on the economy, business, and family. Removing subsidies will allow energy companies to repay debts and provide incentives to develop and expand systems, thereby improving the reliability and quality of fuels. This will help revitalize the economy. World Bank surveys from 2006-2009 found that 32% of Indian businesses cited electricity as a major business constraint, compared to 27% in Thailand (2006 survey) and 14% in Indonesia (2009 survey). In 2002 it was found that higher taxes and improved

electricity supply increased farmers' incomes in India and that farmers in two Indian states were happy to pay more for better supply. Efficient gas products can contribute to the health of the home and the entire business, even without payment. Studies in rural areas in Bangladesh, India, and Vietnam have shown that effective electricity connections can improve household income, expenditure, and educational outcomes In Vietnam, the benefits have been shown to outweigh the costs

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