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TOWARDS CIRCULAR ECONOMY IN POLAND: CONSUMPTION AND WASTE

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Abstract

Purpose - According to the assumptions of the circular economy, consumption consists in satisfying basic human needs in connection with limited waste existence. Therefore, for the article a research question was constructed: Have we got sustainable consumption in Poland after 2015? The thesis of the paper is: The method of waste storage used for many years in Poland (or the one based on the incineration of waste without recovery) is no longer preferred.
Methodology - The Authors used data available in the Statistical Yearbooks of the Republic of Poland from 2005-2023, published by the Central Statistical Office. All analyses in the paper were based on self-constructed linear models. Such action serves to enrich the knowledge available in this area and to determine the trend.
Findings - According to the assumptions of the circular economy, without the implementation of a proper system of collection, segregation, processing and sale of secondary raw materials, as well as new legal regulations, there will be no reduction in the amount of landfilled waste and sustainable consumption. The models were shown which variables mainly determined consumption in individual areas, and how trends in municipal waste changed in the face of increased consumption.

Keywords: Circular economy, global consumption, waste production, econometric modeling
Klasyfikacja JEL: C10, Q5, Y1, R1, O5

Introduction

The actual global human population growth amounts, combined with the increasing consumption of resources, is creating a large amount of waste. Thus, an area is emerging in which the circular economy (CE) plays an important role. It should be emphasized that the first step in the implementation of the assumptions of this concept should be preventive activities. It is about preventing the generation of unwanted waste. However, once they are created, the priority becomes their proper management and disposal. The choices of each consumer can support the

development of the circular economy, but on the other hand, they can effectively block it. Let's assume that as household incomes increased, the demand for food, housing, transport, clothing and energy increased for many years. Is this trend still observed? Model analysis will show the answer.

The authors decided to take a closer look at the indicated area from the polish perspective. However, being aware that waste is a negative externality of the consumption process, she divided the proper analysis into two parts. Firstly, consumption in Poland in two periods was presented (before and after the EU's regulations about circular economy). Then, in the second part, authors attempted to establish the relationship between the previously described household consumption and the negative effects of the consumption process. That part focused on generating municipal waste. Since no change occurs immediately, the authors will compare the period of consumption after 2005 to compare it with the years 2015-2023.

As was mentioned at the beginning, the aim of the discussion will be an attempt for finding an answer to the question: Is consumption in Poland after 2015 sustainable and consists, as the authors assumed, on satisfying basic human needs in connection with reduced waste generation?

The article describes the issue of consumption in relation to the circular economy in Poland (in Authors' point of view), including the issue of waste generation. Empirical research was conducted for two periods, until and after 2014. Based on the analysis, a forecast was also made until 2030 to the direction of changes observation.

The article has been divided into two parts. The first part refers to the area of consumption in Poland, where wastes are generated. The research covers the consumption of households analyzed by objective, according to the classification: COICOP. In the second part, consumption was bound up with the negative effects of the consumption process, which include the production of municipal waste.

1. Literature Review

Transitioning towards a circular economy requires holistic consideration encompassing environmental, economic, and social dimensions (Coskun, Hofgärtner, Metta, Schmidt & Tsolakis, 2024). It takes inspiration from the 'waste not' functioning of the ecosystem to propose more resource efficient production and consumption patterns (Cullen & De Angelis 2021). The circular economy operates at three levels: micro, meso, and macro. The circular economy aims to achieve sustainable development, thus simultaneously creating environmental and social quality and economic wealth for both current and future generations (Jakubelskas & Skvarciany, 2022, p. 196). A circular economy (CE) can be defined as an economic model aimed at the efficient use of resources through waste minimization, long-term value retention, reduction of primary resources, and closed loops of products, product parts, and materials within the boundaries of environmental protection and socioeconomic benefits (Morseletto, 2020).

The circular economy was applied to place the model on the circularity readiness spectrum and to establish the connection between historical sustainability efforts and the current Circular economy framework, like Konash and Nasr said (2022). The European Commission published "Closing the loop - An EU action plan for the Circular Economy", at the end of 2015. As a set of proposals for action in the EU for the coming years to contribute to a change in the economic development model, the plan includes several priority areas, such as plastics, food waste, critical raw materials, demolition and construction waste, and biomass and biomass products. Due to the fact that the economies of the EU Member States differ from each other, there is no single appropriate model for the transition towards a circular economy. Each economy therefore adopts its own set of actions to pursue the common goal of "closing the loop" (The Roadmap,

2019). Key CE strategies include green design, remanufacturing, recycling, and reuse (Makov & Font Vivanco, 2018).

