The Advent of Renewable Energy

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ABSTRACT

Renewable energy accounted for 12.2 % of total primary energy consumption and 14.94 % of the domestically produced electricity in the United States in 2016[2]. The development of renewable energy and energy efficiency marked "a new era of energy exploration" in the United States, according to former President Barack Obama[2]. This descriptive research focuses on how the usage of renewable and non-renewable energy has changed over the past 27 years in the USA. First, this research identifies correlations between renewable and non-renewable energy usage patterns. Second, this research explores the impact of economic factors on energy usage. Having a clear picture of energy usage by the world nations can help make effective policies for renewable energy adoption by different world countries. The data set is provided by the UN and it is used in SAS Enterprise Guide™. Statistical methods such as time series analysis, trend line studies are used to make the visualizations meaningful. At first, the usage patterns of non-renewable energy are shown for the last 27 years from 1990 to 2016. Next, the usage patterns of renewable energy are shown for the same time period. We can see the exponential increase in energy production for solar and wind and a decrease in the usage of charcoal and brown coal. The usage studies of all world nations are made to assess which countries have been influential in fueling the observed trend. We can see from the analysis that the USA is among the countries that have the most significant growth rates in renewable energy usage although its overall capacity is lower in certain cases.

INTRODUCTION

The world has been moving towards using renewable energy and different countries have different policies towards the adoption of renewable energy. How does the United States of America fare when compared to the rest of the world in this context? This work analyses how the use of different kinds of energy changed over the past 3 decades to find out if these changes are correlated with each other. And, it tries to find whether economic factors such as GDP, urbanization might have an influence on changes in the usage of energy.

DESCRIPTION OF THE DATA SET

The data set is provided on the United Nations website (http://data.un.org/Explorer.aspx) and it has 1.04 million observations and 6 features each describing following:

Country: Details the country name that has had the transaction done

Commodity Transaction: Indicates the type of energy – renewable or non-renewable

Year: Year in which the transaction happened

Unit: Unit of the commodity transaction i.e., Metric Ton, KJ, Kilowatt, etc

Quantity: Quantity of the transaction

Category: Type of energy product i.e., coal, wind energy, natural gas, etc.

The study mostly focuses on the United States. However, comparisons with other major economies are made to compare the relative energy use between the USA and those countries.

METHOD

The study uses pearson correlation techniques, multi-variate trend line studies to bring out the hidden correlations between the growth in renewable energy usage, and the decline in non-renewable energy usage and the GDP. The end goal is to give the reader a better understanding of the roles being played by world countries in the adoption of renewable energy trends.

The data set has one input variable that contains more than 90% missing values. It was removed for the purpose of this analysis. The remaining data set is free of missing values. The data set was formatted to convert the numeric column year to mmddyy10. format so that the data can be modeled into a time series plot. To do that, first, the numeric variable year is converted into number of days elapsed since 1/1/1960 by subtracting 1960 from the value of the year and by multiplying by 365.25. Then using the SAS formats, the variable date was created as a mmddyy10. format variable.

ENERGY TRENDS OF THE USA

NON-RENEWABLE ENERGY USAGE PATTERNS

In this section, the research shows how the usage of non-renewable energy sources such as hard coal, coking coal, pet coke, fuelwood, and natural gas has changed from 1990 to 2016.

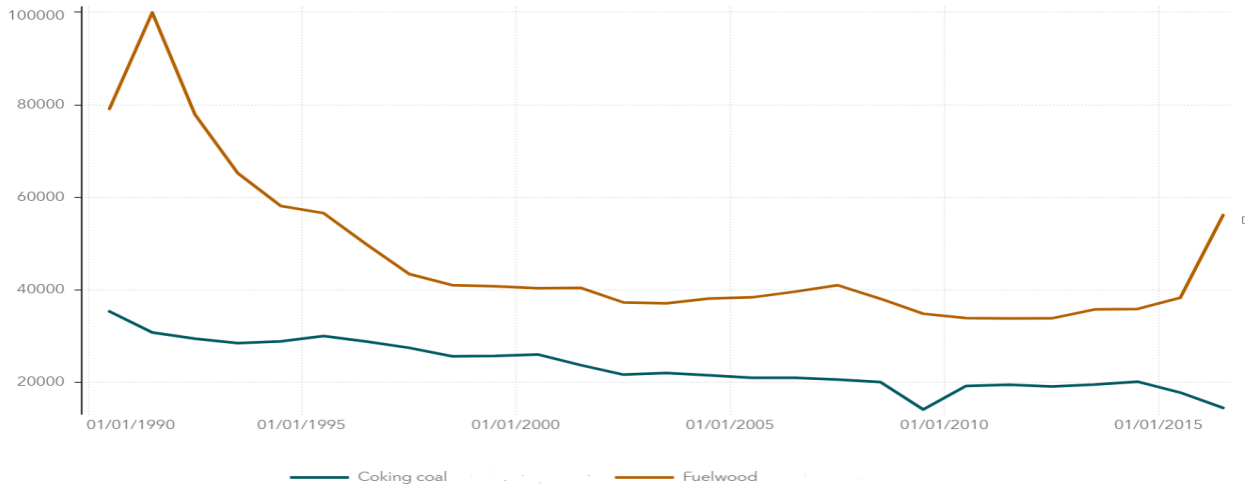


Figure1: Coking coal and fuelwood usage

The above image shows how the final consumption of coking coal and fuelwood. Fuelwood saw a steeper decline from 80,000 MT to 40,000 MT before raising sharply in 2016 to 56,000 MT. Coking coal usage declined steadily by 60% from 35,000 MT to 14,000 MT.

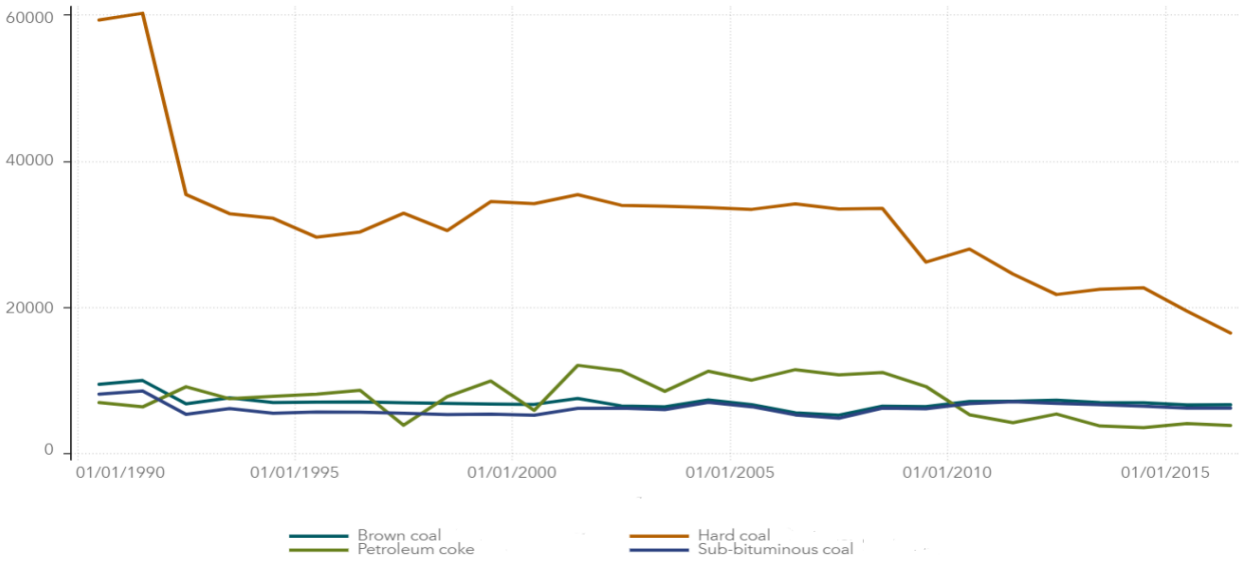
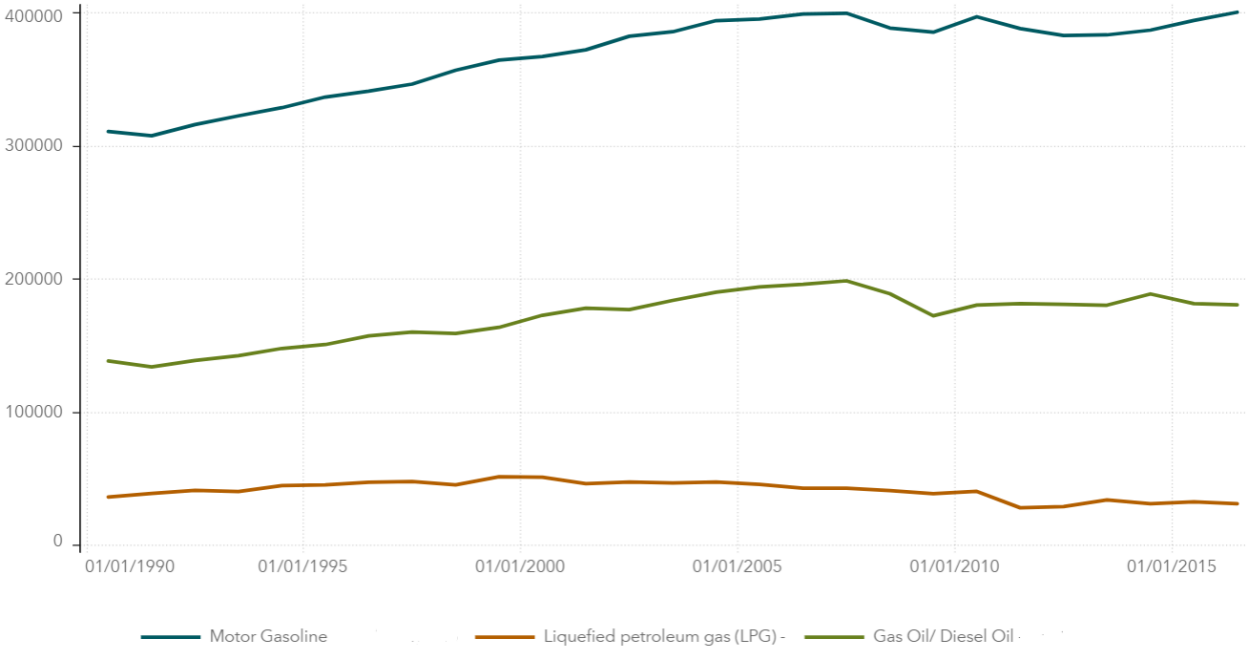


