Intercontinental Geoinformation Days

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Temporal analysis and future prediction of CO_2 emissions of solid, liquid and gas fuels in Python with FBProphet model

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Keywords
FBProphet Model
Python
CO2 Emissions
Temporal Analysis
Fuels

ABSTRACT

Carbon emission simply means the release of carbon into the atmosphere. When it comes to carbon emission, many definitions come to mind, but talking about carbon emission is actually talking about greenhouse gas emission. Because greenhouse gas emissions are often calculated as carbon dioxide equivalents, they are often referred to as carbon emissions in any global warming or greenhouse gas impact debate. According to the predictions of the International Energy Agency, the demand for fossil fuels will increase until 2050 and a 130% increase in carbon emission values will be observed accordingly (O'Neill 2020). For this reason, very important problems such as global warming and climate change, which are beginning to be felt more and more, will become a bigger threat to the world in the coming years. In the study, the effects of solid, liquid and gaseous fuels on CO2 emissions were analyzed in time series using the FBProphet model and a future prediction was made.

1. INTRODUCTION

The concentration of greenhouse gases caused by humans in the atmosphere started to increase especially with the industrial revolution that started in the 1850s. As a natural consequence of this, an increase in energy demand has been observed and a significant increase has been observed in the use of fossil fuels to compensate this increase (Xie et al. 2013). When we look at the air temperatures, in the period from the 19th century until today, the air temperature has increased by 0.5 degrees on average.

As the years progress, greenhouse gas emissions increase and this has negative consequences for nature such as global warming. Energy production is the main cause of carbon emissions. Firms engaged in energy production resort to fossil fuels at a rate of 87% to provide the energy they need. It is known that solid, liquid and gaseous fuels also cause different levels of carbon dioxide emission. According to the "TUIK 2014 Greenhouse Gas Inventory", it was 132.5 million tons (equivalent to CO_2) in 1990, and this figure increased to 340 million tons (CO2 equivalent) in 2014 (Kılıç et al. 2018). In other words, the carbon emission of the energy sector increased by 156% between 1990 and 2014 (Mensah et al. 2018). To reduce this carbon dioxide emission, renewable energy sources should be used. Today, there are studies in many countries that have started to ban diesel and gasoline vehicles (Jochem et al. 2015). The use of fully electric vehicles instead of these vehicles is encouraged. It is thought that electric vehicles can significantly reduce CO_2 emissions, unlike diesel and gasoline cars.

When switching to electric vehicle technology, the question arises from where the needed energy will be met. It is thought that when the number of solar panels, wind power plants and hydroelectric power plants is increased, most of the energy needed can be met. For this reason, energy production from fossil fuels must be limited in order to prevent negative factors such as global warming and seasonal changes (Yilmaz and Yilmaz 2013).

In our study, by considering the role of solid, liquid and gaseous fuels in CO_2 emission amounts, the data were analyzed with time series and FBProphet model, and a future prediction was made as a result of this analysis.

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Cite this study

Kaynakli M & Tabar M.E (2021). Temporal analysis and future prediction of CO_2 emissions of solid, liquid and gas fuels in Python with FBProphet Model. 2nd Intercontinental Geoinformation Days (IGD), 163-166, Mersin, Turkey

2. METHOD

CO_2 emissions data for Turkey is taken from "https://data.worldbank.org/". The received data was transferred to Python software and a column matrix was created as date and emission data. The index data was added to this column matrix with the help of Python software. A fit model was created with the FBProphet model for this defined matrix. Period and freq value are defined in the model for the future forecast. The period was repeated as 34 years and a predictive value was found until 2050. In order to test the accuracy of the model, the entire model was defined as training data and the model predicted for the years whose CO2 emission value was known. CO2 emission data for the next 34 years were also predicted using time series. The FBProphet Model, made open source by Facebook, predicts the future with time series analysis (Chikkakrishna et al. 2019).

$$f(x) = g(x) + s(x) + h(x) + e(t)$$

FBProphet uses time as a regressor and tries to fit several linear and nonlinear functions of time as components (Chikkakrishna et al. 2019).

2.1. Total CO_2 Emissions

Total CO_2 emissions for Turkey are defined and a future forecast is made with the FBProphet model in Python. Total CO_2 Emissions are given in Table 1.

Table 1. Total CO_2 Emissions in Turkey

Index	Date	CO2 Emissions
0	01.01.1960	16820.529
1	01.01.1961	17363.245
2	01.01.1962	21631.633
...	...	...
54	01.01.2014	345908.110
55	01.01.2015	350337.846
56	01.01.2016	372724.881

Estimated future CO_2 emission values with the FBProphet model is given in Table 2.