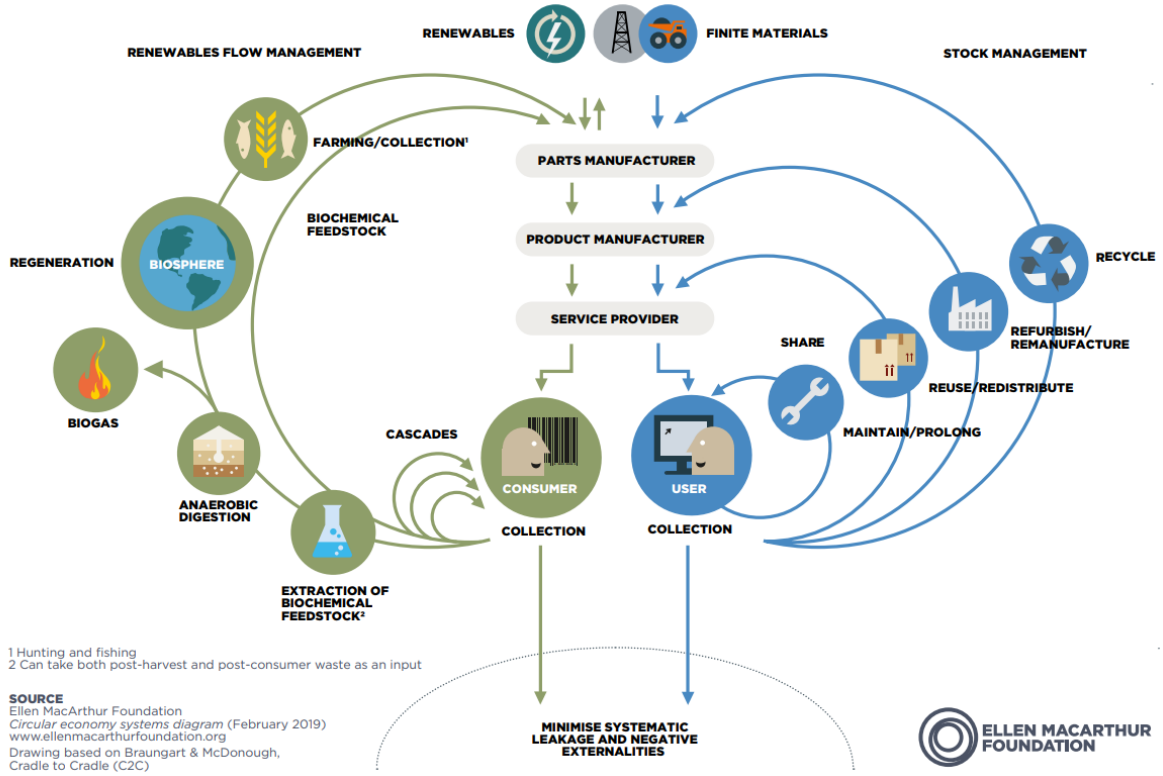


Figure 1. „Butterfly diagram" visualizing the circular economy in a first version
Źródło: https://emf.thirdlight.com/link/7kvazph93afk-owveai/@/preview/1?o (23.10.2025)

The well known diagram shows (Figure 1) that, smaller inner loops are surrounded by larger outer loops. These inner loops are where you can capture the most value because they retain more of the product's built-in value by holding it together. If once purchased goods are functional for a long time, they are worth more than the sum of their parts. This is because the time and energy put into theirs execution are not wasted. Therefore, internal loops such as sharing, maintenance, and reuse should be prioritized over external loops where the product is broken down and reprocessed. These loops also represent lower costs for customers, as they use products and materials already in circulation instead of investing in new ones. On the right side of the butterfly chart is the technical cycle, relevant to products that are used rather than consumed (The technical, 2022).

Using that point of view, we can draw confirms the principle that "In a properly built circular economy, one should rather focus on avoiding the recycling stage at all costs. It may sound straightforward, but preventing waste from being created in the first place is the only realistic strategy" (Recycling, 2021).

The indicated Economy is (analyzing through the prism of waste) an Economy aimed at increasing the durability of items intended for sharing or reuse (Awan, Gölgeci, Makhmadshoev & Mishra, 2022). It is about the intensive use of goods, which may mean designing products in such a way that they can be easily repaired. They should also be treated as modular, during design so that components can be replaced and regenerated. We can also focus on designing products with materials that can be easily separated for recycling. It's also important to design with multiple loops in mind, such as making a repairable product from recyclable materials (The technical, 2022).

An universally accepted definition of circular economy doesn't exist, as J. Kirchherr, D. Reike and M. Hekkert (2017) pointed out. The authors identified and analyzed 144 definitions of circular economy. All of them have in common the main goal of the circular economy, which is considered to be economic prosperity, followed by the quality of the environment. Some of the available definitions also refer to its impact on social justice and future generations. Starting from this point of view, the authors will analyze only those aspects that affect these analytical elements.

For further considerations, it is important to recall estimates from 2019, which show that 20% of total food production was wasted in the EU at that time, while 43 million people could not afford a nutritious meal every other day. Households generate more than half of the EU's food waste – 70% of food waste is generated in households, the catering sector and retail (Reflection Paper 2019, p. 54).

2. Data, methodology and empirical results

2.1. Individual Consumption by Purpose

According to the linguistic nomenclature used by the Central Statistical Office (the author of the statistic data) total consumption is the value of products (goods and services) used for satisfying human needs of the population and includes: private consumption expenditure, i.e. consumption expenditure in the household sector – individual consumption (from personal income) and consumption in the sector of non-profit institutions serving households sector (concerning goods and services provided to households as social transfers) and public consumption expenditure in the general government sector, i.e. individual consumption expenditure (concerning goods and services supplied to households as social transfers in kind) and collective social consumption. Overall household consumption is the sum of private consumption and government private consumption. Households' final consumption expenditure as well as actual individual consumption are presented according to the Classification of Individual Consumption by Purpose (COICOP).

After a preliminary analysis of all available statistical data (Nowak, 2022, pp.11-35), 14 variables were selected for the first part of the analysis, treated in that part as explanatory variables: x_1 – Total average monthly available income in households (in PLN), x_2 – Total average monthly available income in households per capita (in PLN), x_3 – Households' number included in the survey: total amount (in persons), x_4 - Average monthly available income in households per capita (in PLN), x_5 - Average monthly expenditures in households per capita for consumer goods and services (grand total) (in PLN), x_6 – Gross disposable income of the households (in million PLN), x_7 - Gross saving (in million PLN), x_8 - Average number of persons in households (in persons), x_9 - Average number of working persons in households: grand total (in persons), x_{10} - Average number of persons in households: dependents (in persons), x_{11} - Average number of persons in households maintained from non-earned sources: from social benefits (in persons), x_{12} - Average number of persons in households employed on private farm in agriculture (in persons), x_{13} - Nominal income of the households sector: social benefits in grand total (in million PLN), x_{14} – Total average monthly gross wages and salaries (in PLN).

For all models presented in Table 2, the established parameters have been verified. The coefficients calculated, including: the coefficient of determination (R^2), random variability (W_e) and the F-Snedecor test were used (the value of the test statistic F for the model and value F* were determined) (Jajuga, 1998). Tables 3 and 4 contain the mentioned coefficients and S_e, i.e. the standard deviation of the model residuals. For all linear models, the multiple correlation coefficient (R) was significant, which indicated a significant degree of model fit to the data

(Czerwiński, 1969). All models shown in Table 2 are entered with calculated errors in parameter estimation.

