SHORT-TERM FORECASTS OF THE DOMESTIC STEEL PRODUCTION VOLUME AND THE PROPORTION BETWEEN PRODUCTION IN THE INTEGRATED AND ELECTRIC PROCESS

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Abstract: Forecasting is an element of the decision-making process through which a desired vision of the future status of the company is worked out and determines the techniques of achieving it. Creating forecasts is a conscious action and it is based on a certain method. Statistical-econometric methods were used in this publication. The projections concerned steel production and the proportion between the applied technologies. The research covered the domestic steel industry. Due to the time span of the projections, which was assumed until 2020, the designated forecasts were acknowledged as short-term projections.

Keywords: forecast, steel production, integrated process, electric furnaces.

1. Introduction

Enterprises in a dynamic environment forecast changes concerning a lot of different areas of activity. When planning measures it is necessary to evaluate the set of problems and actions which offer an opportunity to reach the desired results. Forecasting is a part of the planning process. Forecasting means becoming involved in the future to undertake proactive measures. Looking ahead enables to answer the question: "What will happen?" and/or " What analyzed volumes will change?". Forecasting makes sense only if it covers a big set of empirical data respectively. In case of projecting or forecasting, extrapolation or interpolation is used based on numerous statistical-econometric methods. The choice of methods is left to the discretion of the researcher. For the purposes of this publication statistical methods were verified and those were chosen which were characterized by the smallest prognostic error.

The goal of this publication was to work out statistical short-term forecasts of the steel production volumes until 2020 broken down by steel production in accordance with the applied production technologies. The study was drawn up on the basis of statistical data. For creating the forecast, data on the total steel production volume, including basic converter and electrical steel from 2000 until 2015 were used. Ex-ante forecasts were made for the period

from 2016 until 2020 – a five-year period. A crawling trend model – forecasting via the harmonic balance method was worked out for the studied phenomena in the domestic steel industry.

2. A methodical procedure in projecting the steel production volume in total and according to the production processes

In order to build a forecast of the steel production volume in total and according to a breakdown by respective technologies applied in the steel industry in Poland until 2020 (5 years), adaptive and econometric models (linear, non-linear and including autocorrelation) were used. Two paths of methodical procedure were assumed. The first methodical procedure was the following: Stage 1 Creating a forecast for the entire steel production. Stage 2a1. Creating a forecast for steel production through the converter process. Stage 2a2. Forecast assessment for steel production through the electric process. The second methodical procedure, in turn, covered: Stage 1. Creating a forecast for the entire steel production. Stage 2b1. Creating a forecast for steel production through the electric process. Stage 2b2. Forecast assessment for steel production through the converter process. The adopted methodical procedure resulted from the fact that the steel obtained through the converter and electric processes made up the total steel production.

For the respective statistical methods used in the course of making projections the minimum value of one of the errors was adopted as the basis for the optimization of the point prediction value: the square root calculated from the mean squared error of the RMSE* simulated forecasts and the mean value of the relative error of the expired forecasts (Pawłowski, 1973, 1982; Sadowski, 1997). Among the tested prognostic methods optimum forecasts were chosen, taking into consideration the above-defined criteria for such exploration. The best method from among the set of optimum methods was chosen. It was the crawling trend method using the harmonic balance method. Table 1 contains a set of optimal methods used in the aforementioned research with respect to the steel production volume forecast. The methodical procedure, the verification of respective statistical methods were repeated with respect to steel production using the converter and electric processes.

Table 1.
A set of optimal prognostic methods for the explored forecast areas[1]

Projection of the total steel production					
No.	**Method or forecast model**	***Ex post error***		***Ex ante error***	***Comments with respect to the model parameters***
		Ψ	***RMSE****	***Ψ***	
1.	**The crawling trend method- forecasting via the harmonic balance method**	**0.044**	**0.521**	0.0230	Number of elements in the segment k = 4
2.	Autoregressive (AR) models (1,2,4,5)	0.061	0.692	0.0190	AR Model (1, 2, 4, 5)
3.	Autoregressive (AR) models (1,4,5)	0.066	0.703	0.0065	AR Model (1, 4, 5)
4.	Holt-Winters additive method (for different actuation mechanisms)	0.088	0.911	0.1092	Min. value: Ψ; α = 0.0001; β = 0.2398; Φ = 0.2597
5.	Holt-Winters additive method (for different actuation mechanisms)	0.088	0.911	0.1124	Min. value *RMSE α = 0.0001; β = 0.2395; Φ = 0.2569
6.	Line model (for illustrative purposes)	0.089	0.924	0.0914	R2 = 0.1521; p = 0.1340
Converter steel production forecast					
No.	**Method or forecast model**	***Ex post error***		***Ex ante error***	*Comments with respect to the model parameters*
		*RMSE**	*Ψ*	*Ψ*	
1.	**The crawling trend method- forecasting via the harmonic balance method**	**0.059**	**0.379**	0.0046	Number of elements in the segment k = 4
2.	Autoregressive (AR) models (1)	0.124	0.772	0.0499	AR Model (1)
Forecasting steel production through the electric process					
No.	**Method or forecast model**	***Ex post error***		***Ex ante error***	*Comments with respect to the model parameters*
		*RMSE**	*Ψ*	*Ψ*	
1.	Autoregressive models	0.039	0.171	0.0340	AR Model (1, 2, 6) R2 = 0.7340
2.	**The crawling trend method- forecasting via the harmonic balance method**	0.041	0.172	0.0615	Number of elements in the segment k = 4

The ex-ante error was set for 2015.

