The impact of the COVID-19 crisis on the manifestation of the rebound effect in energy consumption

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Abstract: *In order to reduce total energy consumption, energy intensity should decrease at a rate higher than the rate of economic growth. This result could be achieved if global energy intensity is reduced or if global economic growth is reduced. The COVID-19 health crisis has a strong impact on global economic growth. The purpose of the article is to analyse the impact of the COVID-19 crisis on the manifestation of the rebound effect in energy consumption. As aresult, the emergence of the pandemic has negatively affected energy consumption, if we refer to the development of the economy, but it can also be seen as a positive effect when it comes to pollution caused by energy processes.*

Keywords: *COVID-19 crisis, rebound effect, energy consumption*

JEL Classification: *Q32, Q43, P28*

Introduction

Economic growth is a desirable phenomenon among the political leaders of each state, but it brings with it the consequences of the setback effect. At the same time, with the application of environmental measures, to reduce greenhouse gas emissions, innovative systems are developed, less polluting, but with greater success in the market.

Current climate policies contain several main ideas designed to stop the emission of carbon dioxide and methane in the first phase.

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The strategies are divided into two approaches. On one hand, there is talk of increasing the volume of renewable energy and reducing the use and production of fossil fuels, and on the other hand, there is a decrease in energy consumption in general.

The energy consumption equation can be expressed according to two factors when it comes to the second strategy, it follows the size of the economy, expressed in GDP and the energy intensity required for each unit of GDP.

In this equation, if the growth rate of the economy is higher than the rate at which the energy intensity decreases, the final energy consumption will be higher than before the increase of energy efficiency. In the last economic century, the evolution of technology and the decrease of energy intensity have led to a continuously sustained economic growth and to a higher energy consumption than ever before.

In order to reduce total energy consumption, energy intensity should decrease at a rate higher than the rate of economic growth. This result could be achieved if global energy intensity is reduced or if global economic growth is reduced. The COVID-19 health crisis has a strong impact on global economic growth.

Daily data on the Covid-19 crisis and energy consumption

Enerdata article "The decline in energy consumption in 2020 will be unprecedented" presents several issues that affect energy consumption and GDP as a result of the medical crisis.

In the first part of 2020, the coronavirus health crisis forced companies to run slower and people to work from home, leading to a significant decrease in final energy consumption. As an example, the situation in France was analyzed.

Based on available first macroeconomic estimates and events from other times of crisis, it was estimated that the impact of two months of isolation on final energy consumption in 2020 in France would have a greater effect than observed during the last financial crisis in 2008, or of the first oil shock of 1975.

The Enerdata article summarizes the main scenarios for the evolution of energy consumption in 2020.

According to the latest INSEE forecasts, economic activity in this period of prevention is about 65% of the normal level in France, which will lead to a record decrease in energy consumption in the industrial, tertiary and transport sectors. Based on these figures, a 35% decrease in energy consumption in the tertiary and industrial sector and an 80% decrease in passenger traffic were estimated. Given the continued existence of the supply chain for goods, it was assumed that, in terms of consumption, there would be no change for freight traffic or agriculture.

The residential sector is facing a significant increase in energy consumption (estimated at about 15%), as a large part of the population has to stay at home and therefore needs more heating, lighting, use of electrical appliances, etc.

Thus, the evolution of all these activities led to a 15% decrease in electricity demand (all sectors combined) in March in France, confirmed RTE, the administrator of the French network.

In the Enerdata analysis, the impact of coronavirus on final energy consumption in 2020 was estimated.

Four scenarios were developed based on the downtime and the speed of economic recovery. It has been difficult to estimate the duration of the closure of certain economic sectors since the beginning of the health crisis, but it is even more difficult to assess its impact on economic growth.

At the beginning of the crisis, the draft law on the amended budget established the hypothesis of a decrease of -1% of GDP in 2020, implying a rapid economic recovery. A few days later, this estimate was revised and "will certainly be much higher," according to French Economy and Finance Minister Bruno Le Maire, who "does not believe in the magic wand" since the end of the crisis. The French government announced on April 14 a decrease of 8% of GDP in 2020 compared to 2019.

What is certain is that the decrease in activity will depend on the duration of the closure. Therefore, four scenarios have been set according to the duration of the closure, which should last at least two months after Macron's statement on April 13, and the speed of economic recovery, which could be faster or slower, as indicated by the minister. French economy. With regard to this assumption, it was established that the macroeconomic impact of a slow economic recovery would include both short-term shock and a slower growth rate for the rest of 2020, as observed during the last financial crisis.

The 4 GDP evolution scenarios are highlighted in table 1.