Table 2. Total CO_2 Emissions FBProphet Outputs

Index	Ds	Trend	T_lower	T_upper	Yearly	Yhat
0	1960	13447.630	13447.630	13447.630	25200.766	11753.135
1	1961	9770.455	9770.455	9770.455	21823.579	12053.124
2	1962	6103.326	6103.326	6103.326	23249.486	17146.160
...	...	...	...	...	...	...
88	2048	67866.082	64788.927	71509.782	25474.416	70413.499
89	2049	68925.117	65688.232	72749.684	25723.441	71498.558
90	2050	69982.197	66573.648	74012.854	25943.213	72576.411

CO_2 emission estimation data are shown graphically in Fig. 1 and trend analysis is shown in Fig. 2.

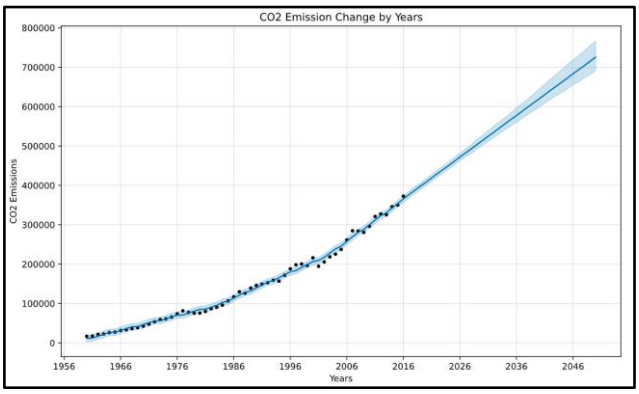

Figure 1. CO_2 Emissions Forecast

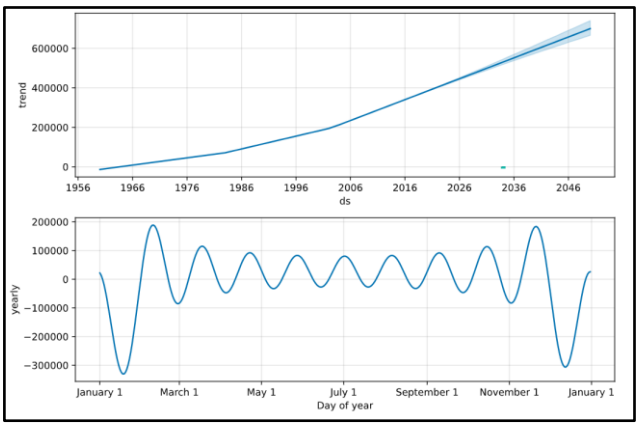

Figure 2. Trend Analysis

2.1.1. CO_2 Emissions from Solid Fuel Consumption

Emission values from solid fuels are shown in Table 3. CO_2 emissions from solid fuel consumption FBProphet outputs are shown in Table 4.

Table 3. CO_2 Emissions from Solid Fuel Consumption

Index	Date	CO_2 Emissions
0	01.01.1960	67.364290
1	01.01.1961	61.224921
2	01.01.1962	55.043228
...	...	...
54	01.01.2014	40.144175
55	01.01.2015	37.958718
56	01.01.2016	39.734168

Table 4. CO_2 Emissions from Solid Fuel Consumption FBProphet Outputs

Index	Ds	Trend	T_lower	T_upper	Yearly	Yhat
0	1960	8.453242	8.453242	8.453242	48.786464	57.239706
1	1961	7.023585	7.023585	7.023585	48.217769	55.241354
2	1962	5.597835	5.597835	5.597835	48.295549	53.893384
...	...	...	...	...	...	...
88	2048	4.729439	12.403263	2.785379	51.097074	46.367636
89	2049	4.637452	12.808790	3.163526	49.199019	44.561567
90	2050	4.545717	13.065674	3.539595	49.722226	45.176509

CO_2 emission from solid fuel estimation data are shown graphically in Fig. 3 and trend analysis is shown in Fig. 4.