3. Steel production and the proportions between production through the integrated and the electric process

Steel, despite the development of competitive materials, is continuously classified as a basic construction material. The production of steel has dynamically increased in recent years. In 2004 it exceeded 1 billion tonnes (World Steel in Figures, 2005). 1.592 billion tonnes were produced across the world in 2015. However, due to the excess capacity there was a drop in production by ca. 2% in 2015 compared to the previous year (World Steel in Figures, 2015). The global excess capacity amounted to 700 million tonnes (The Polish Steel Industry, 2016,

[1] The verification of methods was supervised by Prof. of the Silesian University of Technology Jan Szymszal PhD. Eng. (to whom the author expresses her sincere thanks).

p. 18). The world markets are gradually experiencing a sluggish growth of the Chinese economy. The drop in the demand of steel was reported in steel-consuming sectors (construction, automotive industry, transport, domestic appliances). Over the long-term the situation on the world steel market shows an upward trend, with a slight drop in 2015. Since 1995 the average production growth rate has been positive. According to the data of the World Steel Association, the growth in the years 1995-2000 amounted to 2.5%, in the consecutive years: 2001-2005 a growth of 6.2% was recorded, in the next years the growth amounted to 4.5% and in the years 2010-2014 the increase was lower, ie. 3.8% (World Steel in Figures, 2015).

In Europe production had a growing trend until 2008. The greatest amount of steel in Europe was produced in 2007-210 million tonnes. After the occurrence of the effects of the world economic crisis, the steel production trend in the EU countries showed fluctuations. In 2015 2% less steel was produced in Europe than in the previous year (in 2014 steel production amounted to 168 million tonnes) (European Steel in Figures, 2007/2011; European Steel in Figures, 2008/2012).

In Poland since 2008 steel production has not exceeded 10 million tonnes. 9.2 million tonnes of steel were produced in Poland in 2015 (growth compared to the previous year by 8%) at a production capacity of 73% (The Polish Steel Industry, 2016, p. 18). The highest production volume in the last decade was reported in 2007-10.7 million tonnes (Gajdzik, 2013).

Nowadays, steel is melted in converters (integrated process: blast furnace, converters, CSC – Continuous Steel Casting) and in electric furnaces (first of all arc furnaces). The state of technological development projected by experts for the set year 2050 will not change significantly, the mentioned technologies are considered to be essential (basic) in the metallurgical sector (Paduch, and Szulc, 2014, p. 3-11). In Poland there are two converter plants (converters of the type TBM –Thyssen Blast Metalurgie, LD – Linz-Donawitz), one in Cracow and one in Dąbrowa Unit of ArcelorMittal Poland. A technological process is a combination of converters with continuous steel casting. The other mills use electric furnaces. Among the advantages of this technology is the use of mainly collected (post amortization) steel scrap (the basic iron-bearing material) and steel scrap from post-production wastes of the mills for smelting of steel and a lower energy intensity as compared with the process of producing steel in integrated mills (in the blast furnace – oxygen converter system) (Łędzki, Zieliński, and Klimczyk, 2010, p. 7-14). The steel production technology in the electric furnaces is defined as EAF - Electric Arc Furnace and in converters as BOF – Basic Oxygen Furnace.

Until 2002 the mills in Poland also used open-hearth furnaces. However, the technology was discontinued for economic and environmental reasons. In Poland more steel is produced through the integrated process, rather than the electric process, although reverse situations occurred (such a situation occurred in the years 2009-2010 and was caused by the shut-down

of redundant production capacities in integrated mills) (Gajdzik, 2013, p. 154-179). Currently (data from 2015) 58% of steel is produced through the converter process and 42% through the electric process (The Polish Steel Industry, 2016, p. 18). In the EU countries (27 countries) these proportions are slightly higher, as 61% constitutes converter steel and 39% of steel is melted in electric furnaces. The production of steel produced in Poland indicates a ca. 3% lower share of steel produced through the converter process compared with the European Union and a ca. 17% lower share with regard to world production. Converter steel in the world constitutes over 75% of the total production (table 2) (Szulc, 2014).

Table 2.
Examples of shares of converter and electric steel in the overall steel production

Specification	Poland [%]				EU [%]				The world [%]			
	2005	2010	2012	2015	2005	2010	2012	2015	2005	2010	2012	2015
The share of converter steel	58.7	49.9	50.5	58.0	61.1	58.7	58.4	61.0	65.3	65.2	70.5	75.0
The share of electric steel	41.3	50.1	49.5	42.0	38.9	41.3	41.6	39.0	34.7	34.8	29.5	25.0

Source: Compiled on the basis of data: World Steel in Figures, 2006, 2011, 2013, 2015, worldsteel Association; European Steel in Figures 2007/2011, 2008/2012 EUROFER; Polish Steel Industry, Metallurgical Chamber of Industry and Commerce, Katowice, 2006, 2011, 2013, 2016.