Figure2: Different forms of coals' usage

The above image shows the final energy consumption of the four major coal forms. The usage of brown coal, pet coke, and sub-bituminous coal remained throughout time. But, the dependence on hard coal slumped by 70% in 27 years. This is a significant reduction of 4,250,000 Metric tons of hard coal, which is the most polluting fossil fuel among all fuels.

Figure3: Natural gas usage

The usage of natural gas seen a slow increase of 10% over 26 years from 1990 to 2015. The trend line shows that the usage peaked until 2000, became the lowest in 2006, and slowly raised after the recession ended until 2015 before dropping again.



Fugure4: Gas fuels usage

From figure 4, we can see that the final consumption of motor gasoline and gas oil has seen a slow increase of 29%and LPG is reduced at 13.6%.

RENEWABLE ENERGY USAGE PATTERNS

In this section, the research shows how the usage of renewable energy sources such as solar, wind, nuclear, geothermal, and hydro have changed from 1990 to 2016.

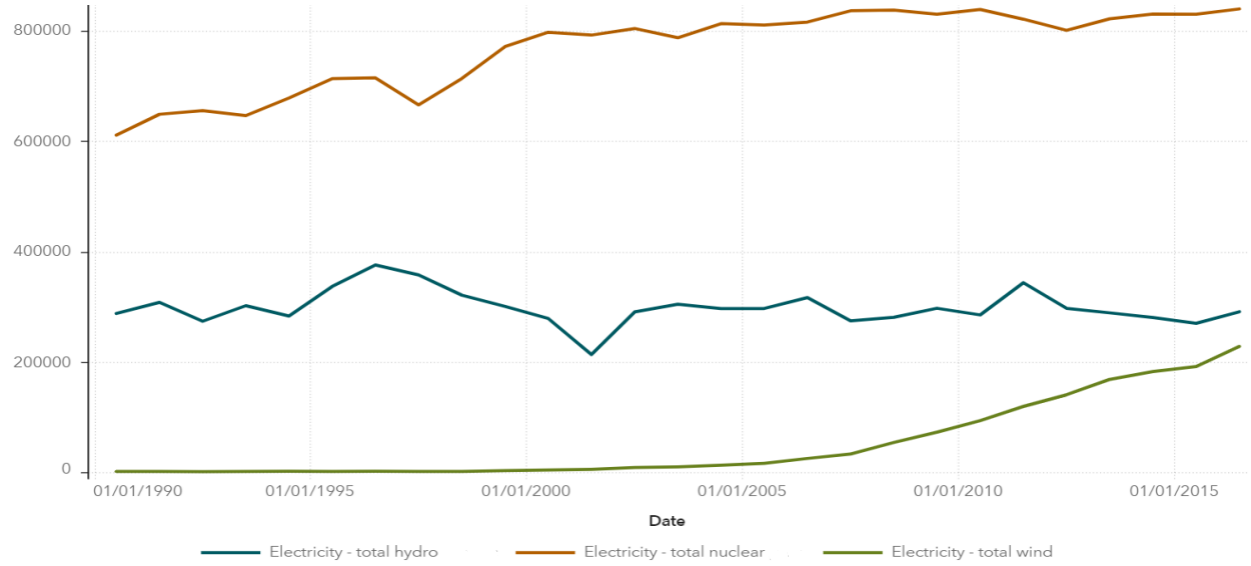


Figure5: Hydro, nuclear and wind power usage

The above image shows that wind power has seen a tremendous increase from 3000 KW to 229471 KW, which is a 7500% increase. Nuclear power saw a 37.3% increase and its overall capacity is much higher than the wind power. The hydropower, however, declined by 2.57%

The reduction in hydropower is due to many reasons. First, some states in the US do not even consider it a renewable energy source. It is because the construction of dams will cause damage to nature in terms of blocking many fish species' migratory paths, causing an imbalance in the water table and unreliability of the water cycle. But the same stance is not maintained by other countries [7][8]. We will see more about this in the coming sections.

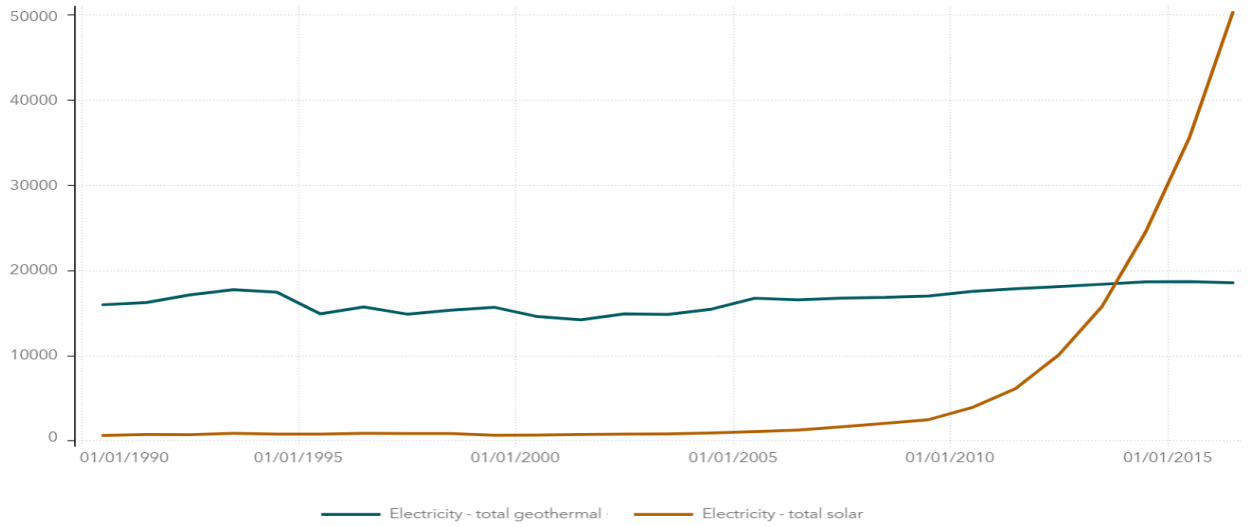


Figure6: Solar and geothermal energy usage

From figure 6, we can see that the growth in solar power generation sees a heavy 8250% increase from 666 MW to 50,000 MW. The geothermal power growth is minute in comparison. It is because of many reasons. The geothermal sources are site-specific and not widespread, lack of enough technology to efficiently mine the trapped energy, and high risk and control costs.