Table 1. Explained variables for consumption according to the Classification of Individual Consumption by Purpose

	in million PLN												
Year	**Households' final consumption ex-**	**Food and non-alcoholic beverages**	**Alcoholic beverages, tabaco and**	**Clothing and footwear**	**Housing, water, electricity, gas**	**Furnishings, household equipment and rou-**	**Health**	**Transport**	**Communication**	**Recreation and culture**	**Education**	**Restaurants and hotels**	**Miscellaneous goods and ser-**
	Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**	**Y12**	**Y13**
2005	612521	129513	43825	28308	135643	26802	24648	53527	20711	47053	7664	17465	69882
2006	652827	136441	43048	29976	154287	28446	26137	55968	21649	47850	8419	19057	81549
2007	701556	144636	46507	29098	162663	30522	27973	62385	22723	52004	9039	20119	93887
2008	773822	156078	50991	31442	181464	33793	30557	72264	24415	58822	9247	21663	103086
2009	809737	162454	56313	31767	197831	35889	33521	74653	24542	62211	9759	23486	97311
2010	875065	167927	70286	35471	199507	38720	35693	96212	26107	67133	10767	24329	102913
2011	939713	173976	7366	38791	211528	41112	40918	107633	27028	72013	10980	25977	116151
2012	979353	179189	77651	42089	207676	44936	44348	113937	26339	77593	11164	28417	126014
2013	997838	179601	76275	44366	213805	45049	45850	118686	25717	75081	10803	30398	132207
2014	1018578	175621	70397	46935	220393	50003	48722	123494	25372	77882	10570	33369	135820
2015	1058512	184874	63895	51944	230868	50945	55632	141703	27135	71996	10916	40287	128317
2016	1073800	183200	62759	53315	227796	56312	60445	128464	25598	84961	10628	41455	138867
2017	1145245	191771	65488	59062	237292	60385	65897	138008	26163	91221	11404	50726	147828
2018	1220916	197536	72500	63576	245902	67629	70668	153371	27012	99851	12251	54228	156393
2019	1299483	227222	77171	70722	231906	67425	76600	187004	30950	87368	10893	63336	171560
2020	1318380	251761	86187	61489	273098	68893	86464	165694	33666	76144	10160	44794	160030
2021	1454876	274339	92780	69493	279631	73181	102425	197852	34882	88608	11462	57325	172898
2022	1772069	325143	104868	86969	360325	87728	116276	234207	33919	101619	13108	79054	228853
2023	1929504	359195	112016	86614	399552	90684	119797	248456	36250	118633	13715	93270	251322

Source: own elaboration based on GUS

Table 2. Models of household's consumption presented according to the Classification of Individual Consumption by Purpose (COICOP), for periods before and after EU's regulations, about CE with an sample interpretation

The value of products (goods and services) used the needs of the total population, according to Classification of Individual Consumption by Purpose (COICOP)	**Models for period before CE regulations**	**Models for period after CE regulations**
1. Total final consumption expenditure	$y_1 = 1{,}078x_6 - 91120{,}38$ (0,033) (102558,83)	$y_{1*} = 0{,}982x_6 - 35115{,}03$ (0,067) (97401,8)
According to the analysis of the available statistical data used to build the model, if for the period preceding the publication of the circular plan, the increase in gross disposable income increased by PLN 1 million on a national scale, it would result in an increase in total consumption by over PLN million. However, since 2015, with the same assumed increase in gross disposable income, the consumption shown in the model has increased more slowly, i.e. by PLN 982 thousand.		
2. Food and non-alcoholic beverage	$y_2 = 31{,}99x_1 + 61071{,}37$ (1,55) (4895,23)	$y_{2*} = 0{,}21x_6 - 53664{,}68$ (0,01) (13780,39)

The linear relationship which was developed, shows that the consumption of food and non-alcoholic beverages in the first analyzed period was depended on the average monthly disposable income of each household. Let's imagine that the increase in the average monthly disposable income per 1 household by one Polish zloty, resulted in an increase in the consumption of food and non-alcoholic beverages by nearly 32 million PLN. After 2015, it was gross disposable income that determined consumption in the same area. The model indicates that as a result of the increase in these revenues by 1 million PLN, consumption in the area of food and non-alcoholic beverages increases by PLN 210 thousand.		
3. Alcoholic beverages, tabaco and narcotics	$y_3 = 15{,}56x_{14} + 5796{,}22$ (1,48) (467,79)	$y_{3*} = 0{,}059x_6 - 1833{,}61$ (0,003) (433,42)
The model analysis showed that among the best correlated with the consumption of alcoholic beverages, tobacco products and drugs descriptive variables, was the one showing the total average monthly gross wages and salaries. The increase in the above-mentioned remuneration by one zloty in the years 2005-2014 resulted in an increase in the consumption of the indicated final goods by over PLN 15.5 million in Poland. In the following period, interest in this type of commodities increased. With increase in gross disposable income by 1 million PLN, consumption increased by PLN 59 thousand. Therefore, it can be concluded that the reason has non-income nature.		
4. Clothing and footwear	$y_4 = 0{,}046x_6 - 4058{,}21$ (0,0062) (5367,31)	$y_{4*} = 0{,}04x_6 + 11332{,}11$ (0,006) (8426,25)
In the area of clothing and footwear consumption, the increase in gross disposable income of the households by PLN 1 million, in accordance with the models, contributes to an increase in consumption in both periods by PLN 40.000. In the second period, the change in consumption is smaller about PLN 6.000 by each PLN 1 million increase in gross disposable income of the households.		
5. Housing, water, electricity, gas and other fuels	$y_5 = 50{,}42x_1 + 31718{,}93$ (2,54) (8003,93)	$y_{5*} = 47{,}871x_1 + 21016{,}78$ (5,71) (31160,6)
Consumption in the area of using a flat or house, together with energy carriers, is increasing in model terms, although the rate of this growth has decreased from period to period. In the first of the analyzed periods, when the average monthly disposable income in households per one household would have been increased by one zloty, consumption in accordance with the model increased by over PLN 50 million. With the same increase in income, consumption continues to increase in the following period, but by over PLN 2 million less.		
6. Furnishings, household equipment and routine maintenance of the house	$y_6 = 0{,}056x_6 - 10434{,}26$ (0,004) (3114,09)	$y_{6*} = 0{,}042x_6 - 9553{,}04$ (0,004) (5905,63)
Consumption in the area of furnishings, household equipment and routine maintenance of the house in both periods increased, but slower after CE regulations. If we assume that gross disposable income increases by PLN 1 million, then the increase in consumption in this area will be: PLN 56.000 (before 2015) and PLN 42.000 (in the second period).		
7. Health	$y_7 = 0{,}06x_6 - 17379{,}82$ (0,005) (4081,79)	$y_{7*} = 0{,}076x_6 - 24905{,}59$ (0,006) (9425,03)
In the model approach, consumption in the area of health in the first analyzed period increased slower than in the later period, which covered period of the Covid-19 pandemic. In the years 2005-2014, the consumption for each additional million zlotys in gross disposable income, increased by about PLN 60.000. Since 2015, the increase in consumption in the health area has already been more than PLN 16.000, with the same change in gross disposable income.		
8. Transport	$y_8 = 0{,}19x_6 - 78053{,}06$ (0,015) (13217,11)	$y_{8*} = 0{,}134x_6 - 14262{,}77$ (0,015) (21731,79)
Consumption related to the purchase of vehicles, the operation of personal transport vehicles, passenger transport services and transport services increased in both analyzed periods, respectively, along with the increase in gross disposable income. For higher gross disposable income by PLN 1 million the analyzed consumption increases by PLN 190.000 and PLN 134.000 respectively.		

