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Methodological Approaches to Electricity Consumption Forecast on Electric Cars

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Abstract: ***The paper describes methodological approaches to electricity consumption of electric vehicles in Moldova based on real data for 3 years using 2 forecasting methods. The linear trend has a more pessimistic growth, while the regression trend has slightly higher values and optimistic growth. The discrepancy between the predicted values by the two methods was 5.1%.***

Keywords: Forecast, electric cars, methods, value

1. Introduction

The number of electric vehicles is gradually growing. The network of charging stations is also expanding, and the use of electricity in vehicles is constantly increasing [1]. For example, in 11 months of 2021, the number of charging station customers increased to 2227. The number of charging sessions and the number of charging hours also increases every next month.

The total number of cars in the country reaches more than 1 million units [2], Table 1.

Table 1: Vehicle categories

	on 1.07.2022	on 1.05. 2023	on 1.06. 2024
Vehicle	number	number	number
Car	731 332	755 929	809 461
Truck	207 269	211 369	217 938
Trailer	68 517	72 092	76 717
Tractor	57 162	59 603	62 821
Motorcycle	53 374	56 221	62 032
Bus	21 073	21 075	21 189
Semitrailer	12 488	12 008	11 535
Other	0	0	0
Total	1 151 215	1 188 297	1 261 693

*) public services agency www.date.gov.md

The number of electric vehicles is still small (for 2021 - less than 1000 and hybrid cars - about 30 000 units, there is no data for other years), but their number is growing every year.

In this regard forecasting the growth of electricity consumption by electric vehicles and what GHG emissions can take place in this case, is relevant, Figure 1.

The *goal* of this work is to build forecasts of electricity consumption by electric vehicles for 5 and 20 years ahead based on the available data for three years using available forecasting methods, to compare the values obtained and to make a choice of method for further use.

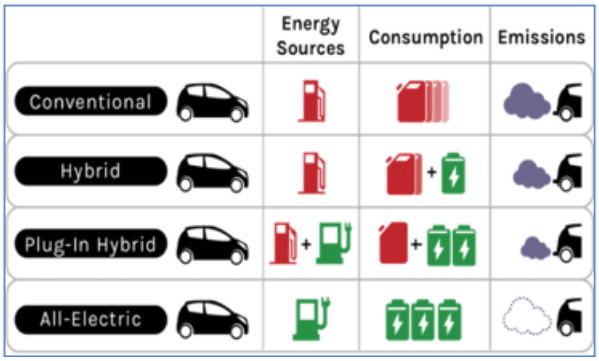

Figure 1: Emissions from electric vehicles compared to other types of vehicles

2. Calculations of forecasts for horizon 5 years

The primary data series includes 36 points -electricity consumption by electric cars during three years, table 2 and figure 2.

Table 2: Electricity consumption at charging stations during months 2021-2023 and numbers of points

Number of point	1	2	3	4	5	6	7	8	9	10	11	12
kWh, 2021	8219	9810	12895	13294	12406	13217	16298	15004	17564	17928	18920	19994
Number of point	13	14	15	16	17	18	19	20	21	22	23	24
kWh, 2022	12361	14754	19394	19994	18659	19878	24512	22566	26416	26964	28456	30071
Number of point	25	26	27	28	29	30	31	32	33	34	35	36
kWh, 2023	16551	19755	25967	26771	24982	26616	32820	30214	35369	36102	38100	40262

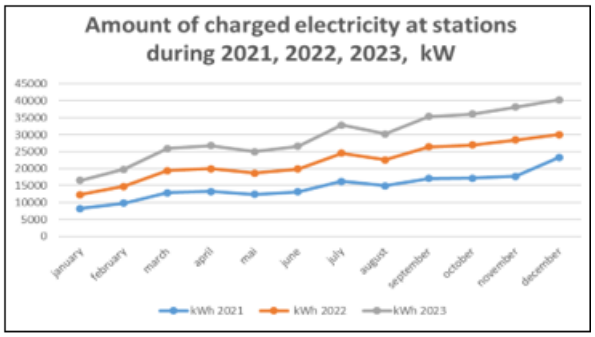

Figure 2: Primary data of electricity consumption by electric cars for 3 years

Forecasts are based on 2 methods available in Excel - linear trend and regression (Analysis Package).
The linear trend has the equation y = 711.89x + 8860.2 with R2 = 0.8254, figure 3.