ENERGY TRENDS OF THE WORLD

GROWTH OF WIND ENERGY

Wind energy usage has witnessed a significant increase in the last 25 years. Many countries have ramped up their infrastructure for harnessing wind power and have become quite successful at that. This can be seen from the growth rates of the respective countries.

54 among the 64 countries studied have doubled their capacity in 25 years and many countries have reported more than a 1,000% increase in wind power usage. The highest increase is for Spain at 1,148,850%, followed by Canada at 969,300 % and France at 906,700%. These are all developed countries and have a large land area, thereby effectively harnessing the geographical advantages they have. However, the percent increase doesn't give the full picture here.

When we see the absolute increase in wind energy usage, China, the US, and Germany contributed to more than 50% of the world's increased usage of Wind energy of 334 million kilowatts. Since the initial capacities of these countries are higher, these countries couldn't increase their capacity by such high percent values.

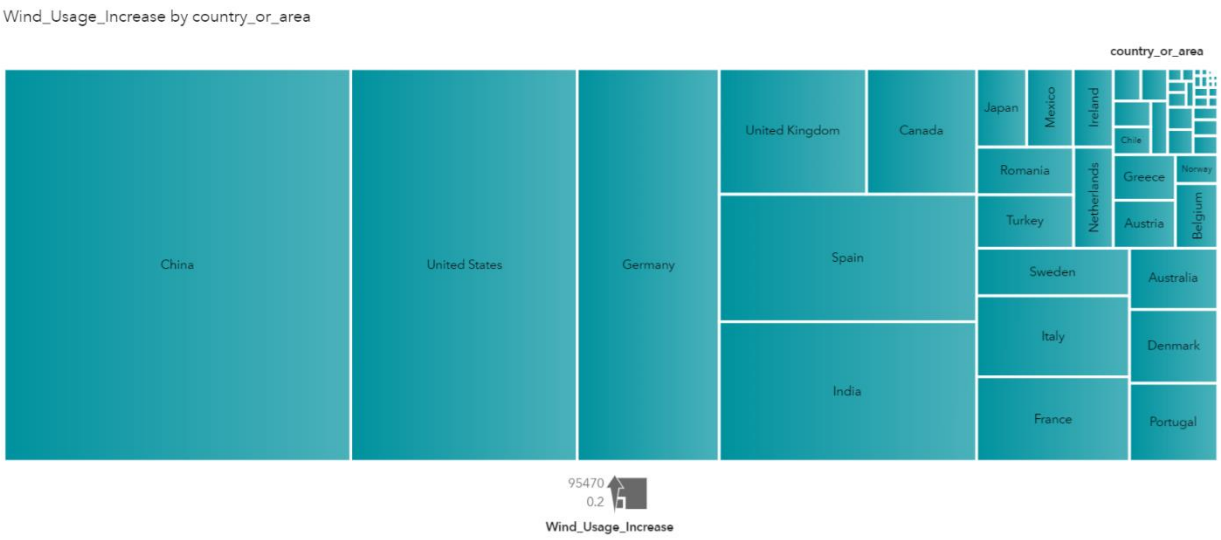


Figure7: Wind power change by country

GROWTH OF SOLAR ENERGY

Solar energy usage has also witnessed a significant increase in the last 25 years. Countries with large unused land areas have put up the infrastructure for harnessing solar energy. This can be seen from the growth rates of the respective countries.
66 among the 74 countries studied have doubled their capacity in 25 years and many countries have reported more than a 1,000% increase in wind power usage. The highest increase is for Germany at 3,605,500%, followed by Japan at 2,450,500 % and France at 590,800%. These countries all are developed countries and have a large land area, thereby effectively harnessing the geographical advantages they have. When we look at the total increase in the usage of solar power, the percent increase doesn't give the full picture here.
Germany alone has increased its capacity by 36,055 thousand kilowatts. Along with Japan, the United States, and Japan, they contributed to more than 50% of the world's increased usage of Wind energy of 169 million Kilowatts. This accounts for a reduced carbon footprint of 35 million tons.

GROWTH OF NUCLEAR ENERGY

The concept of using Nuclear energy as a power source has drawn a lot of controversy and denial in the world. Many people have objected to this concept because of disasters like Chernobyl and Japan Nuclear power plant failure. So, the usage increase has not been so great compared to other forms of energy. Still, few countries have more than doubled their Nuclear power capacity.
China, Pakistan, and Iran have a more than 1,000% increase in their nuclear capacity over 25 years. The growth percentages for the remaining countries have been modest

in the tune of 10%-15%. However, the absolute growths for countries give us a clear picture adjusting for the true capacities as shown below.

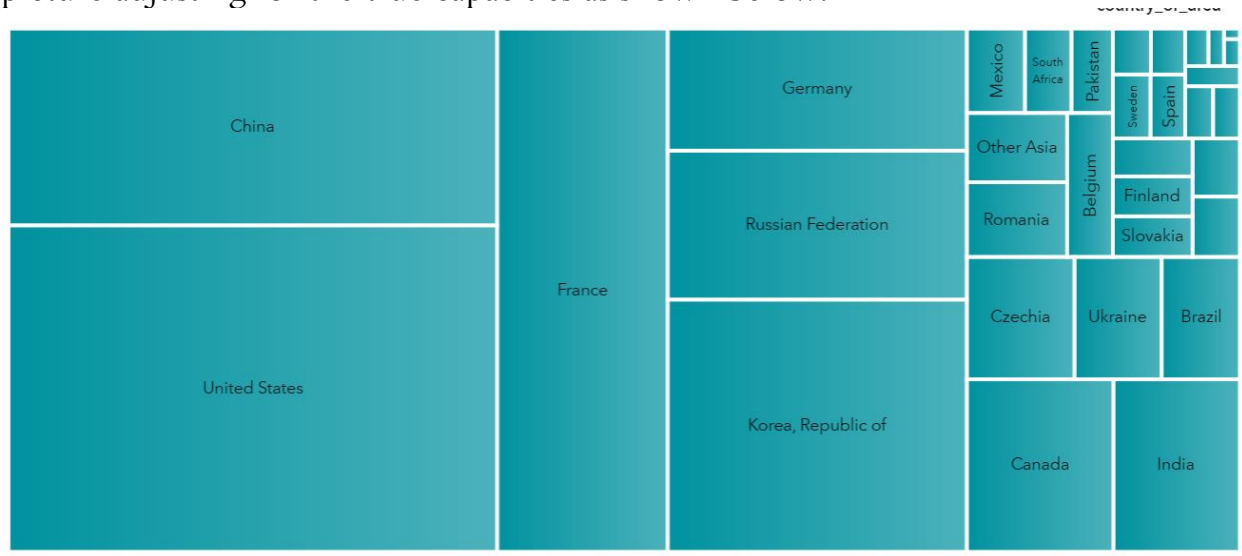


Figure8: Nuclear energy increase by country

The United States alone has increased its capacity by 218,995 thousand KW. Along with China and France, these 3 countries contribute to more than half of the nuclear power's increased usage in the world. Coincidentally, the countries which have higher growth rates, and which have the highest growth in the usage of nuclear power usage also have nuclear weapons in their arsenal and claim to be superpower countries. This might suggest that for being a superpower, a nation needs to have nuclear power usage.

GROWTH OF HYDROPOWER

Analyzing hydropower by countries gives us a different trend. Contrasting to the other renewable sources of energy usage by countries, the highest growth percentages in the hydropower usage is observed in countries that are either developing or underdeveloped.