Table 1. Possible scenarios in France

		Duration of lockdown	
		2 months	3 months
The speed of recovery of the economy	Fast	Scenario 1 GDP 2020 - 5%	Scenario2 GDP 2020 - 8%
	Slow	Scenario 3 PIB 2020 - 8%	Scenario 4 PIB 2020 - 11%

Source: Enerdata

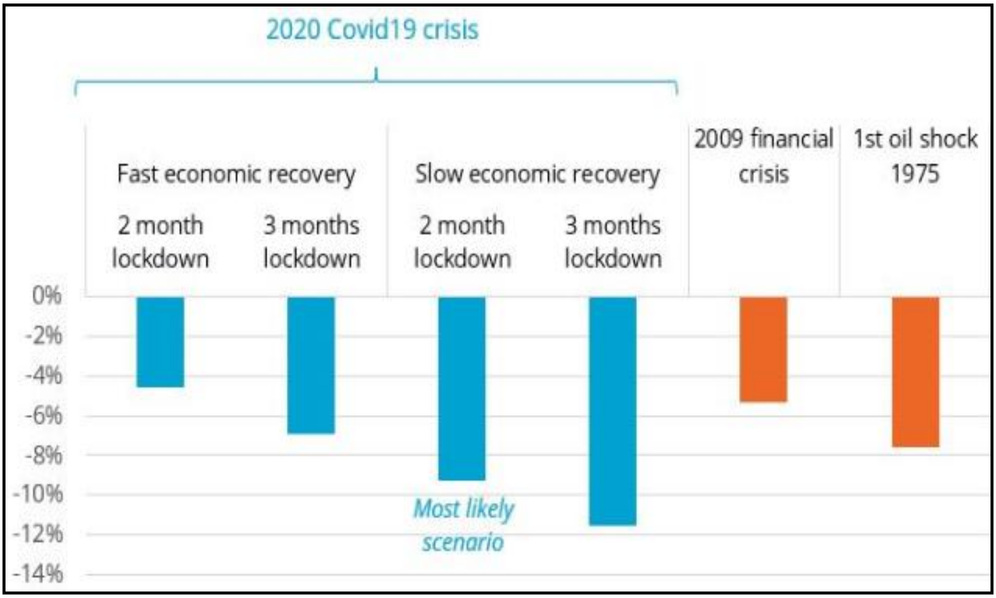
Therefore, we can most likely expect a higher energy consumption than the first oil shock.

Based on the four scenarios and Enerdata statistics, the impact of the health crisis on energy consumption in France for 2020 was assessed.

In scenario 1, according to which the lock would be limited to two months and the economic recovery would be rapid and immediate, total energy consumption would decrease by 4.6%. If the economy recovered more slowly after two months of stagnation (scenario 3), then the impact would be more pronounced and the decrease in energy consumption (9.2%) would be greater than that observed after the first oil shock in 1975.

If the blockage lasts three months, then the effects would be multiplied, and in the worst case (scenario 4) final energy consumption in France would decrease by 11.5%, an unprecedented decrease in the last 50 years (figure 1).

Figure 1. The impact on final energy consumption in the scenarios of the 2020 health crisis and the impact in France during the 2008 financial crisis and the 1975 oil crisis



Source: Enerdata

We also take into account the fact that a contracting of economic activity reduces CO2 emissions CH4 and N2O. Until the onset of the COVID-19 crisis, the latest analysis of WMO Global Atmosphere Watch observations shows how global average concentrations calculated for CO2, CH4 and N2O have reached new highs.

The growth rates of CO2, CH4 and N2O in the atmosphere were on average in the period 2015-2017 for which the data are about 20% higher than in 2011-2015.

Preliminary analysis shows that in 2018 the average annual concentration of CO2 at the Mauna Loa Observatory, Hawaii, reached 408.52 ppm, and the increase from 2017 to 2018 was 1.97 ppm. Between January and August 2019, the increase in concentration was 0.85 ppm (Table 2).

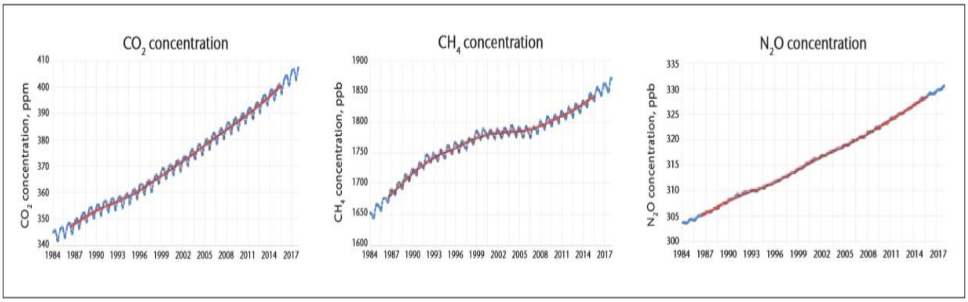
Table 2. Table of CO2 (ppm), CH4 (parts per billion, ppb) and N2O (ppb) concentrations, their growth rates (ppm / year for CO2; ppb / year for CH4 and N2O)

	Concentration			*Growth rate*		
	2015-2017	*2011-2015*	*2015-2017 % to pre-industrial*	*2015-2017*	*2011-2015*	*% change*
CO_2	403	395.5	145	2.6	2.2	+18%
CH_4	1851.7	1826.4	256	8.7	7.2	+21%
N_2O	329.1	326.2	122	0.87	0.73	+19%

Source: WMO

The table above represents the concentrations of CO2 (ppm), CH4 (parts per billion, ppb) and N2O (ppb), their growth rates from one period to another, the relative change in growth rates from 2011-2015 to 2015-2017 and the percentage of concentration in the period 2015-2017 compared to the pre-industrial concentration (before 1750).