Apart from the overall converter and electric technology, steel production using open-hearth furnaces is still indicated. The share of open-hearth processes in the total steel production in the world is insignificant (in 2015 it constituted barely 0.3%) (World Steel in Figures, 2015). In the European Union the open-hearth technology is a historical technology (displayed in the statistical statements for the last time in 2010 at a level of 0.655 million tonnes) (World Steel in Figures, 2011).

4. The time history analysis of the total steel production and according to the production processes in Poland

On the basis of statistical data (table 3) the time history of the following examined volumes: overall steel production, steel production through the converter and electric processes was presented. The analyzed volumes were presented in the years 2000-2015.

Table 3.
Steel production in total and according to processes in the years 2000-2015

NO.	Year	Overall steel production [million tonnes]	Converter process [million tonnes]	Electric process [million tonnes]
1	2000	10.498	6.800	3.285
2	2001	8.809	5.823	2.809
3	2002	8.367	5.799	2.561
4	2003	9.107	6.070	3.037

5	2004	10.578	6.858	3.721
6	2005	8.336	4.893	3.443
7	2006	9.992	5.766	4.225
8	2007	10.631	6.198	4.433
9	2008	9.727	5.225	4.502
10	2009	7.128	3.236	3.893
11	2010	7.993	3.995	3.998
12	2011	8.776	4.424	4.353
13	2012	8.348	4.227	4.132
14	2013	7.950	4.399	3.551
15	2014	8.558	5.067	3.491
16	2015	9.202	5.323	3.879

Source: Polish Steel Industry. Annual reports of the Metallurgical Chamber of Industry and Commerce in Katowice; access: www.hiph.org/polski_przemysl_handlowy.

In the years 2000-2002 steel in Poland was produced through the open hearth furnace (grey colour in table 3), yet its share was not significant (in the years 2000, 2001, 2002, steel production through the open hearth process in Poland amounted respectively to: 0.0413%, 0.0177% and 0.0072%).

The time history of the analyzed phenomena was presented in fig. 1. In general, the course of a series of examined phenomena is difficult because of the construction of a credible forecast – there are high random fluctuations (usually cyclical fluctuations). It is not possible to identify the seasonal (cyclical) fluctuations in the analyzed volumes. In case of the steel production volume a slightly declining trend is noticeable. The production of converter steel until 2009 showed a slightly declining trend and in the years 2009-2015 a growing trend. A reverse situation was reported in case of steel production in electric furnaces. A growing trend until 2009, a declining trend in two consecutive years and a growing trend once more. In fig. 1 situations were also highlighted when in the years 2009-2010 the production of converter steel had a smaller share in the overall steel production than electric steel.

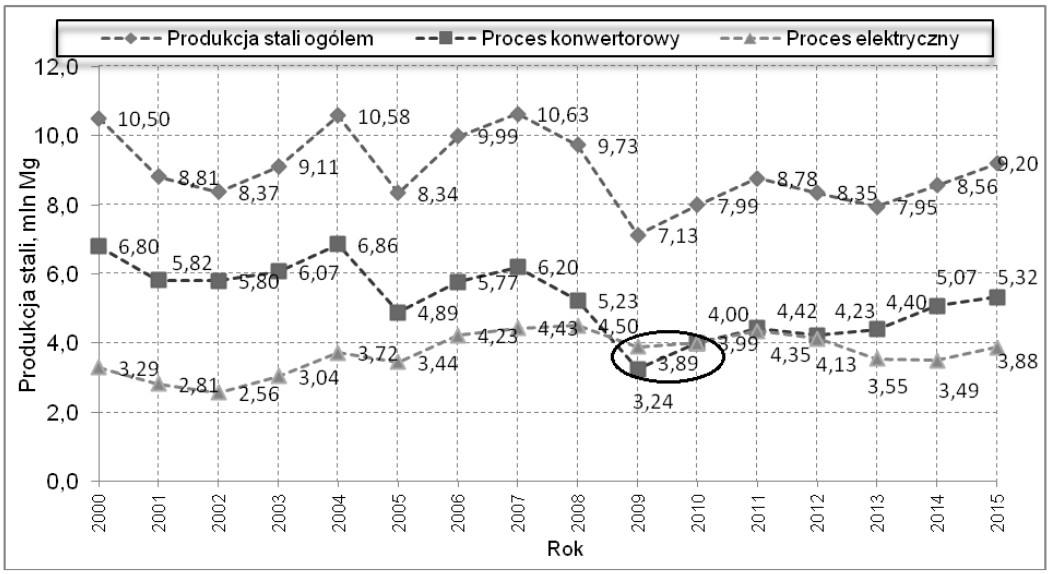

Figure 1. Steel production in total and according to production processes in the years 2000-2015. Source: own elaboration on the basis of statistical data (HIPH publications).