Looking at the data, the highest changes is by Guinea at 9,750%, followed by Mozambique at 5,500% and Cambodia at 3,150%. Looking at the absolute increase in the usage of hydropower, China alone has increased its capacity by 937,617 thousand KW, followed by Brazil and Canada.

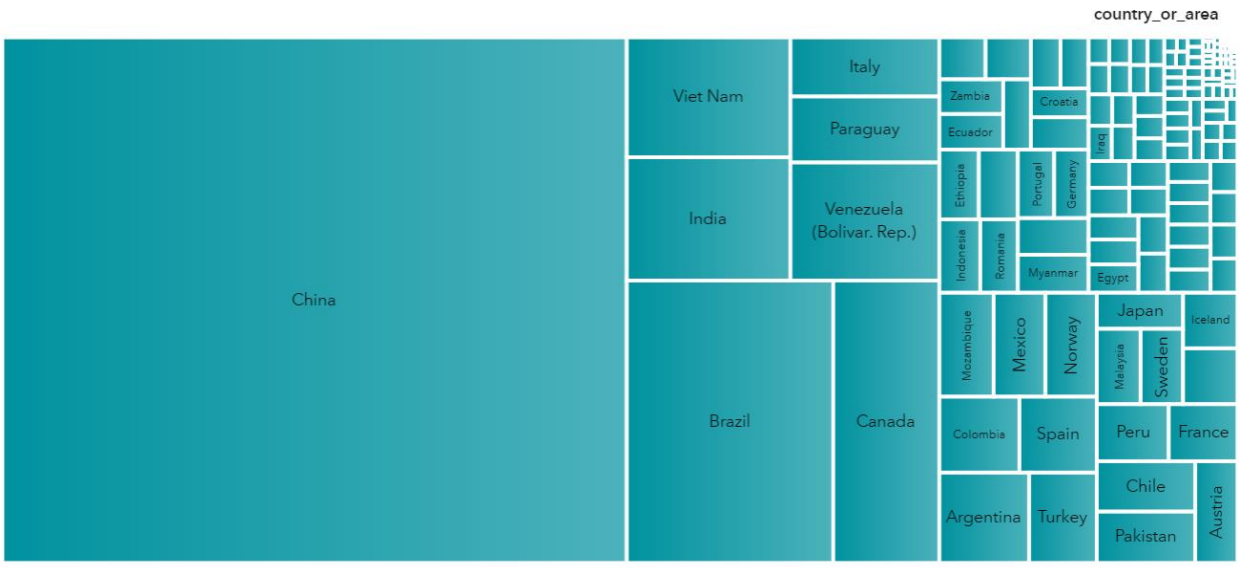


Figure9: Increase in Hydropower by country

China and India together contribute to more than 50% of the total increased hydropower usage. The other big users such as Brazil, Vietnam, and Venezuela are all developing nations. This suggests that the place where developing countries can grow most is the hydro area, which just requires naturally flowing rivers. It is not entirely dependent on the economic condition of a nation perhaps because the technology is well known, even though setting up the dams would require financial resources. This contrasts with other renewable energy places like wind and solar where the biggest economies have made more impact than other nations perhaps because of the newness of the technology.

GROWTH OF GEOTHERMAL

Harnessing geothermal energy requires the presence of underwater energy sources and they are not readily available as other renewable energy sources like wind or solar. This has caused the adoption of geothermal energy by a relatively fewer number of countries. Among the 22 countries that were observed, Portugal has the highest change in its power capacity at 5,025%, followed by Turkey, Iceland, and Russia.
The highest change is observed by Indonesia at 8,871 thousand KW, followed by New Zealand and Iceland. This is the place where the lowest growth rates and the lowest absolute increases are observed. This is due to the limited availability of the energy sources and the lack of proper technology to effectively harness the energy from the source [1][2]. This represents a possibility where scientists can work on to improve technology and to look for further sources of energy.

HARD COAL USAGE

Studying hard coal usage by countries, we can see that few countries were able to reduce usage by more than 90%. This can be called a critical success and can be hailed as moving towards a better world. Fiji, Nepal, and Singapore have reduced their hard coal usage by 99.8% followed by Portugal, Indonesia, and UAE. The least change percent is observed in Uganda where the usage did not change over the decades.
Looking at the absolute reduction tells us the complete story. China is the biggest benefactor here, reducing the usage by 746,288.5 Million tons which is more than 50% of the total reduction, followed by India at 238,504 million tons. The USA stands 3rd at 35,596 million tons.

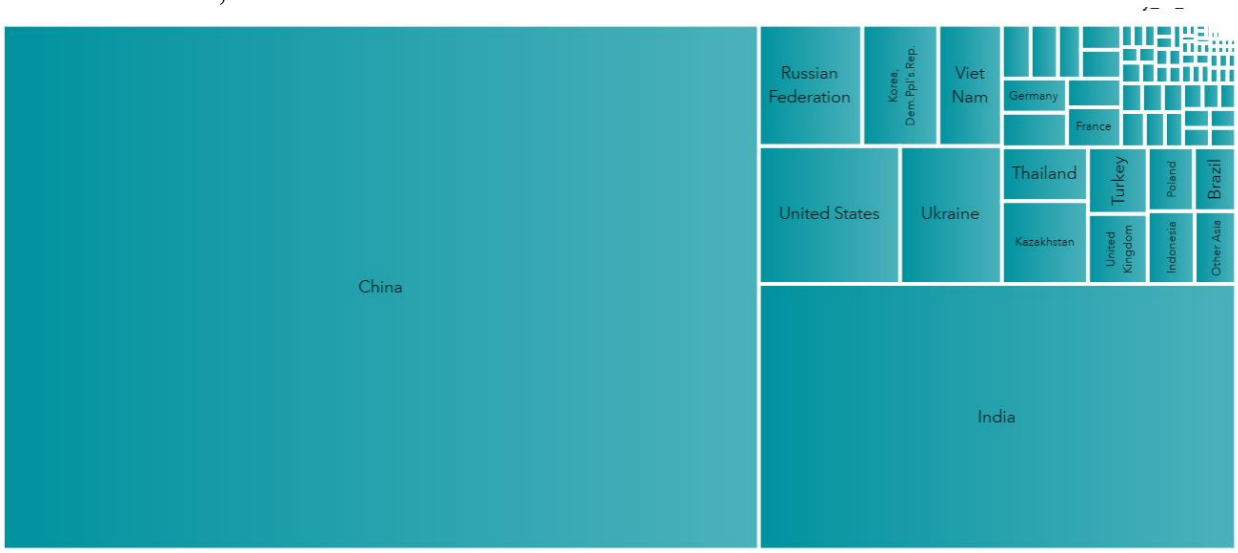


Figure10: Reduction in hard coal by country

Hard coal is one of the prominent causes of global warming and its reduction is seen as a great achievement in the energy arena. It is so welcoming that a nation with such a huge power requirement like China reducing its hard coal dependence to such an extent.

CHARCOAL USAGE

Charcoal too saw a great reduction in its usage over the years. Countries like Mayotte, South Africa, Kazakhstan boast more than 99% reduction in charcoal usage. 15 out of 163 countries have a more than 90% drop in charcoal usage. China, which has reduced its hard coal usage by a great deal, has just a 2.7% reduction in charcoal usage. Kenya, Nigeria, and Congo are the countries where the highest amount of reduction happened. Together with Thailand, India, and Brazil, these 6 countries contribute to more than half the reduction in charcoal usage. Charcoal is not only associated with global warming but also with causing health problems with those associated with it.