Figure 2. Series of global average concentrations of CO2 in ppm, CH4 in ppb and N2O in ppm



Source: WMO

The charts in Figure 2 represent the concentrations of CO2 (ppm), CH4 (parts per billion, ppb) and N2O (ppb), their growth rates from one period to another, the relative change in growth rates from 2011-2015 to 2015-2017 and the percentage of concentration in the period 2015-2017 compared to the pre-industrial concentration (before 1750). (World Meteorological Organization (WMO), 2020)

Returning to the Enerdata scenarios, if we assume that the carbon emissions of energy consumed remain the same as in 2019, then CO2 emissions related to energy will decrease, between -9.9% (according to scenario 3) and up to -12.6% (according to scenario 4) in 2020.

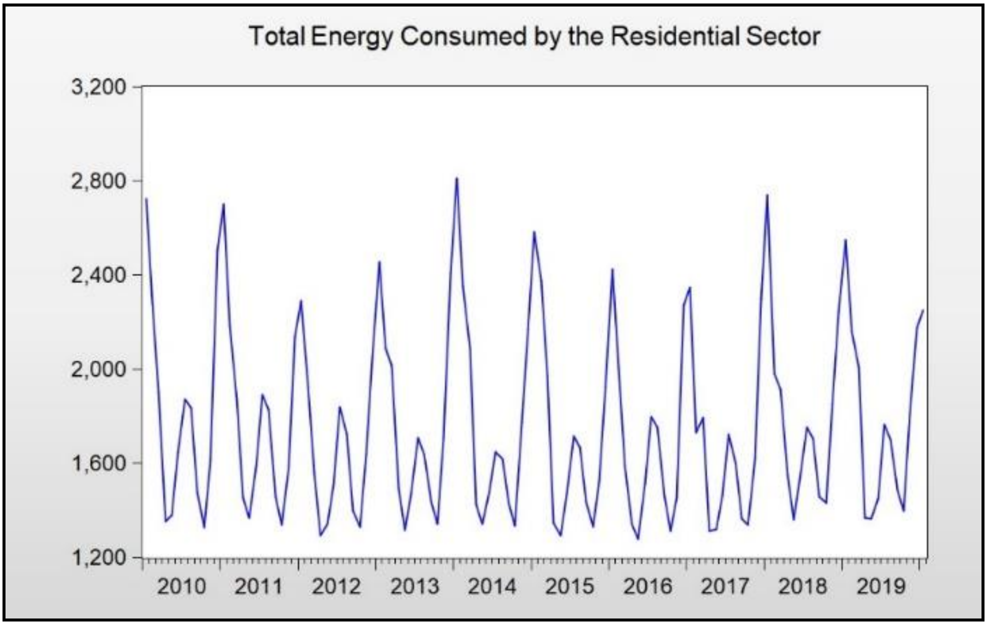
Many agree that once the crisis is over, we will see a setback effect in 2021, with consumption starting to rise again and reversing the trend for 2020.(Enerdata, 2020)

Description of the analyzed data series

If we had enough natural, technological and economic resources to replace all the energy obtained from fossil fuels with renewable energy, then we should no longer limit ourselves to energy consumption or a stagnation of the economy. Following the Paris Agreement, it was disputed to stabilize global temperatures by 2 degrees higher than in the pre-industrial period by the end of 2035. The plan also includes the International Energy Agency (IEA) estimate of $ 53 trillion to be invested in appliances. energy production. Until the implementation of all systems, it is the duty of the population to reduce energy consumption, because there will be no supporters to freeze the economy. The 21st century is prone to economic growth in most states, because it represents prosperity, jobs, financial and social opportunities, along with technological evolution. Chemically, the goal of this century is to reduce the concentration of carbon dioxide (CO2) to 450 parts per million (ppm). If we follow the specialized models, the overall intensity should decrease annually by 3 percent, given that in the period 1990-2015, the annual decrease was about 1.3 percent. In order to achieve the performance of tripling the global energy intensity decrease index, we will have to control the rebound effect.

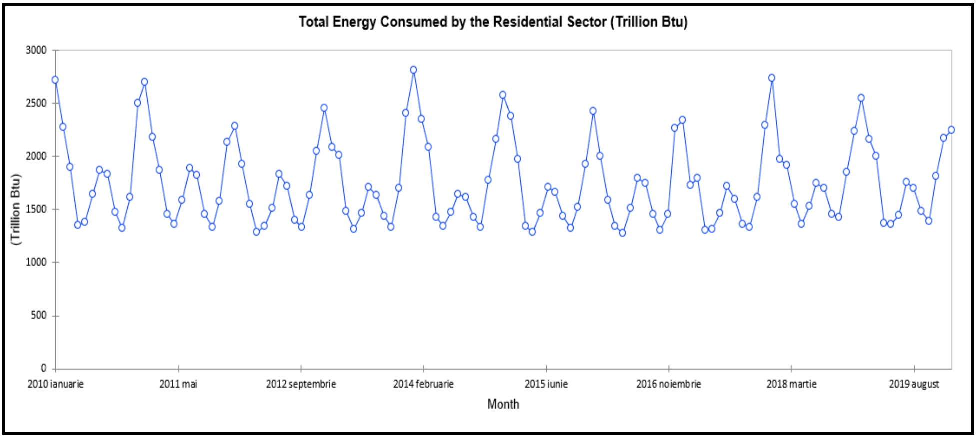
We note that the United States had an average annual economic growth of 3.3% during the postwar period. Reporting this increase of the largest economic power with the decrease of energy intensity, which in the last century was a little over 1% , the need for a global mobilization is strictly necessary to succeed in controlling the rebound effect. Therefore, we intend to analyze a series of data containing information on the total energy consumption of the residential sector in the USA (figure 3).