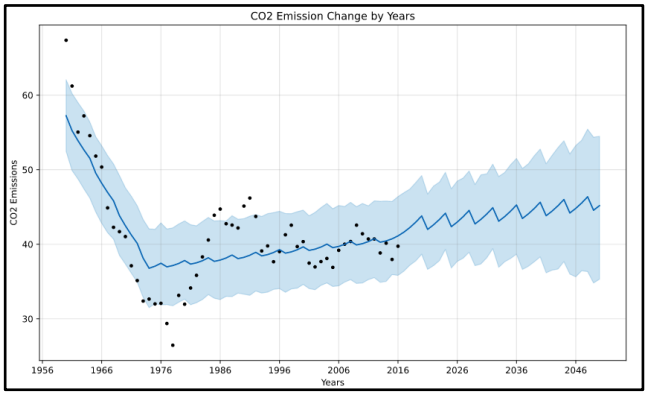

Figure 3. CO_2 Emissions from Solid Fuel Forecast

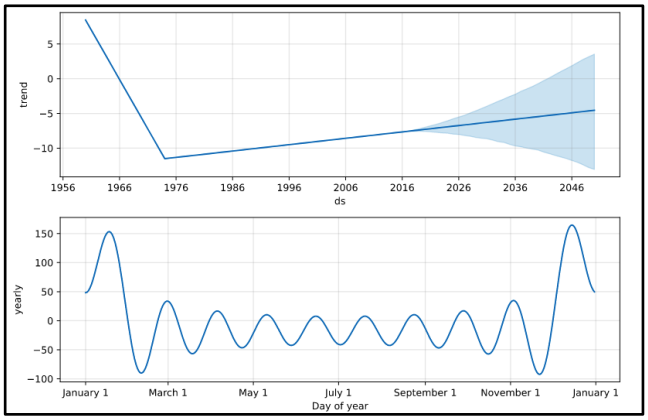

Figure 4. CO_2 Emissions from Solid Fuel Trend Analysis

2.1.2. CO_2 Emissions from Liquid Fuel Consumption

Emission values from liquid fuels are shown in Table 5. CO_2 emissions from liquid fuel consumption FBProphet outputs are shown in Table 6. CO_2 emission from liquid fuel estimation data are shown graphically in Fig. 5 and trend analysis is shown in Fig. 6.

Table 5. CO_2 Emissions from Liquid Fuel Consumption

Index	Date	CO2 Emissions
0	01.01.1960	26.596904
1	01.01.1961	32.946146
2	01.01.1962	39.599932
...	...	...
54	01.01.2014	22.964062
55	01.01.2015	26.127823
56	01.01.2016	26.663912

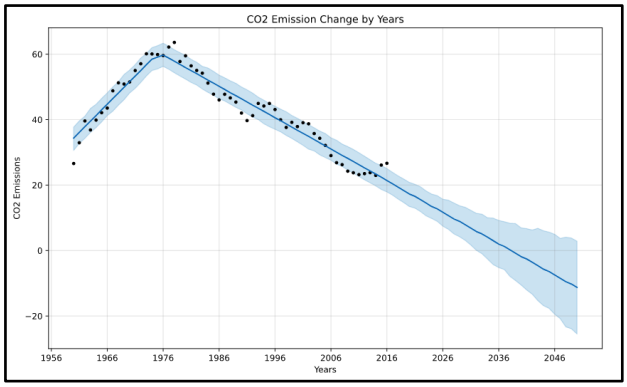

Figure 5. CO_2 Emissions from Liquid Fuel Forecast

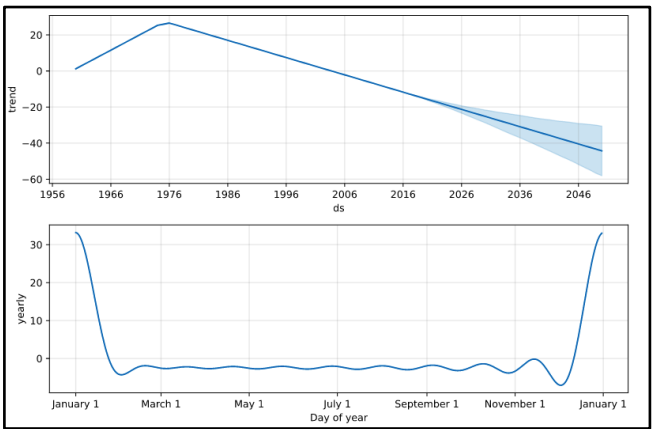

Figure 6. CO_2 Emissions from Liquid Fuel Trend Analysis

Table 6. CO_2 Emissions from Liquid Fuel Consumption FBProphet Outputs

Index	Ds	Trend	T_lower	T_upper	Yearly	Yhat
0	1960	1.207149	1.207149	1.207149	33.143364	34.350513
1	1961	2.931871	2.931871	2.931871	33.192160	36.124031
2	1962	4.651881	4.651881	4.651881	33.191892	37.843773
...	...	...	...	...	...	...
88	2048	42.368239	54.972443	29.763376	32.854304	9.513935
89	2049	43.327891	56.718477	30.035112	33.095079	10.232812
90	2050	44.284922	58.067588	30.565266	33.030788	11.254134

2.1.3. CO2 Emissions from Gaseous Fuel Consumption

Emission values from gaseous fuels are shown in Table 7. CO_2 emissions from gaseous fuel consumption FBProphet outputs are shown in Table 8.