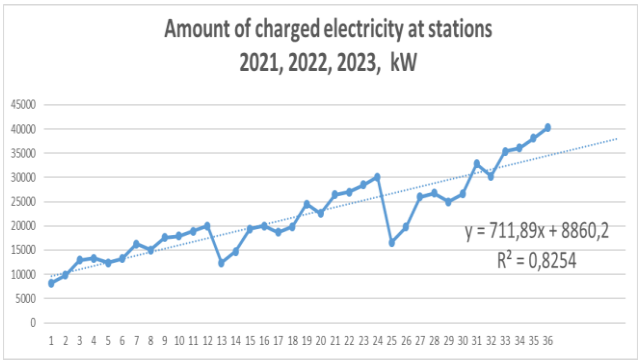

Figure 3: Forecast (linear trend) of the amount of charged electricity

Line Regression is built also and shown in figure 4.

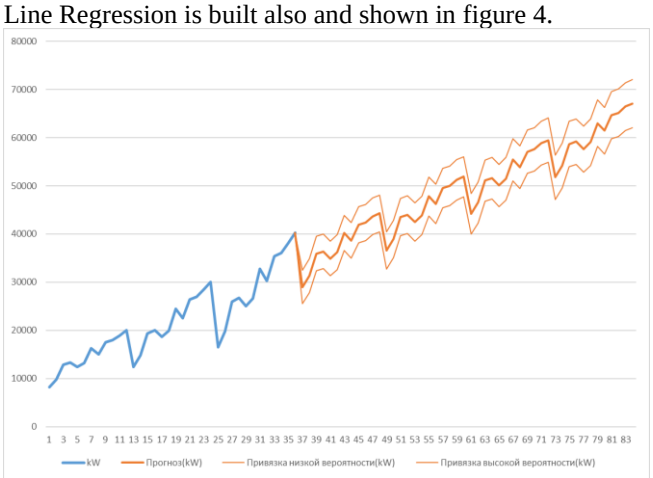

Figure 4: Forecast (regression) of the amount of charged electricity at stations (kWh)

The values of the forecast points for the linear trend are calculated using the obtained equation and are given in table 3, column "Linear trend", and the regression values are given in the column "Linear regression".

Also, in the table is shown the lower and upper boundaries and % of deviation of the values for each point, Figure 3.

Table 3: Forecast electricity consumption on 2 methods- line trend and line regression

Forecast electricity consumption, kWh									
			Line trend	Line regression		Lower Boundary		Upper Boundary	
1	2024	37	35200	29008	*17,6*	25510	*27,5*	32507	*7,7*
2		38	35912	31400	*12,6*	27874	*22,4*	34927	*2,7*
3		39	36624	35932	*1,9*	32377	*11,6*	39487	*-7,8*
4		40	37336	36408	*2,5*	32824	*12,1*	39992	*-7,1*
5		41	38048	34906	*8,3*	31294	*17,8*	38519	*-1,2*
6		42	38760	36291	*6,4*	32649	*15,8*	39932	*-3,0*
7		43	39471	40232	*-1,9*	36562	*7,4*	43903	*-11,2*
8		44	40183	38676	*3,8*	34976	*13,0*	42376	*-5,5*
9		45	40895	41915	*-2,5*	38185	*6,6*	45644	*-11,6*
10		46	41607	42398	*-1,9*	38639	*7,1*	46158	*-10,9*
11		47	42319	43678	*-3,2*	39889	*5,7*	47467	*-12,2*
12		48	43031	44296	*-2,9*	40476	*5,9*	48115	*-11,8*
1	2025	49	43743	36597	*16,3*	32747	*25,1*	40447	*7,5*
2		50	44455	38989	*12,3*	35108	*21,0*	42870	*3,6*
3		51	45167	43521	*3,6*	39609	*12,3*	47432	*-5,0*
4		52	45878	43997	*4,1*	40054	*12,7*	47939	*-4,5*
5		53	46590	42495	*8,8*	38521	*17,3*	46469	*0,3*
6		54	47302	43879	*7,2*	39874	*15,7*	47885	*-1,2*
7		55	48014	47821	*0,4*	43784	*8,8*	51858	*-8,0*
8		56	48726	46265	*5,1*	42196	*13,4*	50333	*-3,3*
9		57	49438	49504	*-0,1*	45403	*8,2*	53604	*-8,4*
10		58	50150	49987	*0,3*	45855	*8,6*	54120	*-7,9*
11		59	50862	51267	*-0,8*	47102	*7,4*	55432	*-9,0*
12		60	51574	51884	*-0,6*	47687	*7,5*	56082	*-8,7*
1	2026	61	52285	44186	*15,5*	39955	*23,6*	48416	*7,4*
2		62	52997	46578	*12,1*	42315	*20,2*	50841	*4,1*
3		63	53709	51109	*4,8*	46813	*12,8*	55406	*-3,2*
4		64	54421	51586	*5,2*	47256	*13,2*	55915	*-2,7*
5		65	55133	50084	*9,2*	45721	*17,1*	54447	*1,2*
6		66	55845	51468	*7,8*	47072	*15,7*	55865	*0,0*
7		67	56557	55410	*2,0*	50979	*9,9*	59840	*-5,8*
8		68	57269	53853	*6,0*	49389	*13,8*	58318	*-1,8*
9		69	57981	57092	*1,5*	52594	*9,3*	61591	*-6,2*
10		70	58693	57576	*1,9*	53043	*9,6*	62109	*-5,8*
11		71	59404	58856	*0,9*	54289	*8,6*	63423	*-6,8*
12		72	60116	59473	*1,1*	54871	*8,7*	64075	*-6,6*
1	2027	73	60828	51775	*14,9*	47138	*22,5*	56412	*7,3*
2		74	61540	54167	*12,0*	49495	*19,6*	58839	*4,4*
3		75	62252	58698	*5,7*	53991	*13,3*	63405	*-1,9*
4		76	62964	59174	*6,0*	54432	*13,6*	63916	*-1,5*
5		77	63676	57673	*9,4*	52895	*16,9*	62450	*1,9*
6		78	64388	59057	*8,3*	54244	*15,8*	63870	*0,8*
7		79	65100	62999	*3,2*	58150	*10,7*	67848	*-4,2*
8		80	65811	61442	*6,6*	56557	*14,1*	66327	*-0,8*
9		81	66523	64681	*2,8*	59760	*10,2*	69602	*-4,6*
10		82	67235	65165	*3,1*	60208	*10,5*	70122	*-4,3*
11		83	67947	66445	*2,2*	61451	*9,6*	71438	*-5,1*
		Distinctions	Linear trend	linear regression	*5,1%*	AVERAGE	*13,4%*	*Average*	*-3,2%*