Most steel is produced in the steel enterprise ArcelorMittal Poland. The enterprise produces about 5 million tonnes of steel annually. 5.2 million tonnes of steel was produced in the enterprise in 2015, what constitutes nearly 55% of the overall steel production in Poland (Our steel, Your world, 2016, p. 26). The enterprise ArcelorMittal Poland produces steel through the converter process. More than 70% of steel produced in the steel enterprise is manufactured in the unit in Dąbrowa Górnicza (former Katowice Mill) and less than 30% in the unit in Cracow (former T. Sendzimir Mill) (table 4). The following mills use the electric furnace steelmaking technology: ArcelorMittal Warszawa S.A. (former Warsaw Mill) (15.7% in the overall electric steel production); CMC Poland Sp. z o.o. (former Zawiercie Mill) (29.8%); Celsa "Huta Ostrowiec" Sp. z o.o. (34.5%); Ferrostal Łabędy Sp. z o.o. (Łabędy Mill) (10.9%); Quality Steel Mill (5.8%) and ISD Częstochowa Mill (0.6%) (table 4).

Table 4.
The share of respective producers in the steel production using the converter and electric process

Enterprise	year 2012	year 2013	year 2014	Share in the overall production
	[tonnes]	[tonnes]	[tonnes]	[%]
Steel industry/steel production through the converter process in total	4 226 542	4 399 432	5 066 954	100
ArcelorMittal Poland	4 226 542	4 399 432	5 066 954	100
ArcelorMittal Poland Unit in Dąbrowa Górnicza	3 028 562	3 057 934	3 719 497	73.4
ArcelorMittal Poland Unit in Cracow	1 197 980	1 341498	1 347 457	26.6
Steel industry/steel production through the electric process in total	4 131 618	3 550 904	3 491 464	100
ArcelorMittal Warszawa S.A.	568 322	554 970	547 870	15.7
Celsa "Huta Ostrowiec" Sp. z o.o.	1 196 560	1 023 458	1 204 066	34.5
CMC Poland Sp. z o.o.	1 424 047	1 274 089	1 038 817	29.8
Ferrostal Łabędy Sp. z o.o.	303 810	324 645	381 477	10.9
Quality Steel Mill	159 052	181 049	200 925	5.8
ISD Częstochowa Mill	394 440	95 987	20 746	0.6

Source: HIPH.

5. Forecasting changes in the steel production volume in total and according to production processes – crawling trend model – forecasting via the harmonic balance method

In the course of forecasting changes in the analyzed phenomenon, the crawling trend model was combined with the projection via the harmonic balance method.

Assumptions:

1. Segments were chosen after k = 4 observations.
2. Weights or coefficients taking account of the information obsolescence were calculated according to the formula:

$$C_{t+1}^{n} = \frac{1}{n-1} \cdot \sum_{t=1}^{t} \frac{1}{n-1} .$$

Ex-ante projections were calculated according to the formula:

$$y_T^* = y_n + (T-n) \cdot (\sum_{t=2}^{n} w_t \cdot c_t) \quad dla \quad T = n+1,...,\tau .$$

The obtained modelling results were presented in the charts. As an example, the results of the overall steel production volume forecast until 2020 were provided in table 5.

Table 5.
Projecting changes in the overall production volume [million tonnes]

	Wartości modelowe Y w poszczególnych segmentach k=4																								
LP	Rok	Produkcja stali ogółem	y*t	1	2	3	4	5	6	7	8	9	10	11	12	13	Segm.	Estymatory parametrów trendu liniowego dla podokresów		Wt przyrosty	Ct-wagi harmoniczne		Wt*Ct	$\frac{\lvert y_t - y_t^* \rvert}{y_t}$	$(y_t - y_t^*)^2$
																					Składniki	Wagi			
1	2000	10,498	9,888	9,9													1	-0,46	932,8						
2	2001	8,809	8,867	9,4	8,3												2	0,60	-1201,8	-1,0204	0,0044444	0,004444	-0,004534	0,007	0,003
3	2002	8,367	8,923	9,0	8,9	8,9											3	0,14	-266,7	0,0556	0,0047619	0,009206	0,000512	0,066	0,309
4	2003	9,107	9,123	8,5	9,5	9,0	9,4										4	0,04	-72,7	0,2000	0,0051282	0,014335	0,002866	0,002	0,338
5	2004	10,578	9,596		10,1	9,2	9,5	9,6									5	0,18	-353,6	0,4731	0,0055556	0,019890	0,009410	0,093	0,565
6	2005	8,336	9,393			9,3	9,5	9,8	8,9								6	0,48	-956,1	-0,2034	0,0060606	0,025951	-0,005278	0,127	1,117
7	2006	9,992	9,941				9,6	10,0	9,4	10,8							7	-0,95	1915,1	0,5483	0,0066667	0,032617	0,017885	0,005	0,003
8	2007	10,631	10,090					10,2	9,9	9,8	10,4						8	-1,05	2120,2	0,1488	0,0074074	0,040025	0,005955	0,051	0,293
9	2008	9,727	9,347						10,4	8,9	9,4	8,7					9	-0,20	407,9	-0,7427	0,0083333	0,048358	-0,035914	0,039	0,145
10	2009	7,128	8,048							7,9	8,3	8,5	7,4				10	0,44	-885,1	-1,2994	0,0095238	0,057882	-0,075211	0,129	0,845
11	2010	7,993	7,947								7,3	8,3	7,8	8,4			11	-0,06	120,2	-0,1002	0,0111111	0,068913	-0,006907	0,006	0,002
12	2011	8,776	8,313									8,1	8,3	8,3	8,6		12	-0,11	220,1	0,3657	0,0133333	0,082326	0,030107	0,053	0,215
13	2012	8,348	8,367										8,7	8,2	8,5	8,0	13	0,32	-629,9	0,0536	0,0166667	0,098993	0,005309	0,002	0,000
14	2013	7,950	8,299											8,2	8,4	8,4				-0,0683	0,0222222	0,121215	-0,008278	0,044	0,121
15	2014	8,558	8,462												8,3	8,7				0,1634	0,0333333	0,154549	0,025257	0,011	0,009
16	2015	9,202	8,990													9,0				0,5284	0,6666670	0,221215	0,116901	0,023	0,045
17	2016		**9,280**																				**0,078080**	**0,044**	**0,521**
18	2017		**9,358**																					ψ	RMSE*
19	2018		**9,437**																						
20	2019		**9,515**																						
21	2020		**9,593**																						