9. Communication	$y_9 = 3{,}5x_1 + 13571{,}48$ (0,46) (1475,56)	$y_{9*} = 3{,}02x_1 + 14540{,}12$ (0,57) (3113,72)
In the communication area, consumption correlated with the average monthly disposable income of households (shown in PLN), increased in both analyzed periods. Each increase in the indicated income by one zloty resulted in an increase in total consumption in a given area, with an increase of PLN 3.5 million by 2014. Since 2015, this growth has been similar like before. It means, that observed changes can't be strait linked with pandemic period (the change is irrelevant).		
10. Recreation and culture	$y_{10} = 0{,}086x_6 - 10630{,}34$ (0,004) (3896,83)	$y_{10*} = 9{,}07x_1 - 52614{,}97x_{10} + 72531{,}6$ (1,83) (16521,40) (13206,22)
In the field of recreation and culture, with an increase in the average monthly disposable income in households per capita by one zloty, consumption increased by 86,000 by 2014. Since 2015, a change in the model level has been visible. Each additional zloty of the average monthly disposable income in households per 1 household caused an increase in consumption by over 9 million, assuming that the average number of dependents did not change. However, it can also be seen that consumption in this area decreased along with the average number of dependents.		
11. Education	$y_{11} = 5{,}36x_4 + 3973{,}17$ (0,55) (607,75)	$y_{11*} = -0{,}011x_7 - 52657{,}09x_{12} + 17536{,}85$ (0,003) (8549,61) (842,35)
Consumption in the area of education also differed significantly in both periods. It should be noted that the period of remote learning during the Covid-19 pandemic has caused a change in consumption, as the model shown. Until 2014, 1 additional zloty of the average monthly disposable income in households per capita brought consumption higher by over PLN 5 million. Nevertheless, the post-2015 model showed an inverse relationship between education consumption and gross savings and average number of persons in households employed on private farm in agriculture. Assuming, ceteris paribus, a decrease in gross savings by PLN 1 million, an increase in consumption in the area of education by PLN 11.000 can be observed. On the other hand, the growing average number of persons in households employed on private farm in agriculture by 1, with the amount of savings unchanged, will result in a decrease in consumption in the area of education by over PLN 52.5 billion.		
12. Restaurants and hotels	$y_{12} = 0{,}036x_6 - 6743{,}99$ (0,003) (2953,3)	$y_{12*} = 15987{,}87x_{11} - 1016840{,}16x_{12} + 153176{,}57$ (21223,54) (193431,12) (16971,53)
Consumption in the area of „Restaurants and hotels" in the analyzed periods differed in terms of the impact of the variables explained on the studied variable. Before 2014, if gross disposable income increased by PLN 1 million, consumption in this area would also increase by PLN 36,000. After 2015, according to the model, the increase in consumption by over PLN 15.98 billion, ceteris paribus, depends on the increase in the average number of people living on social benefits by one. If we treat the change in consumption as determined only by the second variable in the model, the decrease in consumption in the analyzed area by over PLN 1016 billion will be a consequence of an increase in the average number of people working in an individual farm in agriculture by one.		
13. Miscellaneous goods and services	$y_{13} = 0{,}153x_6 - 25423{,}85$ (0,014) (12287,16)	$y_{13*} = -2253561{,}11x_{12} + 390740{,}69$ (278886,55) (27340,99)
With regard to consumption related to goods and services not mentioned above, the explanatory variable in the first period analyzed was gross disposable income. By 2014 when that gross disposable income increases – based on the developed model – by PLN 1 million, resulted in an increase in the consumption of other goods and services by PLN 153 thousand. In the second analyzed period, the average number of people working in an individual farm in agriculture turned out to be the best correlated. Since 2015, its decrease by 1 person has resulted in an increase in consumption in the analyzed range. In the desirable period, an increase in the number of people living on social benefits was observed, which could have had an impact on the studied phenomenon. Moreover, it was in the second of the studied periods that the crisis related to the Covid-19 pandemic appeared, which may be justified by the values of the parameters obtained in the model.		

Source: own elaboration based on GUS

Table 3. Coefficients of determination and standard errors of estimate for the econometric model before GOZ

Number / *Coefficient*	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}	y_{11}	y_{12}	y_{13}
R^2	0,99	0,98	0,42	0,88	0,98	0,97	0,96	0,95	0,88	0,98	0,92	0,93	0,94
S_e	13426,6	2628,84	2112,1	2540,58	4298,28	1474,03	1937,1	6256,23	792,41	1844,54	354,4	1397,9	5816,04
F	1093,02	425,17	5,79	56,48	394,98	242,64	173,9	161,22	56,07	372,82	96,51	113,96	116,82
F*	5,32	5,32	5,32	5,32	5,32	5,32	5,32	5,32	5,32	5,32	5,32	5,32	5,32
W_e (%)	1,61	1,64	3,89	7,09	2,28	3,93	5,39	7,12	3,24	2,89	3,6	5,72	5,49

Source: own elaboration

Table 4. Coefficients of determination and standard errors of estimate for the econometric model after GOZ regulations