Figure 3. Energy consumption in the US residential sector in the period 2010-2020



Unlike primary consumption, total consumption includes both energy use activities by individuals in the residential sector and materials processing activities for this sector (figure 4).

Figure 4. Total energy consumption in the residential sector in the US



The data are part of the time interval January 2010 - January 2020, and the values are monthly. The unit of measurement by which the energy values are represented is BTU (British Thermal Unit), equivalent to 10 ^ 15 joules.

In order to analyze the time series, in the first phase the stationarity of the series is tested, analyzing the graphical representation. The series may feature a stationary process, White Noise or a non-stationary stochastic process, Random Walk. If the series shows a long-term trend, changes systematically in variance, and the graph does not show similar fluctuations around a constant average, the series is not stationary.

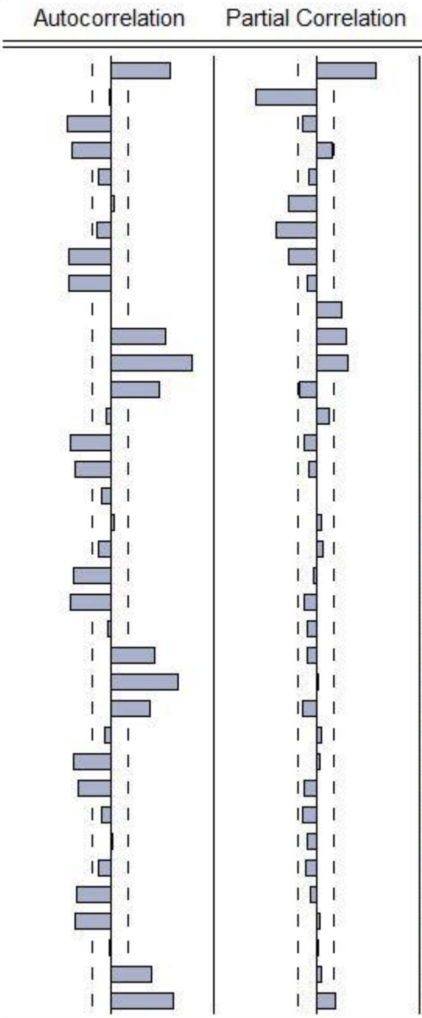
In the case of a non-stationary series, the values will have to be stationary by differentiation of order 1 or 2. At the end of the data processing, an ARIMA type model (p, d, q) is estimated and tested.

Stationarity testing

From the presented graphical representations it is observed that the time series is not stationary and there is a seasonal component. The represented values fluctuate slightly from one year to another, but the movement is similar depending on the period of the year represented. In order to see if the series is integrated of order I, having gone at random or is integrated of order II, the correlogram must be generated and analyzed (figure 5).

Figure 5. Original time series correlogram

Date: 05/17/20 Time: 15:52
Sample: 2010M01 2020M01
Included observations: 121

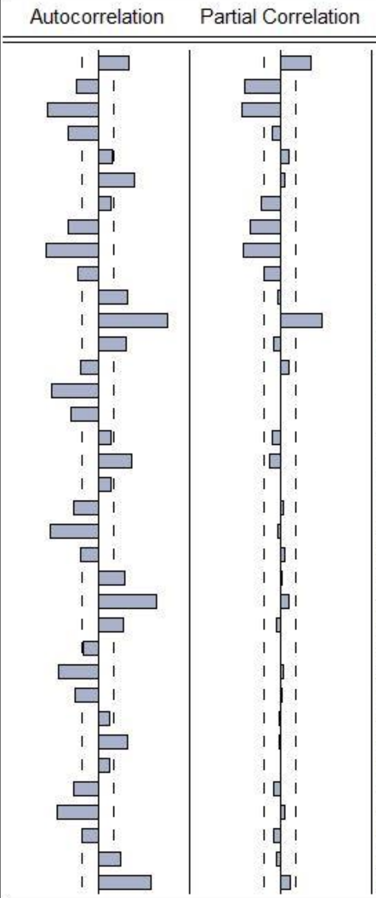


	AC	PAC	Q-Stat	Prob
1	0.605	0.605	45.431	0.000
2	-0.015	-0.602	45.459	0.000
3	-0.432	-0.132	69.013	0.000
4	-0.390	0.170	88.331	0.000
5	-0.108	-0.077	89.832	0.000
6	0.038	-0.284	90.019	0.000
7	-0.138	-0.394	92.492	0.000
8	-0.411	-0.279	114.74	0.000
9	-0.422	-0.085	138.40	0.000
10	0.005	0.267	138.40	0.000
11	0.564	0.302	181.37	0.000
12	0.825	0.323	274.25	0.000
13	0.492	-0.166	307.59	0.000
14	-0.039	0.124	307.80	0.000
15	-0.404	-0.119	330.76	0.000
16	-0.360	-0.080	349.15	0.000
17	-0.098	0.001	350.51	0.000
18	0.041	0.058	350.76	0.000
19	-0.112	0.075	352.57	0.000
20	-0.367	-0.031	372.39	0.000
21	-0.395	-0.122	395.61	0.000
22	-0.028	-0.089	395.73	0.000
23	0.456	-0.095	427.33	0.000
24	0.687	0.024	499.75	0.000
25	0.404	-0.139	525.11	0.000
26	-0.056	0.057	525.61	0.000
27	-0.361	0.049	546.23	0.000
28	-0.319	-0.114	562.48	0.000
29	-0.092	-0.132	563.84	0.000
30	0.030	-0.093	563.99	0.000
31	-0.112	-0.101	566.08	0.000
32	-0.341	-0.055	585.51	0.000
33	-0.350	0.039	606.17	0.000
34	-0.016	0.019	606.22	0.000
35	0.416	0.056	636.15	0.000
36	0.641	0.195	708.09	0.000