The following steel production volumes were set on the basis of the crawling trend model with the projection via the harmonic balance method: 9.280 million tonnes in 2016; 9.358 million tonnes in 2017; 9.437 million tonnes in 2018; 9.515 million tonnes in 2019 and 9.593 million tonnes in 2020. The projected steel volume indicates a slightly growing trend (fig. 2).

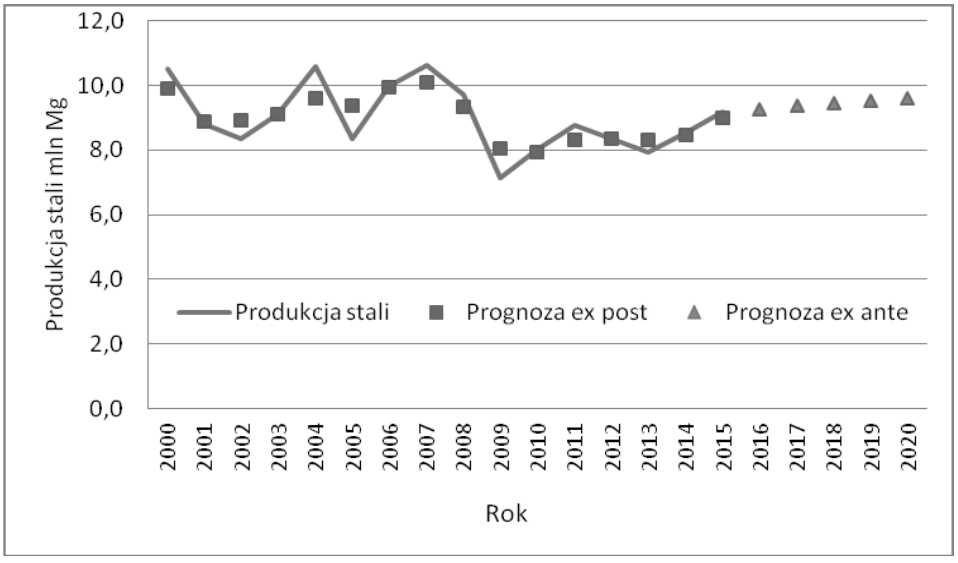

Figure 2. The projections of the overall steel production volume until 2020. Source: own elaboration on the basis of the research methodology presented in the publication.

The following levels were obtained when projecting the steel production volume through the converter process: 5.433 million tonnes in 2016; 5.542 million tonnes in 2017, 5.652 million tonnes in 2018; 5.761 million tonnes in 2019; 5.871 million tonnes in 2020. Percentage shares of steel production through the converter process in the overall steel production were listed in table 6. Figure 3 shows trends in the designated forecast – it is also a growing trend.