The average value of the discrepancies is 5.1% for main values.

The figure shows a graphical visualization of the predicted values for both approaches, and it can be seen that the regression trend also reflects the nonlinear fluctuations that occurred during the year. For calculations, it can be simply used a linear trend, since the total discrepancy of values is on average 5.1%. figure 25.

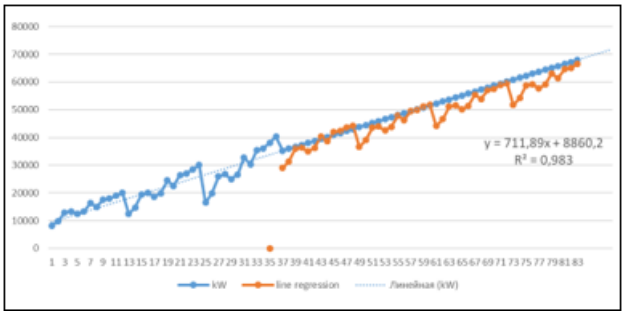

Figure 5: Comparative 2 Methods for Predicting the Amount of Electricity in Charging Stations (kWh)

Conclusion on forecasts

The linear trend has a more pessimistic growth, while the regression trend has slightly higher values and optimistic growth.

3. Assessment electricity consumption by electric cars for the next 20 years

The time series that was used for 5-year forecasts is not sufficient for 20-year forecasts. For our task, we can simply calculate based on the average % growth in electricity consumption per month.

The percentage changes for each month of 2021 compared to the previous month are shown in the table 4. This is the only available series of values at the moment, but this data can be used to calculate the average increase for each month.

The average increase for each month is 0.61%, which can give 7.3% for one year and 146.3% for 20 years (with the same initial data). Thus, consumption in 2043 may amount to 517 345 kWh.

Table 4: Calculation of electricity consumption for the next 20 years

	2021	2022	2023	2024	2043
	Fact	Fact	Fact	Growth in one year	Growth in 20 years
%				7,3	146,3
kWh	175 549	264 026	353 509	379 377	517 345

4. Estimation of greenhouse gas emissions using the CO_2 emission factor per kWh

Greenhouse Gas Emissions are calculated by multiplying the electricity consumed during the reporting year by appropriate emission factors, using formula:

Emissions=Electricity*EF
Where:
Emissions= mass of CO_2 emitted
Electricity = the amount of electricity consumed
EF = CO_2 emission factor per kWh

According to statistical data, the average CO_2 emission factor per kWh (generation) in the world decreased from 0.636 (1998) to 0.407 (2023) and average CO_2 emission factor per kWh (consumption) decreased from 0.727 (1998) to 0.447 (2023) [5], fig.6-7.