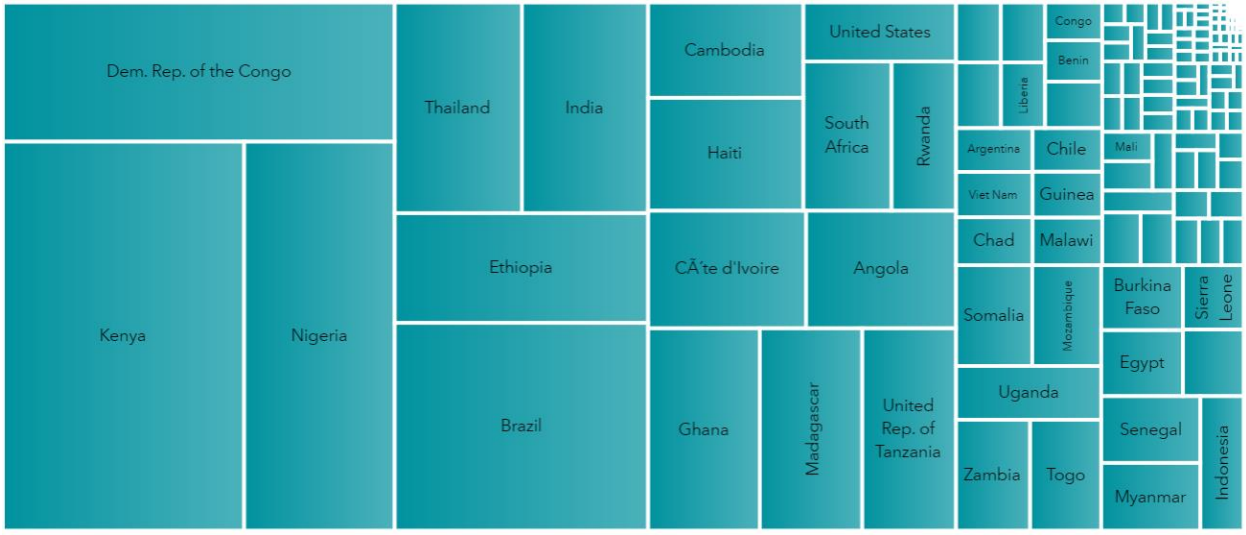


Figure11: Reduction in charcoal usage by country

BROWN COAL USAGE

Brown coal, also called anthracite is one of the most used forms of coal across the world. Reducing its usage represents a critical success in the movement towards an environmentally healthier world. Ukraine and Albania boast more than a 99% reduction in brown coal usage and 31 among the 41 countries studied have reduced their usage by more than half.

Figure12: Reduction in brown coal usage by country

5 countries, Czechia, Germany, Turkey, Indonesia and Bosnia, and Herzegovina have more than 50% of their share in the brown coal usage reduction of 106 thousand million tons. This again is a great feat achieved mostly by developing nations. The

countries which are developed can even do a better job here by switching to renewable energy sources.

SUB-BITUMINOUS COAL

Sub-Bituminous coal is relatively the least used coal. Though it has a high calorific value, it is rarely used owing to its scarcity. The countries that have reduced their dependence on the energy generated by this type of coal are Lithuania, Spain, and Mexico with more than 97% reduction.

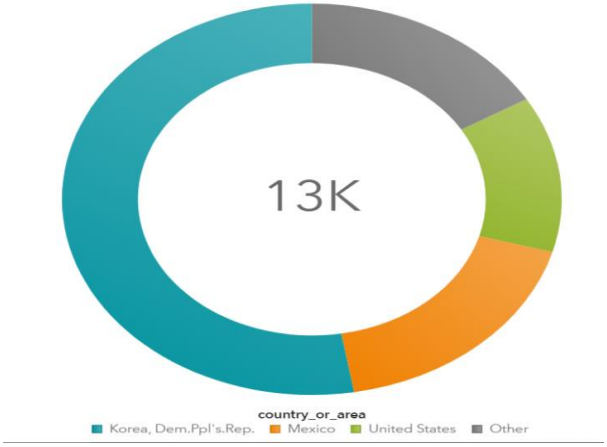


Figure13: Sub-bituminous coal reduction by country

The biggest absolute change in usage is seen in North Korea, followed by Mexico and the United States. Korea alone accounts for more than 50% in the usage reduction which is 13,000 million tons among all countries.

From the above analysis of the usage of the major renewable and non-renewable energy patterns, we can see that there is a great reduction in the dependence on non-renewable sources and growth in renewable power sources. However, the changes by countries reveal interesting insights. Gaining on solar and wind power is mostly restricted to major economies because they can generally afford the high capital. Hydropower is generally restricted to countries that have good perennial rivers flowing in them. There is a maximum cap on the hydro potential of a country, and it can't be unlimitedly tapped on like wind power or solar power. Geothermal power is mostly restricted to certain pockets in the world and so only a few countries have the physical ability to tap it. Whilst it is free and is unlimited, there is a dire need to improve the technology in the respective field which is apparent from its lower growth percentages and much lower overall capacities. The controversial nuclear power tapping is restricted to only a few countries which all are nuclear powers.

The non-renewable energy study gives a different conclusion. The developing economies have a long way to go on this path. It is mostly the developing nations that are carrying the torch forward. China is the pioneer in the overall reduction in the usage of hard coal and countries like Kenya, Congo, Portugal, Guinea, and Brazil are the biggest benefactors to the world. This analysis can be seen in many ways. It says that developing nations are winning in the adoption of renewable energy sources that require initial capital to start and are losing on the reduction on the dependence on the non-renewable energy sources. This shows that a stronger economy finds it easy to tap the power from renewable sources and finds it hard to reduce the dependence on non-renewable sources. A developing economy is more agile in reducing its dependence on coal.

The USA has been the forerunner in the world's race towards greenness. It is the first country to bring into picture the human impact on the environment and started research on global warming, greenhouse gases, and climate change. The overall change the US has made in reducing coal usage and increasing solar and wind usage is second to no country.

Studying the correlations between energy usage and GDP and urbanization might give out some interesting insights which can help us better understand the future trends in the everchanging energy scenario.

RENEWABLE ENERGY CORRELATIONS WITH GDP

The pearson correlation metrics between the renewable energy usage patterns, the real GDP, nominal GDP, and urbanization, show that the usage of hydropower is negatively correlated with the other usage of energies and the GDP and urbanization. This means the US is going back in terms of hydropower generation as its economy which is its ability to harness power increases. Water is the largest renewable source available on the planet and in some cases, it is not called a renewable source because of its negative impact on fisheries and water flows. This can also be seen in the fact the contribution of hydropower to the total electric power declined from 40% in 1930 to 6% now. Only 3% of the 80,000 dams in the country are utilized to generate power [7][8]. However, more emphasis is now being given to increasing hydropower.

X Axis	Electricity - total hydro pr...	Electricity - total nuclear...	Electricity - total solar pr...	Electricity - total wind	GDP_Nominal	GDP_Real	Urbanization
Electricity - total geothermal p	-0.0546	0.1819	0.6495	0.7437	0.4978	0.3778	0.3241
Electricity - total hydro produc	.	-0.2545	-0.1105	-0.0972	-0.1715	-0.1909	-0.1478
Electricity - total nuclear prod	.	.	0.3726	0.5812	0.8994	0.9431	0.9485
Electricity - total solar produc	.	.	.	0.8586	0.6465	0.5600	0.5448
Electricity - total wind	.	.	.	.	0.8453	0.7565	0.7422

Nuclear power production and wind power production are the most highly correlated with both the GDP metrics with strong correlation followed by solar and geothermal production with moderate correlation. This also agrees with the fact that nuclear power generation is mostly restricted to countries that are developed and are supposed superpowers. The highest correlation is observed between urbanization and nuclear power which is 0.9485. The moderate correlation between geothermal power and GDP shows that geothermal power is not totally dependent on the economic capability of a country and it is more of an availability thing. Geothermal sources are not widespread and found mostly in the western US. The relatively smaller distribution of geothermal sources makes it difficult for bigger countries such as the US, China to make geothermal power a major contributor to their power needs [2]. Smaller countries have a larger proportion of power needs coming from geothermal sources. The need for technology in tapping trapped earth's heat efficiently is being addressed by researchers at MIT.

NON-RENEWABLE ENERGY CORRELATIONS WITH GDP

The pearson correlation metrics between different form of coal usage and GDP and urbanization is shown in the image below. Charcoal usage is the only thing that is positively correlated with GDPs. This means that despite the nation's success in reducing other forms of coal consumption, the usage of charcoal has increased. This is understandable from the fact that charcoal comes as a byproduct from many industries like steel and powerplants and it is not a fossil fuel. Charcoal is increasingly being used by metallurgical industries, and barbecue applications [3]. The fact that it is positively correlated with GDP makes sense as the economic activities increase, the industries increase, and the waste also increases.