Both the correlogram for the original time series and for the differentiated series were approached (figure 6), and the values became stationary after differentiation. Thus, it is identified that the time series under analysis is an integrated first-order series and a random wolk process.

Figure 6. Correlogram of the time series differentiated by degree 1

Date: 05/17/20 Time: 15:57
Sample: 2010M01 2020M01
Included observations: 120



Autocorrelation / Partial Correlation		AC	PAC	Q-Stat	Prob
	1	0.347	0.347	14.828	0.000
	2	-0.239	-0.409	21.938	0.000
	3	-0.579	-0.436	63.831	0.000
	4	-0.336	-0.087	78.061	0.000
	5	0.159	0.102	81.294	0.000
	6	0.426	0.062	104.57	0.000
	7	0.149	-0.216	107.46	0.000
	8	-0.333	-0.328	121.96	0.000
	9	-0.594	-0.421	168.48	0.000
	10	-0.228	-0.172	175.37	0.000
	11	0.340	-0.026	190.85	0.000
	12	0.792	0.474	275.80	0.000
	13	0.323	-0.081	290.10	0.000
	14	-0.190	0.101	295.09	0.000
	15	-0.520	0.010	332.76	0.000
	16	-0.297	0.011	345.15	0.000
	17	0.146	-0.091	348.16	0.000
	18	0.379	-0.118	368.75	0.000
	19	0.154	0.011	372.20	0.000
	20	-0.279	0.044	383.63	0.000
	21	-0.545	-0.024	427.60	0.000
	22	-0.193	0.062	433.16	0.000
	23	0.306	0.024	447.30	0.000
	24	0.670	0.098	515.72	0.000
	25	0.290	-0.048	528.66	0.000
	26	-0.163	0.005	532.80	0.000
	27	-0.449	0.039	564.54	0.000
	28	-0.260	0.021	575.31	0.000
	29	0.125	-0.004	577.81	0.000
	30	0.335	-0.016	596.12	0.000
	31	0.137	0.013	599.21	0.000
	32	-0.274	-0.072	611.69	0.000
	33	-0.467	0.064	648.45	0.000
	34	-0.178	-0.073	653.82	0.000
	35	0.258	-0.038	665.25	0.000
	36	0.601	0.121	728.20	0.000

As a seasonality is observed according to each of the four quarters of the year, as shown in Figures 3 and 4, it can be stated that the highest energy consumption in the residential sector are recorded between December and February, and the most low values of consumption are found in the monthly interval May - October.

Applying the ADF test for the original series gives a result of - 2.388363, having an absolute value lower than the critical values specific to the usual significance levels. This result leads to the definition of the time series, with a probability of 14.74%, as a non-stationary series, with at least one unit root.

Table 3. ADF test for the original time series

Null Hypothesis: TOTAL_ENERGY_CONSUMED_BY has a unit root
Exogenous: Constant
Lag Length: 12 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.388363	0.1474
Test critical values:	1% level	-3.491928	
	5% level	-2.888411	
	10% level	-2.581176	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TOTAL_ENERGY_CONSUMED_BY)
Method: Least Squares
Date: 05/17/20 Time: 16:51
Sample (adjusted): 2011M02 2020M01
Included observations: 108 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TOTAL_ENERGY_CONSUMED_BY(-1)	-0.504694	0.211314	-2.388363	0.0189
D(TOTAL_ENERGY_CONSUMED_BY(-...	0.044186	0.216116	0.204455	0.8384
D(TOTAL_ENERGY_CONSUMED_BY(-...	0.007556	0.206550	0.036581	0.9709
D(TOTAL_ENERGY_CONSUMED_BY(-...	0.006224	0.191618	0.032479	0.9742
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.110366	0.172268	-0.640665	0.5233
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.160068	0.159585	-1.003028	0.3184
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.142261	0.148515	-0.957892	0.3406
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.178522	0.136068	-1.312005	0.1927
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.178078	0.123278	-1.444521	0.1519
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.389180	0.108184	-3.597375	0.0005
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.285968	0.107368	-2.663450	0.0091
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.216315	0.098807	-2.189263	0.0311
D(TOTAL_ENERGY_CONSUMED_BY(-...	0.413282	0.092672	4.459627	0.0000
C	870.6592	367.0106	2.372300	0.0197

R-squared	0.865483	Mean dependent var	-4.188954
Adjusted R-squared	0.846880	S.D. dependent var	326.5238
S.E. of regression	127.7707	Akaike info criterion	12.65877
Sum squared resid	1534584.	Schwarz criterion	13.00646
Log likelihood	-669.5738	Hannan-Quinn criter.	12.79975
F-statistic	46.52283	Durbin-Watson stat	2.046951
Prob(F-statistic)	0.000000		

In order to obtain stationaryization, a differentiation operation was performed (table 4) and the results were improved.