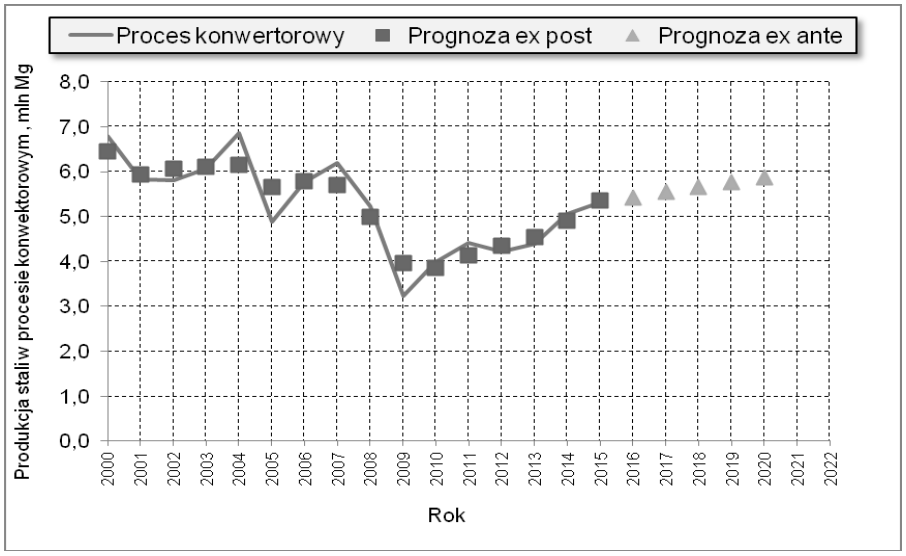

Figure 3. Projections of the steel production volume through the BOF converter process until 2020. Source: own elaboration on the basis of the research methodology presented in the publication.

Table 6.
Proportions between production in converter and electric furnaces

Year	Steel production through the converter process [%]	Steel production through the electric process [%]
2000	64.7	31.3
2001	66.1	31.9
2002	69.3	30.7
2003	66.6	33.4
2004	64.8	35.2
2005	58.7	41.3
2006	57.7	42.3
2007	58.3	41.7
2008	53.7	46.3
2009	45.4	54.6
2010	49.9	50.1
2011	50.4	49.6
2012	50.6	49.4
2013	55.3	44.7
2014	59.2	40.8
2015	57.8	42.2
2016	58.5	41.5
2017	59.2	40.8
2018	59.9	40.1
2019	60.5	39.5
2020	61.2	38.8

The projections of the steel production volume through the electric process are the following: 3.850 million tonnes in 2016; 3.820 million tonnes in 2017, 3.790 million tonnes in 2018; 3.761 million tonnes in 2019; 3.731 million tonnes in 2020. Percentage shares of steel production through the electric process in the overall steel production were listed in table 6. Figure 4 shows trends in the designated forecast – It is a slightly declining trend. A slight drop in the production of steel in electric furnaces may be caused by the reduction in the production capacity of the mills. The Polish steel market has already suffered sharp declines in steel production through the electric processes, eg. in 2012 ISD Częstochowa Mill produced 394 440 tonnes of steel and two years later 20 746 tonnes (drop by 95%).

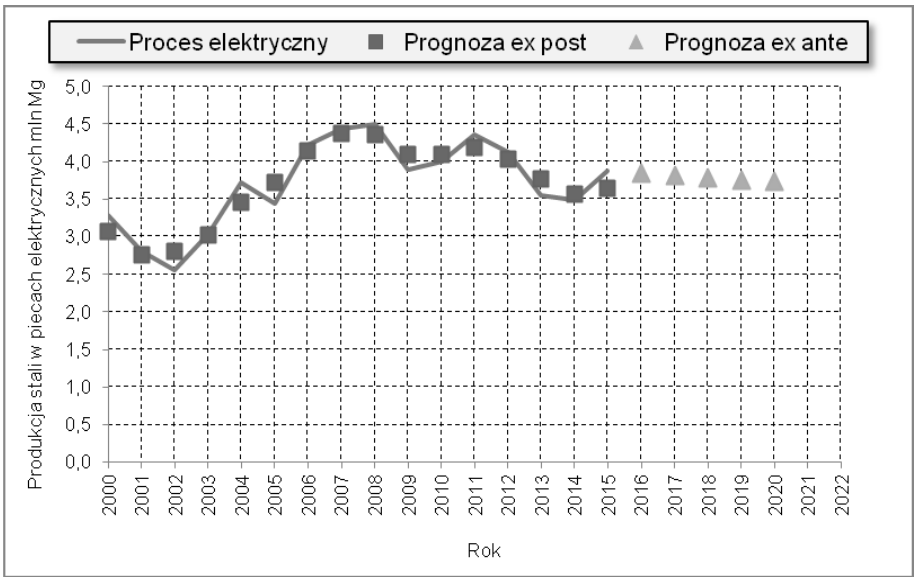

Figure 4. Projections of the steel production volume through the electric (EAF) process until 2020. Source: own elaboration on the basis of the research methodology presented in the publication.

The obtained results of all forecasts – crawling trend model with the projection via the harmonic balance method were listed in table 7.

Table 7.
Summary of the obtained forecasts of the steel production volume in total and according to technological processes

Year	Projected steel production volume in total [million tonnes]	Projected steel production volume through the converter process [million tonnes]	Projected steel production volume through the electric process [million tonnes]
2016	9.280	5.433	3.850
2017	9.358	5.542	3.820
2018	9.437	5.652	3.790
2019	9.515	5.761	3.761
2020	9.593	5.871	3.731

Source: own elaboration on the basis of the research methodology presented in the publication.

6. The projected steel production volume according to processes in available studies

The steel production volume forecast was carried out by the Polish Electricity Association (PKEE) (Report 2030, 2008)[2]. On the basis of the worked out scenarios, the steel production does not exceed the current production capacity and the proportions between production in electric furnaces (EAF) and converter furnaces are slightly changing in favour of production in electric furnaces (table 8). The forecasts were carried out in 2007, assuming empirical evidence based on the production of steel in the years 1996-2006 (table 8). The forecasts of the steel production volume and the proportion between production in electric and converter furnaces were determined until 2030. Two scenarios were developed on the basis of data: the baseline and the moderate scenario (table 8).