X Axis	Charcoal - Final energy...	Coking coal - total energy...	Fuelwood - Final energy...	GDP_Nominal	GDP_Real	Hard coal - final energy...	Lignite - Final energy cons...	Other bituminous c...	Sub-bituminous c...	Urbanization
Brown coal - Fi...	-0.5678	0.5821	0.7102	-0.4830	-0.5479	0.6773	0.4147	0.6847	0.8145	-0.577
Charcoal - Fina...	.	-0.8767	-0.9352	0.8798	0.9169	-0.7339	-0.7578	-0.7441	-0.1294	0.951
Coking coal - to...	.	.	0.8013	-0.9114	-0.9260	0.6649	0.8536	0.6789	0.0837	-0.939
Fuelwood - Fin...	.	.	.	-0.7686	-0.8294	0.7823	0.6184	0.7897	0.3719	-0.883
GDP_Nominal	.	.	.	.	0.9872	-0.6445	-0.8639	-0.6600	0.0297	0.970
GDP_Real	.	.	.	.	.	-0.6347	-0.8640	-0.6511	-0.0403	0.988
Hard coal - fina...	.	.	.	.	.	.	0.4228	0.9995	0.4612	-0.710
Lignite - Final e...	.	.	.	.	.	.	.	0.4428	-0.1902	-0.824
Other bitumino...	.	.	.	.	.	.	.	.	0.4564	-0.723
Sub-bituminous...	.	.	.	.	.	.	.	.	.	-0.097

Sub-bituminous coal usage has the lowest negative correlation with GDP. Its usage, however, is very low. The usage of fuelwood and coking coal has the strongest negative correlation with GDP which suggests that deforestation has been reducing as the country's economy is improving [4]. This is a very good sign and is considered a critical success by the US.

X Axis	GDP_Nominal	GDP_Real	Gas Oil/ Diesel Oil - Final ener	Liquefied petroleum gas (LPG) -	Motor Gasoline - Final energy...	Natural Gas (including LNG) - fi	Urbanization
Bagasse - Final...	-0.1273	-0.0486	0.0400	0.5545	0.0556	0.4798	0.0292
GDP_Nominal	.	0.9872	.	-0.2679	0.8878	0.1841	0.9704
GDP_Real	.	.	.	-0.1416	0.9459	0.2183	0.9883
Gas Oil/ Diesel...	0.8624	0.9241	.	0.1008	0.9742	0.2234	0.9057
Liquefied petrol...	.	.	.	.	0.0919	0.5354	-0.0643
Motor Gasoline...	.	.	.	.	.	0.2105	0.9459
Natural Gas (in...	.	.	.	.	.	.	0.3030

Bagasse and LPG usages are negatively correlated with the GDP. Bagasse is a byproduct of sugarcane manufacturing industries and its production should not be reduced as it is considered a healthy replacement of wood paper. However, the use of sugar (both cane and beet) in domestic food and beverage industries have been declining. The North American Free Trade Agreement stipulates the removal of import duty on sugar and US production is reducing because of that [5]. This reduces the bagasse production and hence the negative correlation values. Gas/Diesel oil has the highest positive correlation with GDP. This is attributed to the heavy increase in automobile usage in the US over the years and it can't be considered a failure in reducing energy usage. In fact, the usage of diesel should be one of the most critical parameters to measure the nations' success in economic growth.

One of the important observations is the positive correlation between natural gas usage and GDP. The usage of natural gas has been increasing over the years, replacing coal as the major energy producer. The low correlation with the GDP says that the US has done a great job in tempering its dependence on NG as the industries grew. Renewables are taking the space now.

CONCLUSION

We can see that the world is now using a lot of renewable energy than ever before. Renewable energy resources exist over wider geographical areas, in contrast to fossil fuels. The development of renewable energy technologies is resulting in energy security, climate change mitigation, and economic benefits. The USA has an excellent improvement in reducing coal usage over time. China and India have an excellent track of harnessing hydropower. On a general note, developed countries are doing well in the adoption of renewable energy and developing countries are doing good in reducing their dependence on non-renewable energy. The above-shown analysis proves this beyond doubt. A lot of further studies can be done in this area to discover some more hidden insights. Other countries should take an example from the pioneer countries in the adoption of renewable energy. Eventually, it is all about making our plant sustainable for the generations to come.

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ACKNOWLEDGMENTS

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CONTACT INFORMATION

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APPENDIX

Country	Wind Growth percent
Spain	1148850.00%
Canada	969300.00%
France	906700.00%
Portugal	485500.00%
New Caledonia	364900.00%
Romania	324300.00%
Italy	289333.33%
Japan	275200.00%
Austria	208500.00%
Greece	197700.00%
Australia	189750.00%
United Kingdom	129770.00%
Thailand	109900.00%
Mexico	85533.33%
India	81332.26%
Sweden	63612.50%
Finland	62600.00%
Korea, Republic of	61100.00%
Turkey	40288.89%
Belgium	38500.00%
Ireland	36750.00%
Chile	36450.00%
Germany	35530.00%
Hungary	32800.00%
Norway	28666.67%
China	28079.41%
Czechia	27700.00%
Other Asia	24407.69%
Peru	20285.71%

Country	Solar Growth percent
Germany	3605500.00%
Japan	2450500.00%
France	590800.00%
Italy	557550.00%
United Kingdom	404900.00%
Greece	379100.00%
RÃ©union	294775.00%
Belgium	288200.00%
Korea, Republic of	255600.00%
Spain	227783.33%
Czechia	212200.00%
Thailand	138400.00%
Canada	87700.00%
Switzerland	84100.00%
Austria	78400.00%
Netherlands	78400.00%
Portugal	62600.00%
Denmark	59500.00%
Australia	44063.64%
Ukraine	42800.00%
Bulgaria	41633.33%
Malaysia	33233.33%
Mexico	22000.00%
Argentina	19900.00%
Ecuador	16400.00%
Madagascar	13984.51%
Tunisia	12400.00%
Luxembourg	9400.00%
Cyprus	8300.00%

Country	Solar change
Germany	36055
Japan	24505
United States	23937
Italy	22302
Spain	13667
China	9625
France	5908
Australia	4847
United Kingdom	4049
Greece	3791
Belgium	2882
Korea, Republic of	2556
Czechia	2122
Canada	1754
Romania	1616
India	1587
Thailand	1384
Bulgaria	1249
South Africa	1120
Switzerland	841
Israel	816
Austria	784
Netherlands	784
Portugal	626
Denmark	595
Slovakia	580
Other Asia	552
Chile	489

country	Nuclear change percent
China	26407.60%
Pakistan	1637.20%
Iran (Islamic Rep. of)	1267.58%
Romania	742.42%
Armenia	710.86%
Brazil	587.44%
India	487.88%
Mexico	229.49%
Korea, Republic of	195.74%
Czechia	147.55%
South Africa	64.21%
Slovenia	60.41%
Russian Federation	51.10%
Canada	47.57%
Slovakia	40.26%
France	38.97%
United States	35.81%
Other Asia	28.98%
Finland	22.71%
Ukraine	19.85%
Netherlands	16.82%
Switzerland	16.59%
Hungary	13.97%
Bulgaria	8.20%
Spain	5.60%
German Dem. R. (former)	0.00%
USSR (former)	0.00%
Germany, Fed. R. (former)	0.00%
United Kingdom	(3.04%)
Czechoslovakia (former)	(3.25%)
Sweden	(4.85%)
Yugoslavia, SFR (former)	(5.02%)
Argentina	(20.94%)
Belgium	(21.11%)
Lithuania	(25.86%)
Germany	(34.03%)
Japan	(100.00%)