Table 4. ADF test for differentiated time series

Null Hypothesis: D(TOTAL_ENERGY_CONSUMED_BY) has a unit root
Exogenous: Constant
Lag Length: 11 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.134766	0.0000
Test critical values:	1% level	-3.491928	
	5% level	-2.888411	
	10% level	-2.581176	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TOTAL_ENERGY_CONSUMED_BY,2)
Method: Least Squares
Date: 05/17/20 Time: 16:53
Sample (adjusted): 2011M02 2020M01
Included observations: 108 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(TOTAL_ENERGY_CONSUMED_BY(-...	-5.125982	0.998289	-5.134766	0.0000
D(TOTAL_ENERGY_CONSUMED_BY(-...	3.704638	0.921467	4.020371	0.0001
D(TOTAL_ENERGY_CONSUMED_BY(-...	3.277222	0.836296	3.918737	0.0002
D(TOTAL_ENERGY_CONSUMED_BY(-...	2.890239	0.750027	3.853511	0.0002
D(TOTAL_ENERGY_CONSUMED_BY(-...	2.430829	0.672166	3.616411	0.0005
D(TOTAL_ENERGY_CONSUMED_BY(-...	1.964038	0.590683	3.325027	0.0013
D(TOTAL_ENERGY_CONSUMED_BY(-...	1.556156	0.504672	3.083498	0.0027
D(TOTAL_ENERGY_CONSUMED_BY(-...	1.152240	0.418255	2.754878	0.0070
D(TOTAL_ENERGY_CONSUMED_BY(-...	0.791175	0.333154	2.374805	0.0196
D(TOTAL_ENERGY_CONSUMED_BY(-...	0.260332	0.255709	1.018080	0.3112
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.119962	0.171832	-0.698138	0.4868
D(TOTAL_ENERGY_CONSUMED_BY(-...	-0.392077	0.094502	-4.148871	0.0001
C	-5.402643	12.60693	-0.428546	0.6692

R-squared	0.894329	Mean dependent var	-1.106083
Adjusted R-squared	0.880981	S.D. dependent var	379.4176
S.E. of regression	130.8960	Akaike info criterion	12.69917
Sum squared resid	1627708.	Schwarz criterion	13.02202
Log likelihood	-672.7552	Hannan-Quinn criter.	12.83007
F-statistic	67.00106	Durbin-Watson stat	2.000740
Prob(F-statistic)	0.000000		

The ADF test performed on the differentiated series is -5.134766, having a value higher than the critical values (1% = -3.491328, 5% = -2.888411, 10% = -2.581176), and the value p-value index is 0, which indicates the stationaryity of the energy value series and the lack of a unit root.

Identification, estimation and testing of an ARIMA type process

ARIMA (p, d, q) is a process defined by three components, as follows: p - the value of the order of the autoregressive model, d - the degree of differentiation, q - the order of the moving average in the model.

The analysis of the correlation program shows the values of the self-correlation function that change exponentially, both with positive and negative values. Lags 1,2,3 associated with it (0.347, -0.409, -0.436), as well as those associated with the moving average function (0.347, -0.239, -0.579), applied to a differentiated series of degree I, suggest an ARIMA model (1 , 1, 2).

Given lags 1 and 2 that have approximate values for both components, 4 combined models were tested, AR (1), AR (2), MA (1), MA (2), and following the probability of the models was chosen the final model. The criteria calculated based on the variance of the error dispersions, Akaike and Schwartz, are also analyzed, and their values are close from one model to another (table 5).

Table 5. Testing combinations for the ARIMA model

Dependent Variable: TOTAL_ENERGY_DIF1
Method: Least Squares
Date: 05/17/20 Time: 18:50
Sample (adjusted): 2010M03 2020M01
Included observations: 119 after adjustments
Convergence achieved after 22 iterations
MA Backcast: 2010M01 2010M02

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.794787	24.29720	0.115025	0.9086
AR(1)	0.268611	0.088444	3.037077	0.0030
MA(2)	-0.359020	0.087066	-4.123523	0.0001

R-squared	0.204864	Mean dependent var	-0.252706
Adjusted R-squared	0.191155	S.D. dependent var	332.5523
S.E. of regression	299.0836	Akaike info criterion	14.26421
Sum squared resid	10376316	Schwarz criterion	14.33427
Log likelihood	-845.7205	Hannan-Quinn criter.	14.29266
F-statistic	14.94350	Durbin-Watson stat	1.947257
Prob(F-statistic)	0.000002		

Inverted AR Roots	.27	
Inverted MA Roots	.60	-.60

The statistical model must be tested according to the significance of the parameters, and the hypotheses are accepted according to the value other than 0 of the parameters. Residues with values close to 0 constitute white noise, a constant dispersion and normal distribution. In this sense, the Jarque-Bera test is applied which verifies the normality of the errors, being an asymptotic test, following a chi-square distribution, with 2 degrees of freedom and with the following calculation formula:

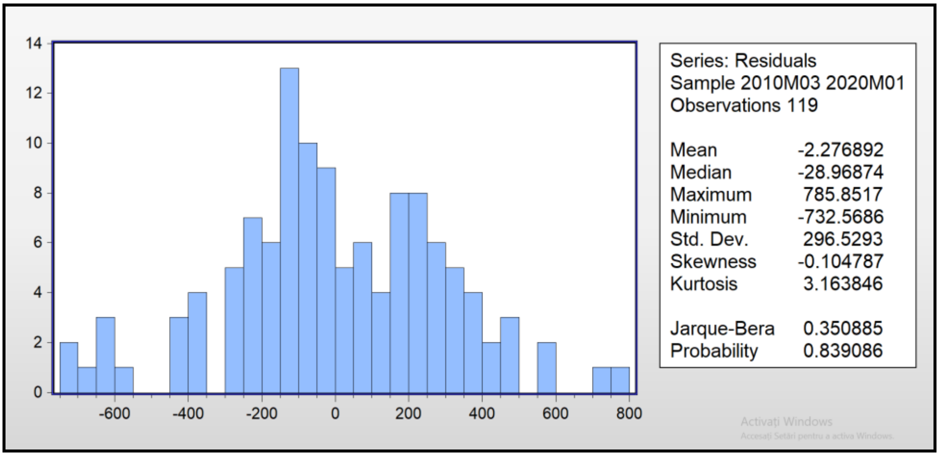
$$JB = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right] \sim \chi^2_{\alpha;2} \quad (1)$$

The Jarque Bera test considers the normal distribution hypothesis, which has an asymmetry coefficient with value 0 (S = 0) and a flattening coefficient close to the value K = 3.

If the probability of the test has a low value, then the error normality hypothesis is rejected, and in case of a higher value, the error normality hypothesis can be accepted..

Given that the probability is equal to 0.839086 (83%) and exceeds the significance threshold of 0.05, and the test statistic has a value of 0.350885, less than $\chi^2_{0,05;2} = 5,9915$ the hypothesis that errors are normally distributed is accepted. In order to be able to use the economic vision model, residues must be corrected (figure 7).

Figure 7. Histogram of normality of errors corrected for the time series of energy values



Analyzing the value of the asymmetry coefficient, Skewness, -0.104787 which is close to 0 and the value of the Kurtosis flattening coefficient is 3.163846, a value greater than 3, indicating a leptokurtic distribution. The possibility of an extreme event being higher compared to the appearance of a perfectly normal distribution. The null hypothesis can be accepted because it indicates the normal distribution of errors.

To test the heteroskedasticity of errors, the White test is used. As can be seen in Table 6, all the probabilities obtained have values higher than 0.05 (significance threshold), and the null hypothesis can be accepted, because it represents the typology of homoskedastic errors and a constant dispersion.

Table 6. White test for ARIMA (1,1,2)

Heteroskedasticity Test: White

F-statistic	0.989152	Prob. F(3,115)	0.4006
Obs*R-squared	2.993429	Prob. Chi-Square(3)	0.3926
Scaled explained SS	3.081993	Prob. Chi-Square(3)	0.3792

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 05/17/20 Time: 20:27
Sample: 2010M03 2020M01
Included observations: 119

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	81533.11	113411.8	0.718912	0.4737
GRADF_01^2	21026.26	88138.67	0.238559	0.8119
GRADF_02^2	-0.104127	0.084399	-1.233758	0.2198
GRADF_03^2	-0.110820	0.083798	-1.322474	0.1886

R-squared	0.025155	Mean dependent var	87195.93
Adjusted R-squared	-0.000276	S.D. dependent var	128903.3
S.E. of regression	128921.1	Akaike info criterion	26.40482
Sum squared resid	1.91E+12	Schwarz criterion	26.49824
Log likelihood	-1567.087	Hannan-Quinn criter.	26.44276
F-statistic	0.989152	Durbin-Watson stat	2.047659
Prob(F-statistic)	0.400579		

Energy consumption prediction

The Oracle Crystal Ball program is used to predict the next 24-month time series of energy consumption. Following the analysis of the series in eviews, it was established the compatibility of this to make a prediction. Because a seasonal component has also been identified, methods specific to seasonal data series are used. The result obtained in Crystal Ball is presented in table 7.

Table 7. Comparison of seasonally specific data methods in Oracle Crystal Ball

Methods	Rank	RMSE	MAD	MAPE	Theil's U	Durbin-Watson	Transformation Lambda	**BIC**	AIC	AICc	Alpha	Beta	Gamma	Phi
Damped Trend Seasonal Additive	6	125,10	93,06	5,37%	0,40	1,79					0,5085	0,0010	0,6853	0,0010
Damped Trend Seasonal Multiplicative	2	117,05	87,35	5,03%	0,37	1,94					0,5049	0,0010	0,6708	0,0010
Holt-Winters' Additive	7	125,16	93,11	5,37%	0,40	1,79					0,5088	0,0010	0,6856	
Holt-Winters' Multiplicative	3	117,07	87,37	5,03%	0,37	1,94					0,5048	0,0010	0,6704	
SARIMA(1,0,0)(1,0,0)	4	124,84	87,43	5,01%	0,37	2,01	1,00	9,77	9,70	9,71				
Seasonal Additive	5	125,10	93,06	5,37%	0,40	1,79					0,5085		0,6853	
Seasonal Multiplicative	**1**	**117,05**	**87,35**	**5,03%**	**0,37**	**1,94**					**0,5049**		**0,6708**	

The program has the ability to calculate several possible tests for the introduced series, and will choose the most convenient results from a statistical point of view.