Number / oefficient	y_{1*}	y_{2*}	y_{3*}	y_{4*}	y_{5*}	y_{6*}	y_{7*}	y_{8*}	y_{9*}	y_{10*}	y_{11*}	y_{12*}	y_{13*}
R^2	0,97	0,99	0,98	0,87	0,91	0,94	0,95	0,92	0,80	0,84	0,91	0,85	0,90
S_e	58035	8210,91	2582,44	5020,58	20055,44	3518,73	5615,68	12948,36	2004,04	6413,46	416,29	5542,87	13662,59
F	214,7	485,4	389,14	45,47	70,34	106,35	138,49	80,80	27,95	19,07	34,24	19,45	65,30
F*	5,59	5,59	5,59	5,59	5,59	5,59	5,59	5,59	5,59	4,74	4,74	4,74	5,59
W_e (%)	4,26	3,37	3,15	7,49	7,26	5,08	6,70	7,31	6,54	7,04	3,58	9,51	7,9

Source: own elaboration

2.2. Selected models for municipal waste in Poland

In the first part of the paper, the Authors adopted the division of household consumption taking into account the target (according to the classification: COICOP). The same division was also consistently used in the further part of the analysis. This time, the explanatory variables given in Table 1 are treated as explanatory variables. The following variables were used for the analysis: y_1 - Wastewater discharged by sewage network (in hm^3), y_2 - Waste by type: grand total (in million tonnes) generated during the year, y_3 - Waste by type: recovered (in million tonnes) generated during the year, y_4 - Waste by type: total disposed (in million tonnes) generated during the year, y_5 - Waste by type: temporarily stored (in million tonnes) generated during the year, y_6 - Waste by type: landfilled up to now (in million tonnes) generated during the year, y_7 - Municipal waste: (in thousand tonnes) grand total, y_8 - Municipal waste collected from households (in thousand tonnes), y_9 - Municipal waste collected: recycling (in thousand tonnes), y_{10} - Municipal waste collected: incineration (in thousand tonnes), y_{11} - Waste by type: transferred to other recipients (in million tonnes) generated during the year, y_{12} - Waste by type: landfilled (in million tonnes) generated during the year (accumulated on landfills), y_{13} - Municipal waste collected from households separately (in thousand tonnes).

Only those models were adopted to observed relationships interpretation, which explain more than 50% of the variability of the explanatory variable (i.e. $R^2 > 0.5$). These are presented in Table 5. In the next step, a forecast based on these models was made and its parameters are presented in Table 7.

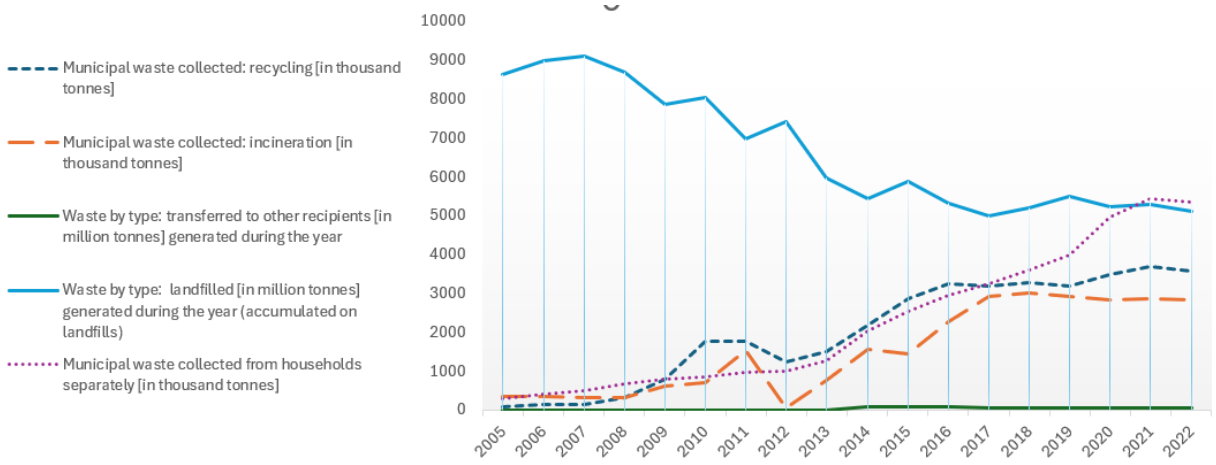


Figure 2. Municipal waste by management method since 2005
Source: own elaboration

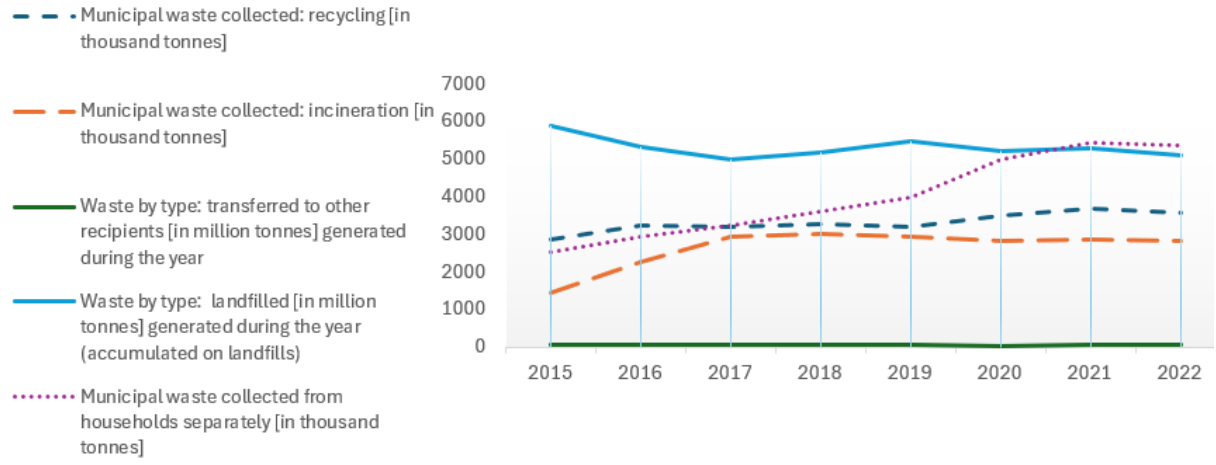


Figure 3. Municipal waste by management after 2014
Source: own elaboration

Taking information given above, in the further part of the paper, the explanatory variables was individual consumption in the household sector by target, according to the classification: COICOP (here expressed in each group in PLN million): x_1 - Total final consumption expenditure, x_2 - Food and non-alcoholic beverage, x_3 - Alcoholic beverages, tabaco and narcotics, x_4 - Clothing and footwear, x_5 - Housing, water, electricity, gas and other fuels, x_6 - Furnishings, household equipment and routine maintenance of the house, x_7 - Health, x_8 – Transport, x_9 - Communication, x_{10} - Recreation and culture, x_{11} – Education, x_{12} - Restaurants and hotels, x_{13} - Miscellaneous goods and services.