country	Hydro change percent
Equatorial Guinea	9750.00%
Mozambique	5660.14%
Cambodia	3149.12%
Estonia	2600.00%
Viet Nam	1044.67%
Burkina Faso	905.26%
Martinique	866.67%
China	739.91%
Sierra Leone	652.23%
Myanmar	640.05%
Belarus	611.76%
Angola	595.31%
Sudan (former)	590.18%
Ethiopia	579.10%
South Africa	558.39%
French Guiana	420.83%
Belize	412.20%
Nepal	396.88%
Vanuatu	386.11%
Iraq	380.49%
Korea, Dem.Ppl's.Rep.	(16.67%)
Poland	(17.48%)
Czechoslovakia (former)	(20.41%)
Latvia	(20.97%)
RÃ©union	(22.44%)
Azerbaijan	(25.59%)
Suriname	(28.45%)
Bangladesh	(33.48%)
Armenia	(34.54%)
Lebanon	(35.67%)
New Caledonia	(37.46%)
Denmark	(46.43%)
Haiti	(52.63%)
Liechtenstein	(67.40%)
Puerto Rico	(71.07%)
Republic of Moldova	(77.13%)
Turkmenistan	(100.00%)

country	Geothermal change percent
Portugal	5025.00%
Turkey	2855.00%
Iceland	1646.00%
Russian Federation	1468.97%
Indonesia	788.53%
Kenya	768.27%
Germany	444.44%
Guadeloupe	400.00%
Costa Rica	349.71%
Ethiopia	280.00%
El Salvador	271.84%
New Zealand	240.59%
Papua New Guinea	219.70%
Philippines	88.59%
Italy	83.61%
Nicaragua	71.50%
Guatemala	69.18%
Japan	48.02%
Mexico	17.10%
United States	16.85%
USSR (former)	7.14%
Ethiopia, incl. Eritrea	3.03%
Australia	0.00%
Thailand	0.00%
Austria	(100.00%)

country	Geothermal change
Indonesia	8871
New Zealand	5127
Iceland	4938
Philippines	4842.1
United States	2698
Italy	2694
Kenya	2581.4
Turkey	2284
Costa Rica	1196
El Salvador	1139
Mexico	876
Japan	836
Russian Federation	426
Papua New Guinea	290
Nicaragua	276
Portugal	201
Guatemala	101
Germany	80
Guadeloupe	60
Ethiopia	14
USSR (former)	2
Ethiopia, incl. Eritrea	2
Viet Nam	0
Australia	0
Thailand	0
Austria	-3

country	Hard coal change percent
Nepal	80668.00%
Singapore	51900.00%
Indonesia	10733.33%
United Arab Emirates	9693.33%
Sri Lanka	9677.00%
United Rep. of Tanzania	6050.00%
Thailand	3452.17%
Madagascar	3126.56%
Viet Nam	2512.33%
Ethiopia	2040.00%
Afghanistan	2036.46%
Costa Rica	1155.23%
Myanmar	781.67%
Lao People's Dem. Rep.	756.40%
Peru	729.91%
Russian Federation	(80.27%)
Netherlands	(81.61%)
Albania	(82.88%)
Turkmenistan	(83.33%)
Czechia	(86.43%)
Finland	(89.26%)
Cuba	(90.38%)
Morocco	(95.51%)
Cyprus	(96.30%)
T.F.Yug.Rep. Macedonia	(96.42%)
Portugal	(99.38%)
Fiji	(99.98%)
Bermuda	(100.00%)
Mauritania	(100.00%)
Tunisia	(100.00%)

country	charcoal change percent
Mayotte	49900.00%
South Africa	19300.00%
Kazakhstan	17900.00%
Bosnia and Herzegovina	6200.00%
Cambodia	3474.28%
Rwanda	1226.09%
Cyprus	1100.00%
Oman	1097.13%
Bhutan	974.23%
United Arab Emirates	900.00%
Nigeria	853.85%
French Polynesia	804.29%
Angola	795.38%
Bahrain	750.00%
Ukraine	700.00%
Romania	(69.41%)
Chile	(71.49%)
Mauritius	(80.00%)
Iran (Islamic Rep. of)	(81.58%)
Lithuania	(83.33%)
Bulgaria	(84.21%)
Costa Rica	(84.62%)
Hungary	(91.78%)
Myanmar	(93.40%)
Sri Lanka	(93.41%)
Cabo Verde	(94.89%)
Slovakia	(95.87%)
Gibraltar	(100.00%)
Malaysia	(100.00%)
Mexico	(100.00%)

country	brown coal change percent
Mexico	2900.00%
Switzerland	907.69%
Georgia	821.88%
Philippines	330.50%
Poland	217.62%
Serbia and Montenegro	(8.18%)
Australia	(9.50%)
United States	(26.50%)
Serbia	(26.67%)
United Arab Emirates	(28.92%)
Kyrgyzstan	(31.32%)
Montenegro	(39.29%)
France	(42.35%)
Thailand	(44.58%)
Kazakhstan	(49.02%)
Netherlands	(50.00%)
Romania	(53.07%)
Mongolia	(54.36%)
Turkey	(54.49%)
Russian Federation	(57.66%)
Greece	(59.19%)
Lao People's Dem. Rep.	(64.03%)
Korea, Dem.Ppl's.Rep.	(66.45%)
Tajikistan	(72.00%)
Austria	(73.15%)
Croatia	(81.03%)
Hungary	(85.77%)
Czechia	(86.26%)
Portugal	(87.50%)
Bulgaria	(87.85%)
Slovenia	(89.14%)
Bosnia and Herzegovina	(89.24%)
Italy	(90.91%)
Belgium	(96.34%)
Germany	(96.41%)
Slovakia	(97.69%)
Spain	(97.92%)
Albania	(99.51%)
Ukraine	(99.90%)

The code to create the data set that contains the data on non-renewable energy usage.

```
DATA IRP.US;
        Set work.US;
        Format Date mmddyy10.;
        Date = (year – 1960 + 0.5) *365.25;
RUN;

PROC SQL;
Select country, commodity_transaction, date, unit, quantity, category from IRP.US where commodity_transaction like "%Brown Coal%" or commodity_transaction like "%Charcoal%" or commodity_transaction like "%Coking Coal%" or commodity_transaction like "%Petcoke%" or commodity_transaction like "%Natural Gas%" and country = "United States"
Order by country;
QUIT;
```

The code to create the data set that contains the data on renewable energy usage

```
DATA IRP.US;
        Set work.US;
        Format Date mmddyy10.;
        Date = (year – 1960 + 0.5) *365.25;
RUN;

PROC SQL;
Select country, commodity_transaction, date, unit, quantity, category from IRP.US where commodity_transaction like "%Solar%" or commodity_transaction like "%wind%" or commodity_transaction like "%nuclear%" and country = "United States"
Order by country;
QUIT;
```