Table 8.
Forecasts of the steel production volume and the proportion between production in converter and electric (arc) furnaces

Year	Statistics		Baseline				Moderate			
	BOF Steel [million tonnes]	EAF Steel [million tonnes]	BOF Steel [million tonnes]	BOF Steel [%]	EAF Steel [million tonnes]	EAF Steel [%]	BOF Steel [million tonnes]	BOF Steel [%]	EAF Steel [million tonnes]	EAF Steel [%]
1996	6.757	2.554								
1997	7.531	2.994								
1998	6.223	3.143								
1999	5.452	3.022								
2000	6.794	3.290								
2001	5.823	2.809								
2002	5.799	2.561								
2003	6.070	3.037								
2004	6.858	3.721								
2005	5.001	3.443								
2006	5.766	4.242								
2010	Forecasts		7.000	58.3	5.000	41.7	6.200	59.6	4.200	40.4
2015	Forecasts		7.200	55.4	5.800	44.6	6.300	59.4	4.300	40.6
2020	Forecasts		7.400	53.6	6.400	46.4	6.400	57.2	4.800	42.8
2025	Forecasts		7.400	52.1	6.800	47.9	6.500	56.5	5.000	43.5
2030	Forecasts		7.400	51.4	7.000	48.6	6.600	56.9	5.000	43.1

Report 2030: The impact of the proposed EU regulations in terms of implementing the European development strategy of CO2-free energy production on Poland's energy safety and, in particular, the options to restore generation capacities using fossil fuels and the prices of electricity. App. 2. Assumptions concerning the levels of activity and energy intensity of distinguished types of production or services, Warsaw, June 2008. The study was carried out by the company Badania Systemowe EnergoSys on behalf of PKEE, access: www.toe.pl/plwybrane-dokumenty/rok-2008?download=455:załącznik-2.

Because the forecast was evaluated in 2007, it is possible to refer the projected volumes from the years 2010 and 2015 to the actual production (table 9). This summary will enable to

[2] The study was carried out by the company Badania Systemowe EnergoSys on behalf of PKEE. Retrieved from www.toe.pl/plwybrane-dokumenty/rok-2008?download=455:załącznik-2.

determine the differences between the projected and actual volumes. The obtained (positive) differences are evidence of overestimated volumes of the forecast in the considered scenarios. In case of the baseline scenario, the dynamics of changes is greater than in the moderate scenario. Assuming that the indicators of the dynamics of changes are forecast errors, the volumes in forecasts for 2020 and the next years were verified (table 10). The dynamics of changes was calculated according to the following formula:

$$Dz = \frac{Pz - Wr}{Pz} x\ 100\%$$

where:
Dz – indicator of the dynamics of changes,
Pz – projected volumes of the analyzed phenomenon,
Wr – actual volume.

Table 9.
Differences between the projected and actual volumes in the overall steel production volume and in the technological processes

No.	Specification	2010	Indicator of the dynamics of changes	2015	Indicator of the dynamics of changes
1	Baseline – forecast of the volume of produced steel in total [million tonnes] (projected volume of the analyzed phenomenon)	12.000	-	13.000	-
2	Actual volumes of produced steel [million tonnes] (actual volume)	7.993	-	9. 202	-
Difference between the projected and actual volumes [million tonnes] (1-2)		4.007	33.39%	3.798	29.21%
3	Baseline – forecast of the volume of produced steel in the BOF technology [million tonnes] (projected volume of the analyzed phenomenon)	7.000	-	7.200	-
4	Actual volumes of produced steel in the BOF technology [million tonnes] (actual volume)	3.995	-	5.323	-
Difference between the projected and actual volumes [million tonnes] (3-4)		3.005	42.92%	1.877	26.06%
5	Baseline – forecast of the volume of produced steel in the EAF technology [million tonnes] (projected volume of the analyzed phenomenon)	5.000	-	5.800	-
6	Actual volumes of produced steel in the EAF technology [million tonnes] (actual volume)	3.998	-	3.879	-
Difference between the projected and actual volumes [million tonnes] (5-6)		1.002	20.04%	1.921	33.12%
7	Moderate scenario – forecast of the volume of the produced steel in total [million tonnes] (projected volume of the analyzed phenomenon)	10.400	-	10.600	-
8	Actual volumes of produced steel [million tonnes] (actual volume)	7.993	-	9. 202	-
Difference between the projected and actual volumes [million tonnes] (7-8)		2.407	23.14%	1.398	13.19%
9	Moderate scenario – forecast of the volume of produced steel in the BOF technology [million tonnes] (projected volume of the analyzed phenomenon)	6.200	-	6.300	-

10	Actual volume of produced steel in the BOF technology [million tonnes] (actual volume)	3.995	-	5.323	-
Difference between projected and actual volumes [million tonnes] (9-10)		2.205	35.56%	0.977	15.50%
11	Moderate scenario – forecast of the volume of produced steel in the EAF technology [million tonnes] (projected value of the analyzed phenomenon)	4.200	-	4.300	-
12	Actual volumes of produced steel in the EAF technology [million tonnes] (real value)	3.998	-	3.879	-
Difference between the projected and actual volumes [million tonnes] (11-12)		0.202	4.8%	0.421	9.79%

Source: Projections from: Report 2030: The impact of the proposed EU regulations in terms of implementing the European development strategy of CO2-free energy production on Poland's energy safety and, in particular, the options to restore generation capacities using fossil fuels and the prices of electricity. App. 2. Statistical data concerning the volume of steel production from the reports: Polish Steel Industry, Metallurgical Chamber of Industry and Commerce (HIPH), Katowice.