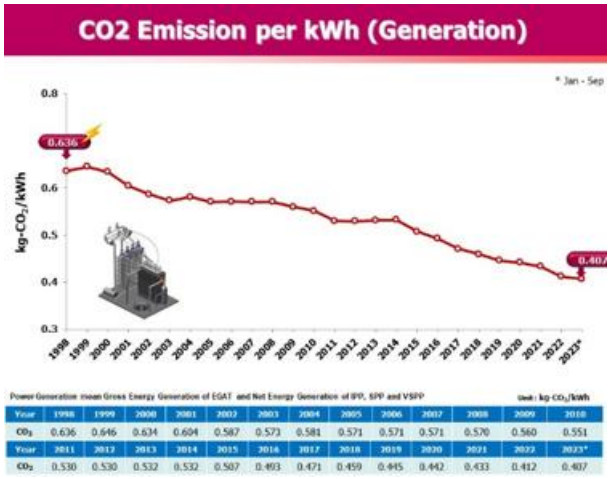

Figure 6: CO_2 emission factor per kWh (generation), during the period 1998-2023

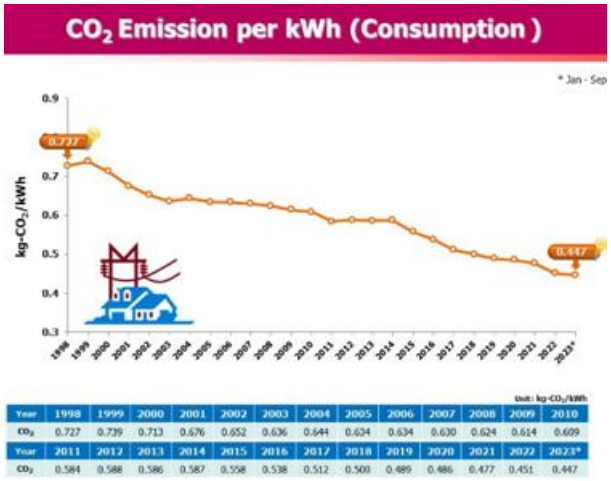

Figure 7: CO_2 emission factor per kWh (consumption), during the period 1998-2023
Source: CO2 Statistic (eppo.go.th)

When selecting emission factor, it is important to consider import and export of electricity at a country level for calculation. There is a Methodological Approach for the Common Default Grid Emission Factor Dataset (https://unfccc.int/sites/default/files/resource/IFITWG_Methodological_approach_to_common_dataset.pdf) [3] and Emission factors 2023 database documentation (https://iea.blob.core.windows.net/assets/bf862218-7fd8-4637-aca6-5a347b6ca4f1/IEA_Methodology_Emission_Factors_2023.pdf) [4] where it is described how to calculate grid Emission factor.

In this work it was decided to use the default grid emission factor (541 gCO_2/kWh) available at https://unfccc.int/documents/437880 [3], separately for Republic of Moldova.

Emissions from the electricity consumed by electric cars for the next 20 years are presented in table 5.

Table 5: Calculated GHG Emissions from electricity consumed by electric cars for the next 20 years

	2021	2022	2023	2024	2043
tonn CO_2	95.0	142.8	191.2	205.2	279.9

It should be noted that the latest official national grid emission factor for the Republic of Moldova, which was

used in the CDM project, was calculated in 2020 and amounted to 547 gCO_2/kWh.

5. The Way Forward

In order to increase the number of electric vehicles in the Republic of Moldova and to minimize the cost of charging electric vehicles, as well as to equalize the maximum load caused by charging electric vehicles during peak hours, it is proposed to analyze for the future installation of photovoltaic panels for electric vehicle charging stations.

Figure 7: Design of charging stations for electric vehicles (using PVS panel)

6. Conclusions

An analysis was conducted using two methods - linear trend and linear regression for real values of electricity consumption by electric vehicles in Moldova.

The time series consisted of 36 points (36 months), the forecast was built for 5 years.

The linear trend has a more pessimistic growth, while the regression trend has slightly higher values and optimistic growth.

The discrepancy between the predicted values by the two methods was 5.1%.

Emissions from electricity consumed by electric cars in 2043 will amount to 279.9 tons of CO_2.

References

[1] https://cned.gov.md/
[2] www.date.gov.md
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[5] https://gd.eppo.int/

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