It is noticed that the best RMSE and U Thell values are obtained for Damped Trend Sesonal Multiplicative and Seasonal Multiplicative. The program classifies Seasonal Multiplicative as the best prediction method and therefore it is applied (Table 8).

Table 8. The result of the prediction in Oracle Crystal Ball

Forecast results:

Period	Lower: 2,5%	Forecast	Upper: 97,5%
121	2.350,04	2.579,45	2.808,87
122	1.820,22	2.082,03	2.343,84
123	1.673,59	1.949,03	2.224,48
124	1.121,10	1.427,22	1.733,35
125	1.050,98	1.368,76	1.686,53
126	1.195,46	1.510,77	1.826,07
127	1.482,24	1.798,80	2.115,37
128	1.421,55	1.733,50	2.045,46
129	1.181,11	1.493,72	1.806,32
130	1.108,30	1.412,09	1.715,88
131	1.440,66	1.746,64	2.052,62
132	1.877,90	2.190,78	2.503,65
133	2.272,94	2.579,45	2.885,96
134	1.789,63	2.082,03	2.374,42
135	1.664,70	1.949,03	2.233,36
136	1.152,05	1.427,22	1.702,40
137	1.094,92	1.368,76	1.642,59
138	1.229,12	1.510,77	1.792,41
139	1.500,15	1.798,80	2.097,46
140	1.400,58	1.733,50	2.066,43
141	1.129,35	1.493,72	1.858,08
142	1.034,33	1.412,09	1.789,85
143	1.359,59	1.746,64	2.133,68
144	1.803,07	2.190,78	2.578,48

The data set consisted of 10 years in the form of monthly values and was scheduled to generate a forecast for the next 24 months. The program predicted both point forecasts and minimum and maximum limits (figure 8).

Figure 8. The chart of the forecast obtained in Oracle Crystal Ball

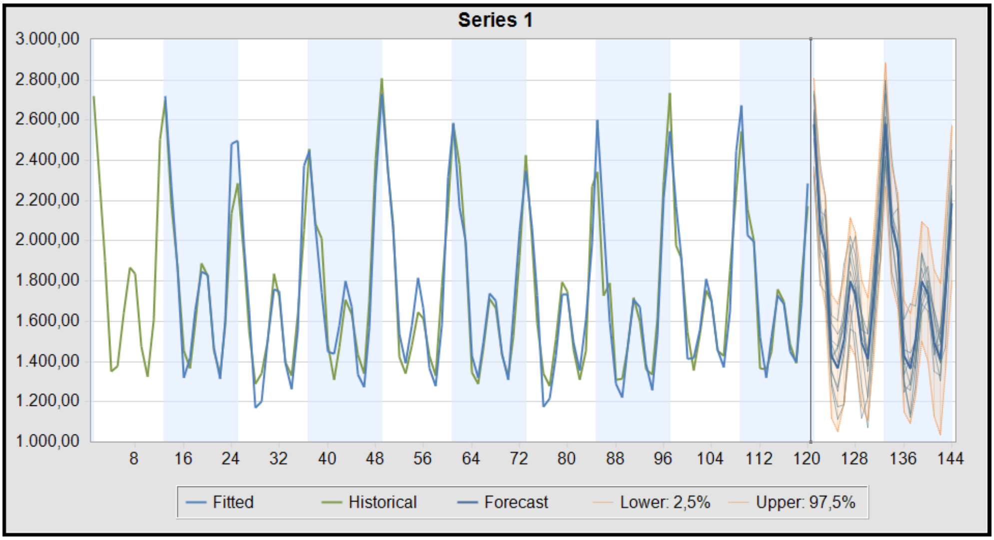


Figure 8 shows the movement of the original (historical) series, the movement of the adjusted series and the prediction of the next 24 values together with other possible movements framed between the upper and lower limits for each point.

Differences and expectations

By analyzing the total energy consumption in the US residential sector, several aspects are identified through which the impact of the health crisis caused by the COVID-19 virus can be analyzed.

Including in the analysis the data of primary energy consumption, a number of relevant conclusions can be drawn. Compared to the beginning of the previous year, there was a decrease of 11.7% for total energy consumption in the residential sector, while primary consumption decreased by 13.8%. In 2019, primary consumption represents 47.3% of total consumption, while in 2020, it represents 46.2%.

Also, the forecast indicated 2579.45, a possible value between 2350 and 2808, and the actual value recorded was less than the possible lower threshold calculated in Crystal Ball.

In other words, the emergence of the pandemic has negatively affected energy consumption, if we refer to the development of the economy, but it can also be seen as a positive effect when it comes to pollution caused by energy processes.

With all the above, we are sure that next year, the implication of the rebound effect will be felt, as more strategies will be set in motion to recover the unrealized activity during the pandemic and to get the economy back on its feet. The effect of the economic setback will be manifested by increased energy consumption in all sectors and by increased pollution indices, due to aggressive recovery activities.

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