The method of municipal waste management in Poland has undergone noticeable changes since 2005. According to the data obtained, until 2010 the dominant method of municipal waste management was disposal by landfilling (Figure 2).

In 2010, only 17.8 percent of the collected municipal waste was recycled. On the other hand, municipal waste collected mainly selectively in Poland since 2015 has been mainly intended for recycling. Subsequently, they were directed to processes such as thermal transformation, storage and biological processing processes (composting or fermentation).

The last of the processes, i.e. transfer to other recipients, was omitted in further analysis due to the lack of comprehensive data. The analysis also does not take up the issue of the

participation of specialized institutions in the collection of specific types of waste, despite the fact that the authors are aware of their existence and participation in the processes taking place in the circular economy.

Table 5. Selected models of municipal waste, including waste collected from total households and separately collected waste intended for recovery and disposal processes after 2015, with coefficients of determination and standard errors of estimation

Method of municipal waste management	**Models for period after CE regulations**	**R^2**	**S_e**	**F**	**F***	**W_e (%)**
Wastewater discharged by sewage network in hm3	$y_{1*} = 0{,}003x_6 + 1132{,}67$ (0,0004) (31,58) According to the model analysis, after 2014, the additional PLN million allocated for consumption in the area of furnishings, household equipment and routine maintenance of the house causes an increase in the amount of sewage discharged through the sewage system by 3000 m^3.	0,86	16,82	42,09	5,59	1,26
Waste by type: Waste landfilled up to now (accumulated; end of the year) in million tonnes	$y_{6*} = 0{,}004x_6 + 1503{,}56$ (0,0005) (36,72) According to the model, the waste generated so far generated during the year increases by 4,000 tons due to the increase in consumption by PLN 1 million in the area of furnishing housing and running households in the country.	0,89	19,55	55,44	5,59	1,10
Municipal Waste: Municipal waste collected in thousand tonnes	$y_{7*} = 0{,}0025x_1 + 9241{,}51$ (0,0007) (989,58) Presented model shows that total municipal waste (i.e. from households and the public sector combined) increases by 2.5 tonnes, while total final consumption expenditure in households increases by PLN 1 million.	0,64	613,54	12,29	5,59	4,91
Municipal waste collected of which from households in thousand tonnes	$y_{8*} = 0{,}067x_6 + 6000{,}23$ (0,014) (962,66) Municipal waste from households, according to the model received, increases by 67 tonnes, as a result of an increase in consumption in the area of: Furnishings, household equipment and routine maintenance of the house, by PLN 1 million.	0,77	512,57	24,10	5,59	4,81
Municipal waste collected of which from households in thousand	$y_{9*} = 0{,}015x_3 + 2179{,}26$ (0,004) (302,9) The change in the volume of municipal waste collected during the year and intended for recycling is influenced by	0,71	152,35	20,14	5,59	4,59

tonnes: designated for recovery and disposal operations: recycling	the consumption of alcoholic beverages, tobacco products and drugs. If this consumption increases by PLN 1 million per year, the amount of waste intended for recycling will increase by 15 tonnes.					
Waste generated during the year: transferred to other recipients in million tonnes	$y_{11*} = -0{,}001x_9 + 106{,}87$ (0,0003) (7,79) The amount of waste generated during the year and transferred to other recipients, according to the model, decreases as consumption in the area of communication increases. When consumption increases by PLN 1 million, the amount of waste transferred to other recipients will decrease by 1000 tons.	0,80	2,99	28,08	5,59	4,53
Waste by type: Waste generated during the year in million tonnes (of which landfilled)	$y_{12*} = -0{,}01x_6 + 6177{,}32$ (0,008) (549,2) According to the model, the amount of waste stored in landfills generated during the year decreases with the increase in consumption in the area of routine maintenance of the house. If we increase consumption by PLN 1 million, the amount of waste deposited in landfills will decrease by 10 thousand tons. According to Figure 3, the amount of waste collected in a selective manner has been increasing since 2014. Therefore, it can be concluded that this is a visualization of growing consumer awareness, as the last model shown.	0,7	250,7	25,3	5,99	4,72
Municipal waste collected in thousand tonnes of which separately	$y_{13*} = 0{,}06x_3 - 733{,}79$ (0,008) (701,21) The amount of municipal household's waste collected selectively increases – according to the model – by 60 tonnes, while the consumption of alcoholic beverages, tobacco products and drugs increases by PLN 1 million.	0,88	430,43	51,09	5,59	8,32

Source: own elaboration

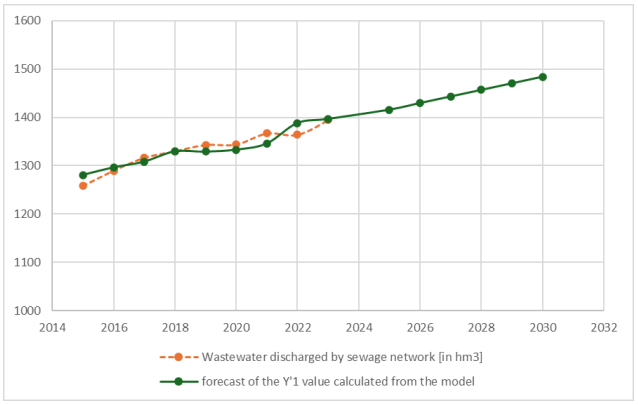
3. Results and discussion with forecasting