The following codes create different individual data sets for a single type of energy usage for all countries

```
PROC SQL;
create table wind as
```

```
select country_or_area , year, quantity  from work.all_energy_statistics
where commodity_transaction like '%total%wind%'
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
create table wind_growth_rate as
select country_or_area, max(quantity) - min(quantity) as
Wind_Usage_Increase, ((max(quantity) - min(quantity))/ min(quantity))*100
as Wind_Growth_Rate from wind
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
RUN;

PROC SQL;
create table solar as
select country_or_area , year, quantity from work.all_energy_statistics
where commodity_transaction like '%total solar production%'
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
create table solar_growth_rate as
select country_or_area, max(quantity) - min(quantity) as
Solar_Usage_Increase, ((max(quantity) - min(quantity))/ min(quantity))*100
as Solar_Growth_Rate from solar
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
RUN;
    PROC SQL;
create table nuclear as
select country_or_area , year, quantity from work.all_energy_statistics
where commodity_transaction like '%total nuclear production%'
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
create table nuclear_growth_rate as
select country_or_area, max(quantity) - min(quantity) as
Nuclear_Usage_Increase, ((max(quantity) - min(quantity))/
min(quantity))*100 as Nuclear_Growth_Rate from nuclear
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
```

```
        RUN;
        PROC SQL;
create table hydro as
select country_or_area , year, quantity from work.all_energy_statistics
where commodity_transaction like '%total hydro production%'
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
create table hydro_growth_rate as
select country_or_area, max(quantity) - min(quantity) as
Hydro_Usage_Increase, ((max(quantity) - min(quantity))/
min(quantity))*100 as Hydro_Growth_Rate from hydro
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
        RUN;
        PROC SQL;
create table geothermal as
select country_or_area , year, quantity from work.all_energy_statistics
where commodity_transaction like '%total geothermal production%'
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
create table geothermal_growth_rate as
select country_or_area, max(quantity) - min(quantity) as
Geothermal_Usage_Increase,((max(quantity) - min(quantity))/
min(quantity))*100 as Geothermal_Growth_Rate from geothermal
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
        RUN;

PROC SQL;
create table Subbituminous_coal as
select country_or_area , year, quantity, category  from
work.all_energy_statistics
where commodity_transaction like '%Sub-bituminous coal - Final
consumption%' /*or
      commodity_transaction like '%Other bituminous coal - final
consumption%' or
           commodity_transaction like '%Hard coal - final energy
consumption%' or
```

```
      commodity_transaction like '%Charcoal - Final consumption%' or
      commodity_transaction like '%Brown coal - final consumption%' or
          commodity_transaction like '%Bitumen - Final consumption%'*/
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
RUN;
create table Sub_bituminous_decline as
select country_or_area, (max(quantity) - min(quantity)) as
sub_bitumunous_Change, ((max(quantity) - min(quantity))/
max(quantity))*100 as Sub_bituminous_decline_Rate from
Subbituminous_coal
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
run;
PROC SQL;
create table otherbituminous_coal as
select country_or_area , year, quantity, category  from
work.all_energy_statistics
where /*commodity_transaction like '%Sub-bituminous coal - Final
consumption%' /*or*/
      commodity_transaction like '%Other bituminous coal - final
consumption%'
          /*commodity_transaction like '%Hard coal - final energy
consumption%' or
      commodity_transaction like '%Charcoal - Final consumption%' or
      commodity_transaction like '%Brown coal - final consumption%' or
          commodity_transaction like '%Bitumen - Final consumption%'*/
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
RUN;
create table other_bituminous_decline as
select country_or_area, (max(quantity) - min(quantity)) as
other_bitumunous_Change,((max(quantity) - min(quantity))/
max(quantity))*100 as other_bituminous_decline_Rate from
otherbituminous_coal
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
RUN;
```

```
PROC SQL;
create table hard_coal as
select country_or_area , year, quantity, category  from
work.all_energy_statistics
where /*commodity_transaction like '%Sub-bituminous coal - Final
consumption%' /*or
      commodity_transaction like '%Other bituminous coal - final
consumption%' or   */
            commodity_transaction like '%Hard coal - final energy
consumption%'
      /*commodity_transaction like '%Charcoal - Final consumption%' or
      commodity_transaction like '%Brown coal - final consumption%' or
            commodity_transaction like '%Bitumen - Final consumption%'*/
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
RUN;
create table hardcoal_decline as
select country_or_area, (max(quantity) - min(quantity)) as
hard_coal_Change,((max(quantity) - min(quantity))/ max(quantity))*100 as
hardcoal_decline_Rate from hard_coal
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
RUN;
PROC SQL;
create table charcoal as
select country_or_area , year, quantity, category  from
work.all_energy_statistics
where /*commodity_transaction like '%Sub-bituminous coal - Final
consumption%' /*or
      commodity_transaction like '%Other bituminous coal - final
consumption%' or
            commodity_transaction like '%Hard coal - final energy
consumption%' or*/
      commodity_transaction like '%Charcoal - Final consumption%'
     /* commodity_transaction like '%Brown coal - final consumption%' or
            commodity_transaction like '%Bitumen - Final consumption%'*/
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
```

```
RUN;
create table charcoal_decline as
select country_or_area, (max(quantity) - min(quantity)) as
charcoal_Change,((max(quantity) - min(quantity))/ max(quantity))*100 as
charcoal_decline_Rate from charcoal
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
RUN;
PROC SQL;
create table Brown_coal as
select country_or_area , year, quantity, category  from
work.all_energy_statistics
where /*commodity_transaction like '%Sub-bituminous coal - Final
consumption%' /*or
      commodity_transaction like '%Other bituminous coal - final
consumption%' or
            commodity_transaction like '%Hard coal - final energy
consumption%' or
      commodity_transaction like '%Charcoal - Final consumption%' or*/
      commodity_transaction like '%Brown coal - final consumption%'
           /*commodity_transaction like '%Bitumen - Final consumption%'*/
group by country_or_area
having year = max(year) or year = min(year)
order by country_or_area;
RUN;
create table Browncoal_decline as
select country_or_area, (max(quantity) - min(quantity)) as
brown_coal_Change,((max(quantity) - min(quantity))/ max(quantity))*100 as
Browncoal_decline_Rate from Brown_coal
group by country_or_area
having min(quantity) ne 0 and (max(quantity) ne min(quantity));
RUN;
```

The code that pulls data of all energy types for the USA

```
PROC SQL;
create table US_Energy as
select country_or_area, year, commodity_transaction, quantity
from work.all_energy_statistics where
country_or_area = 'United States' and (
```

```
commodity_transaction = 'Brown coal - Final energy consumption' or
commodity_transaction = 'Charcoal - Final energy consumption' or
commodity_transaction = 'Coking coal - total energy supply' or
commodity_transaction = 'Hard coal - final energy consumption' or
commodity_transaction = 'Lignite - Final energy consumption' or
commodity_transaction = 'Other bituminous coal - final energy
consumption' or
commodity_transaction = 'Petroleum coke - final consumption' or
commodity_transaction = 'Sub-bituminous coal - Final energy consumption'
or
commodity_transaction = 'Fuelwood - Final energy consumption' or

commodity_transaction = 'Liquefied petroleum gas (LPG) - Final
consumption' or
commodity_transaction = 'Natural Gas (including LNG) - final energy
consumption' or
commodity_transaction = 'Motor Gasoline - Final energy consumption' or
commodity_transaction = 'Gas Oil/ Diesel Oil - Final energy consumption'
or

commodity_transaction = 'Bagasse - Final energy consumption' or

commodity_transaction = 'Electricity - total nuclear production' or
commodity_transaction = 'Electricity - total geothermal production' or
commodity_transaction = 'Electricity - total hydro production' or
commodity_transaction = 'Electricity - total solar production' or
commodity_transaction = 'Electricity - total thermal production' or
commodity_transaction = 'Electricity - total net installed capacity of electric
power plants, wind');
RUN;
PROC TRANSPOSE
DATA=WORK.'API_SP.URB.TOTL.IN.ZS_DS2_EN_EXC'N OUT=
URBANIZATION_TRANSPOSED (RENAME= (_NAME_ = YEAR
COL1 = Urbanization));
RUN;
DATA urnanization;
set urbanization_transposed;
date = input(year, best12.);
RUN;
PROC SQL;
```

```
CREATE TABLE US_ENERGY_GDP AS
SELECT A.*, B.* , c.* FROM WORK.US_ENERGY_TRANSPOSED1
AS A, WORK.GDP_US_0000 AS B, work.urnanization as c
WHERE A.YEAR = B.DATE and a.year = c.date;
RUN;

PROC SORT DATA= us_energy;
by country_or_area  year commodity_transaction;
run;
PROC TRANSPOSE data= us_energy out= us_energy_transposed1
(drop=_name_);
by country_or_area year;
var quantity;
id commodity_transaction;
RUN;
```

The code that transposes the data to join tables accordingly

```
PROC SORT data= work.'CORRELATION _ ELECTRICITY _
TOTA'N;
by 'x axis'n 'Y axis'n;
RUN;
PROC TRANsPOSE DATA =  work.'CORRELATION _
ELECTRICITY _ TOTA'N    OUT = CORR_TRANSPOSED
(drop=_name_);
BY 'x axis'n;
id 'Y axis'n;
var correlation;
RUN;
PROC SORT data= work.'correlation _ brown coal _ final'n;
by 'x axis'n 'Y axis'n;
RUN;
PROC TRANsPOSE DATA =  work.'correlation _ brown coal _ final'n
OUT = COal_TRANSPOSED (drop=_name_);
BY 'x axis'n;
id 'Y axis'n;
var correlation;
RUN;
PROC SORT data= work.'correlation _ bagasse _ final en'n;
by 'x axis'n 'Y axis'n;
```

```
        RUN;
        PROC TRANsPOSE DATA =  work.'correlation _ bagasse _ final en'n
        OUT = bag_TRANSPOSED (drop=_name_);
        BY 'x axis'n;
        id 'Y axis'n;
        var correlation;
RUN;
```