CO_2 emission from gaseous fuel estimation data are shown graphically in Fig. 7 and trend analysis is shown in Fig. 8.

Table 7. CO_2 Emissions from Gaseous Fuel Consumption

Index	Date	CO2 Emissions
0	01.01.1960	0.000000
1	01.01.1961	0.000000
2	01.01.1962	0.000000
...	...	...
54	01.01.2014	26.620375
55	01.01.2015	25.746823
56	01.01.2016	23.510719

Table 8. CO_2 Emissions from Gaseous Fuel Consumption FBProphet Outputs

Index	Ds	Trend	T_lower	T_upper	Yearly	Yhat
0	1960	3.851375	3.851375	3.851375	2.886529	0.964847
1	1961	3.792307	3.792307	3.792307	3.299266	0.493041
2	1962	3.733399	3.733399	3.733399	3.243385	0.490014
...	...	...	...	...	...	...
88	2048	56.114847	51.847369	60.451480	1.201026	57.315873
89	2049	57.059376	52.592689	61.530913	2.585954	59.645330
90	2050	58.001325	53.297120	62.657709	2.204451	60.205775

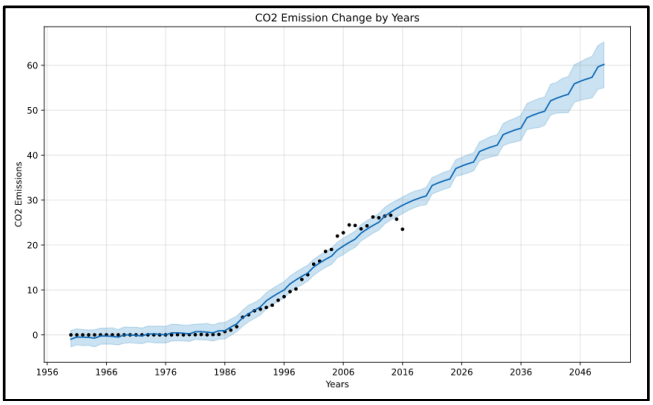

Figure 7. CO_2 Emissions from Gaseous Fuel Forecast

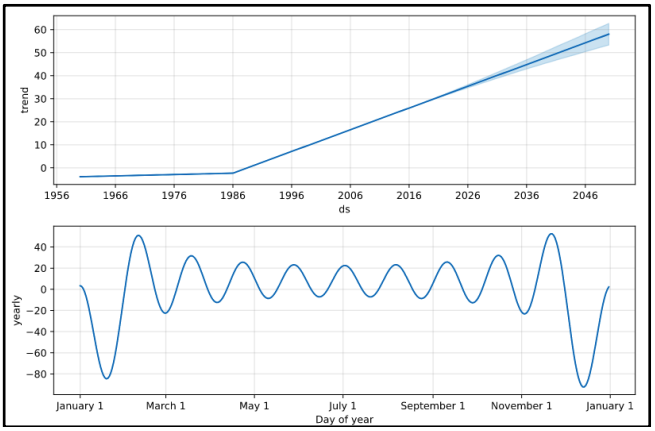

Figure 8. CO_2 Emissions from Gaseous Fuel Trend Analysis

3. RESULTS

The International Energy Agency has made a statement that the demand for fossil fuels will increase until 2050 and a 130% increase in carbon emission values will be observed accordingly. The carbon emission in 2016 is 372724.881. In our study, it was estimated that carbon emission in Turkey could increase by 94.720% until 2050. It is estimated that the CO2 emission of solid fuels will increase by 13,698%, that of liquid fuels will decrease by 57,793% and that of gaseous fuels will increase by 156,076%.

4. DISCUSSION

When the trend analyzes are examined, it is seen that the increase in CO_2 emission values are more in the autumn and winter transition months. This increase is likely due to residents' heating needs. The contribution of liquid fuels to CO_2 emissions will decrease with the transition to electric vehicles. The increase in the contribution of gaseous fuels to CO_2 emissions is due to the widespread use of natural gas. Therefore, alternative energy sources such as solar energy and hydroelectric power plants should be directed.

5. CONCLUSION

Continuing to use fossil fuels for needs such as warming and energy production will accelerate global warming and seasonal changes. Using renewable energy sources in energy production allows us to leave a more livable world to future generations. Therefore, renewable energy sources such as water, wind and solar energy should gradually replace fossil fuels.

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