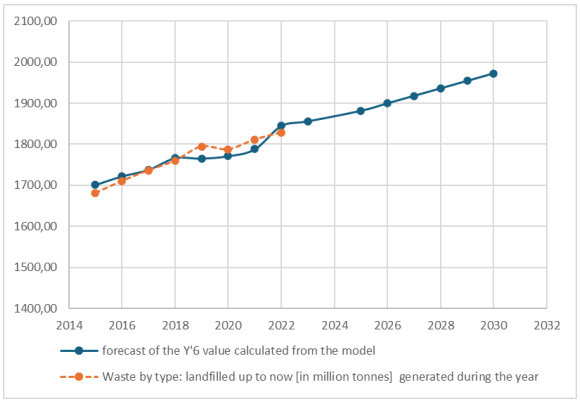
The authors would like to emphasize that forecasting has an important role in the analytical process. Hence, taking 2030 perspective, this part of the paper includes a forecast on the method of municipal waste management for selected models (shown in Table 5). It seems to complete the whole analysis, due to the fact that the available data cover only the first eight years of the functioning the circular economy rules in Poland. This is the period that only allows for the presentation of the most important issues in relationships between the selected variables - as a part of the *ex ante* analysis - in a long-term research perspective (until 2030).

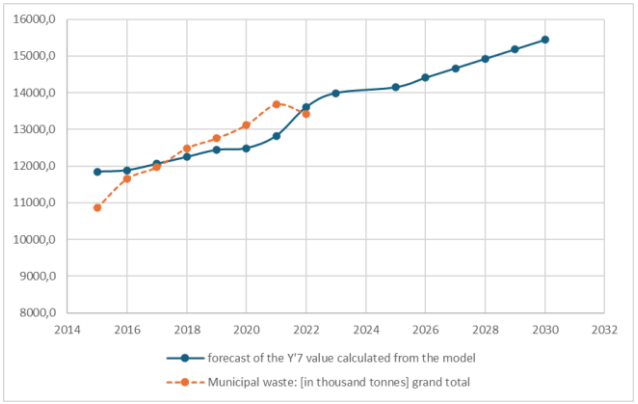
Table 6. Forecast based on selected models presented in Table 5 in the 2030-perspective

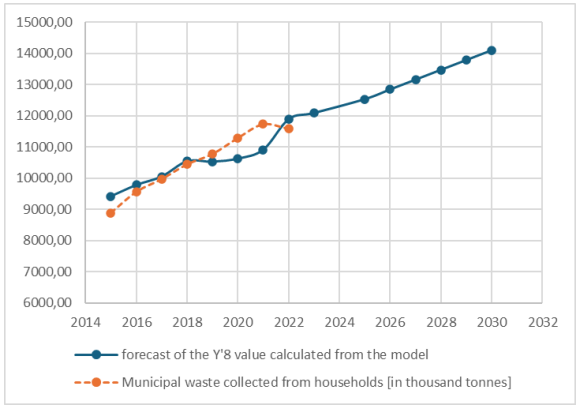
Years	y_{1*}	y_{6*}	y_{7*}	y_{8*}	y_{9*}	y_{11*}	y_{12*}	y_{13*}
2025	1415,87	1881,46	14147,76	12532,67	3936,33	54,50	4940,00	6489,24
2026	1429,46	1899,59	14406,03	12846,19	4030,26	52,59	4882,16	6875,38
2027	1443,05	1917,73	14664,31	13159,71	4124,19	50,69	4824,32	7261,52
2028	1456,65	1935,87	14922,58	13473,23	4218,13	48,78	4766,47	7647,66
2029	1470,24	1954,01	15180,86	13786,75	4312,06	46,88	4708,63	8033,80
2030	1483,83	1972,14	15439,13	14100,26	4405,99	44,97	4650,79	8419,94

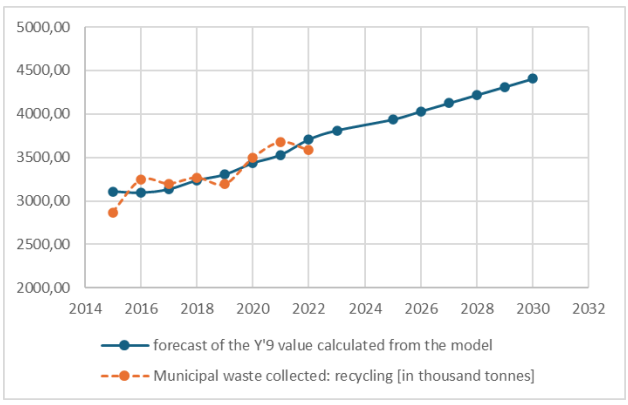
Source: own elaboration

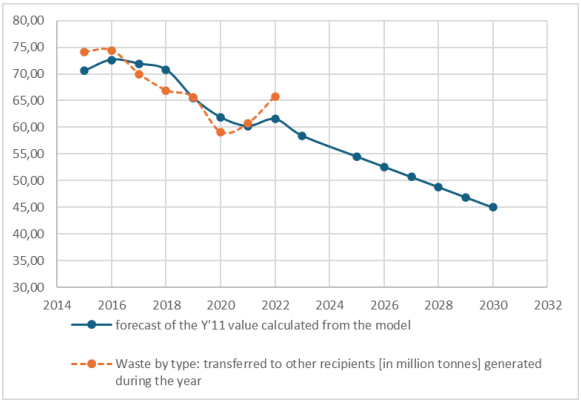












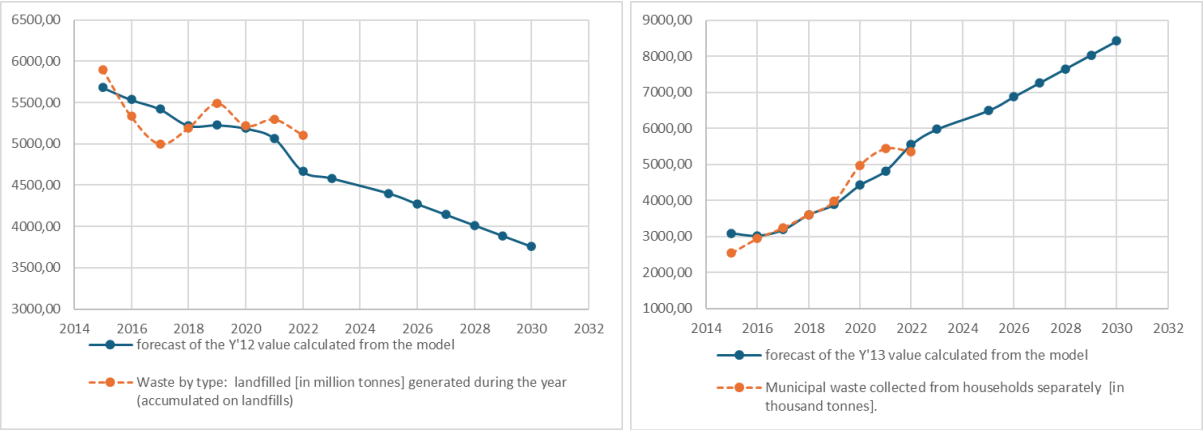


Figure 4. Graphical depiction of wastewater and waste up to 2030 with forecast's amounts
Source: own elaboration