Table 10.

Verified projections of the value of steel production in total and according to production technology

No.	Specification	Indicator of the dynamics of changes*	2020		2025		2030	
			Projected volume of the analyzed phenomenon	Projected volume of the analyzed phenomenon*	Projected volume of the analyzed phenomenon	Projected volume of the analyzed phenomenon*	Projected volume of the analyzed phenomenon	Projected volume of the analyzed phenomenon*
1	Baseline – forecast of the volume of the produced steel in total [million tonnes]	33.39%	13.800	9.192	14.200	9.459	14.400	9.592
		29.21%		9.769		10.052		10.194
2	Baseline – forecast of the value of produced steel in the BOF technology [million tonnes]	42.92%	7.400	4.224	7.400	4.224	7.400	4.224
		26.06%		5.471		5.471		5.471
3	Baseline – forecast of the volume of produced steel in the EAF technology [million tonnes]	20.04%	6.400	5.117	6.800	5.437	7.000	5.5972
		33.12%		4.280		4.548		

4	Moderate scenario – forecast of the volume of produced steel in total [million tonnes]	23.14%	11.200	8.608	11.500	8.839	11.600	8.916
		13.19%		9.723		9.983		10.070
5	Moderate scenario – forecast of the volume of produced steel in the BOF technology [million	35.56%	6.400	4.124	6.500	4.189	6.600	4.253
		15.50%		5.408		5.492		5.577
6	Moderate scenario – forecast of the volume of produced steel in the EAF technology [million	4.8%	4.800	4.570	5.000	4.760	5.000	4.760
		9.79%		4.330		4.510		4.510

* dynamics indicators from table 9 for the years 2010, 2015, Projected volume of the analyzed phenomenon*-adjusted forecast.

Source: own study.

Adjusted forecasts of PKEE (Polish Electricity Association) were referred to forecasts of the overall steel production volume and broken down by respective technological processes carried out on the basis of the crawling trend model with the projection via the harmonic balance method. The obtained results were presented in table 11.

Table 11.
Summary of the projected changes in the volume of steel production in total and according to technological processes in 2020

Specification	Crawling trend model	Baseline of PKEE (Polish Electricity Association)	Moderate scenario of PKEE (Polish Electricity Association)
Forecast of the volume of produced steel in total [million tonnes]	9.593	9.192-9.769	8.608-9.723
Forecast of the volume of produced steel in the BOF technology [million tonnes]	5.871	4.224-5.471	4.24-5.408
Forecast of the volume of produced steel in the EAF technology [million tonnes]	3.731	4.280-5.117	4.330-4.570

Source: own study.

7. Conclusions

On the basis of the summary (table 11), it can be concluded that the respective forecasts of the volume of steel produced in Poland will not exceed 10 million tonnes in 2020. According to the optimistic scenario metallurgical enterprises will produce ca. 9.7 million tonnes and according to the moderate scenario from 9.2 to 9.5 million tonnes. The pessimistic scenario assumes the production at the level of 8.6 million tonnes. The share of steel obtained through the BOF technology in the total steel production can assume two extreme scenarios: the share of this technology will still be significant (reaching even 60% of production in total) or it will drop and the share of steel obtained from electric furnaces will slightly increase. According to the second scenario, the shares of respective technologies in the total steel production will slightly differ from the current ones (table 6). It can be concluded that in 2020 in the range of the steel production technology in Poland there will not be any major changes (the present proportions shall be maintained). In the long run (projections until 2050) the increase of the share of recovered scrap from the present 45% to 70% will entail the increase of the share of the electric process in the production of steel (Paduch, and Szulc, 2014, p. 3-11). When the present proportions are reversed, the approximate 60% of steel shall not be produced through the converter process, but in electric furnaces. Reaching the proportion: 40% – integrated process and 60% – electric furnaces is dictated by ecological requirements – reduction of CO_2 emissions (the adopted proportions will reduce the CO_2 emissions from the present level of 1.8 to 0.6 tonnes per 1 tonne of steel in 2050) (Paduch, and Szulc, 2014, p. 3-11). The technological changes will also bring about energy savings – lower energy consumption from the current level of 21GJ to 8.6 GJ per tonne of steel. Within the next three years (short-term forecast until 2020) the Polish steel sector will not record any major changes. The current production capacity amounts to 13.055 million tonnes of crude steel, including 7.6 million tonnes in the integrated process.

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