Table 7. Mean error and forecast interval limits for the forecast

Coefficient	y_{1*}	y_{6*}	y_{7*}	y_{8*}	y_{9*}	y_{11*}	y_{12*}	y_{13*}
S_{pT}	29,08	33,81	1043,95	886,31	327,98	5,06	495,9	747,72
dy_{2050}	1435,85	1916,36	13716,61	12637,85	3864,83	36,63	3832,5	7186,21
gy_{2050}	1531,81	2027,92	17161,64	15562,68	4947,15	53,32	5469,1	9653,68

Source: own elaboration

The forecast values for the studied variables are presented in Table 6. The predicted trend of changes in the method of municipal waste management by 2030 was shown here, (with the ceteris paribus rule). The analysis shows that an increase in the amount of waste can still be expected, as a consequence of growing consumption in Poland. It is bringing joy, that the model shows that in the coming years we can expect decrease in the number of waste deposited in landfills and transferred to other recipients is forecast.

4. Final conclusions

The idea of circular economy (CE) has been presented in the scientific literature since the late 1960s. However, the implementation and improvement of its principles took place only at the beginning of the 21st century. Asian countries (China, Japan) were the first ones, and now, following the recommendations presented in the documents of the European Commission (since 2014), we can observe it in many countries in EU (Kulczycka, 2019). In Poland, long-term work on both the Roadmap for the transformation towards a circular economy and the National Environmental Policy – 2030 took place in the second half of 2019.

It should be noted that the *action plan* for the EU's community, which was adopted in 2015, identified measures to meet possibilities for circularity (CE) and supported the EU's leading position in this transformation. This plan includes actions based on changes in structure of consumption and production. The most important features for all product should be now: durability, reparability, reusability and recyclability. But there are the others areas worth attention: waste management (avoidance, recycling of materials, energy recovery and avoidance of landfill) and raising consumer awareness. All that issues were a part of a *Paper on Sustainable Europe by 2030* (30 January 2019), which introduce us into debate about circularity. Although some of the objectives are already in realization processes, further steps are needed in the 2030 perspective to create a European circular economy.

In the article, the authors assume that circular economy is an economic system that replaces the concept of the "end of product life" with reducing, alternative use, recycling and recovery of materials in the processes of production, distribution and consumption. She treated that it exists everywhere: at the micro level (here the analysis from the consumer side) and the macro level (the role of the states and associations). To achieve sustainable development, using a circular economy approach, the authors have compared selected data to be able to identify the value for the environment, economic prosperity and social justice (consumption analysis), with the benefits for current and future generations (waste analysis with a forecast until 2030).

The discussion about amount of wastes has been begun with the statement that: with the growing population on the Earth, we need to expect a higher level of them. The analysis confirmed the authors' assumptions about the need to take further actions in the field of meeting the assumptions of the circular economy in Poland. The prepared forecast, until 2030, confirms that the increase in the number of people in the World, combined with the growing consumption of resources, generates a large number of wastes. According to the forecast for Polish until 2030, the set trends will be maintained. This allows us to draw the conclusion that, according to the observed dependencies, without the introduction of systemic solutions and further increase in consumer awareness, a full-closed loop is not possible. Therefore, referring to the purpose of the paper, in Poland after 2015, in accordance with the assumptions of the policy for the entire EU, the taken actions supported the circular economy in every link of the value chain. With the Circular Economy Package, the EU is sending a clear signal to businesses and society about the future.

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W KIERUNKU GOSPODARKI O OBIEGU ZAMKNIĘTYM W POLSCE: KONSUMPCJA I ODPADY

Streszczenie

Cel – Zgodnie z założeniami gospodarki o obiegu zamkniętym, konsumpcja polega na zaspokajaniu podstawowych potrzeb człowieka przy ograniczonej ilości odpadów. W związku z tym w artykule sformułowano pytanie badawcze: Czy po 2015 r. w Polsce mamy do czynienia z konsumpcją zrównoważoną? Teza artykułu brzmi: Metoda składowania odpadów stosowana od wielu lat w Polsce (lub oparta na spalaniu odpadów bez odzysku) nie jest już preferowana.
Metodologia – Autorzy wykorzystali dane dostępne w Rocznikach Statystycznych Rzeczypospolitej Polskiej z lat 2005-2023, publikowanych przez Główny Urząd Statystyczny. Wszystkie analizy w artykule oparto na samodzielnie skonstruowanych modelach liniowych. Takie działanie służy wzbogaceniu wiedzy dostępnej w tej dziedzinie oraz określeniu trendu.
Wyniki – Zgodnie z założeniami gospodarki o obiegu zamkniętym, bez wdrożenia odpowiedniego systemu zbiórki, segregacji, przetwarzania i sprzedaży surowców wtórnych, a także nowych regulacji prawnych, nie nastąpi zmniejszenie ilości odpadów składowanych na wysypiskach i zrównoważona konsumpcja. W modelach wykazano, które zmienne miały największy wpływ na konsumpcję w poszczególnych obszarach oraz jak zmieniały się trendy w zakresie odpadów komunalnych w obliczu wzrostu konsumpcji.

Słowa kluczowe: Gospodarka o obiegu zamkniętym, globalna konsumpcja, produkcja odpadów, modelowanie ekonometryczne
Klasyfikacja JEL: C10, Q5, Y1, R1, O5

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