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EXTERNAL COSTS OF OPEN-CAST LIGNITE MINING FOR THE AGRI-FOOD INDUSTRY (AS ILLUSTRATED BY THE EXAMPLE OF THE OCZKOWICE MINE)

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Abstract. The purpose of this study is to calculate the externalities for the agriculture and the agri-food industry of planned open-cast lignite mining on the Oczkowice reserve. The mine's area of impact extends to 7 districts of south-west Wielkopolska. The study envisages 2 options for the depression crater's impact (mine dewatering) on crop production and 2 scenarios of losses in livestock production. Losses due to unrealized production in the agricultural and agri-food sectors within a 100-year time horizon (50 years of mining and 50 years for hydrological recovery) are estimated to range from PLN 22.4 billion to PLN 174 billion. Externals costs, defined as lost profits, are estimated to range from PLN 5.1 billion to PLN 39.5 billion. Compared to the value of lignite from the Oczkowice reserve, the level of external costs and production losses in the agricultural and agri-food sectors make open-cast lignite mining at that location an economically unviable project.

Keywords: open-cast lignite mining, externalities, crop production, agri-food industry

INTRODUCTION

According to estimations, from 2010 to 2050, as a consequence of rapid population growth and a shift in diets, the demand for agricultural products in the world will double due to increased demand for food (by 70%) and biofuel (by 30%) (Zegar, 2012). Additionally, the demand for high-quality (animal and horticultural) products grows at an even higher pace, reaching 6–7% p.a. in developing countries (Zegar, 2013).

Already now, the shortage of fresh water poses an important barrier to production growth in the agriculture and beyond. In many regions around the world, the agriculture sector must compete for water with the industrial and processing plants or, recently, with the water-expensive shale oil and gas extraction sector. The increasing competition for water, which cannot be substituted, gives rise to increasingly stronger tensions that threaten the world's order (Zegar, 2013).

According to recent forecasts, by 2050, the global consumption of energy will grow by a rate ranging from 30% to over 100%, depending on the estimations. Forecasts which envisage lower energy consumption levels assume that energy efficiency will improve considerably (Frei et al., 2013). In Poland, by 2050, the demand for final energy will probably decrease by 10–25% compared to 2010 (Polityka energetyczna..., 2015).

Due to exhaustion of lignite resources in active open-cast mines, Polish energy holdings look for new reserves to extract lignite. One of the potential sites is Oczkowice, a lignite reserve located in the Gostyń and Rawicz districts, with identified resources of ca. 1.0 billion tons (Przybyłek and Górski, 2016). ZE PAK S.A., the investor, believes this reserve to be very promising. In 2016, they started preparing a technical and economic study

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and an environmental impact report. It may be expected that if the exploration of this reserve is economically viable to the investor, they will undertake measures to implement the investment. However, on the other hand, open-cast lignite mining involves numerous externalities (economic, environmental and social impacts). The conventional economic theory (neoclassical economics, mainstream economics) promotes such concepts as 'perfect competition on a free market' and '*homo oeconomicus*', and assumes the absence of externalities (which are illegitimate). This theory, due to its microeconomic nature, is focused on private economic benefits while leaving the disadvantages to others (the society, nature, future generations). Therefore, it gave rise to global issues in the economic, environmental and socio-cultural dimension (Zegar, 2013). Because free goods (including natural resources) were not appraised, less attention was paid to the need for ensuring social and ecological sustainability. The foregoing demonstrates the need to deploy the institutional factor (policy) in order to create such boundary conditions for the market mechanism that will bring the outcome of microeconomic competitiveness as close as possible to the social and environmental optimum. The key to an environmentally friendly economy is to make the market (prices) reflect the full costs of products, including externalities, which are often very difficult to appraise (Baum, 2014).

In view of the above, the purpose of this study is to calculate the externalities for the agriculture and the agri-food industry of the planned open-cast lignite mining on the Oczkowice reserve. The static variant used in this study assumes that the agriculture productivity level will remain stable throughout the impact period. Externalities that affect the natural environment (fauna and flora), forestry, air quality, health, displacement, infrastructure and other issues are not covered. The mines' agricultural impact will be felt in Gostyń and Rawicz districts (the location of the Oczkowice deposit) and in neighboring districts. The external costs related to agri-food processing will be imposed on collectors of agricultural raw materials originating from the area considered, and will therefore be spread across the country. The time interval for this analysis is a period of around 50 years where lignite is supposed to be extracted, extended with another 50-year period of hydrological recovery in the area of the exploited reserve.

EXTERNALITIES OF OPEN-CAST LIGNITE MINING

External economies is a term first used in 1890 by Alfred Marshall, a Briton and one of the founders of neoclassical economics (Baum, 2014). However, neoclassical economics focused on an unrestricted growth of wealth through the maximization of productivity based on exploitation and exhaustion of resources, both human and natural (whether renewable or not) (Zegar, 2012). Because focusing on microeconomic efficiency and related matters exacerbates the global problems, the concept of sustainable development grows in importance (Kiełczewski, 2011). This may be seen as a compromise between the commitment to continued socio-economic development, the need to seriously address the natural and social limitations (Baum and Śleszyński, 2008), and the commitment to intra- and intergenerational fairness (Poskrobko, 2011). Sustainable development also redefines the concept of true enrichment which means increasing wealth in a specific area without detriment to other ones. National wealth comprises natural and environmental wealth, anthropogenic material and financial wealth, physical and intellectual human wealth, and social, cultural and institutional wealth (Poskrobko, 2011). Therefore, a shift must be made from economic (market) competition to social competition which takes macroeconomic externalities into account.

The construction of, and extraction of lignite from, new open-cast mines (especially in new locations) result in a series of (both favorable and adverse) secondary effects experienced in the economic, environmental and socio-cultural area.

The investment will have a positive impact on the labor market, at least initially. Unfortunately, as the highest-paid jobs will probably be offered to professionals from the investor's other plants, the local population will be left with several hundred less attractive blue collar jobs. In the local labor market, demand will also be generated by local suppliers of services to the investor and its collaborators. The supply of professionals will increase the population size, and will boost demand for accommodation and more expensive products and services, thus making the region less dependent on the broadly defined agribusiness sector. Lignite mining is also subject to a mining fee charged by the municipality which will significantly improve the investment capacity of Miejska Górka and Krobia municipalities.

The construction of a new power plant will also enable increasing the production of cheap electricity in Poland (without taking externalities into account). However, recently – due to decreasing prices of coal, oil and gas-energy from lignite has become quite expensive. Also, as a part of the environmental restoration process, the investor shall leave intact the pre-agreed leisure areas for use by the local community.

Adverse effects mean, on the one hand, the temporary nature of positive effects, most of which will no longer be generated upon discontinuation of extraction operations. On the other hand, open-cast mining is the most invasive method of lignite extraction which leaves the local community with a significantly altered landscape, including the high external dump and the flooded pit.

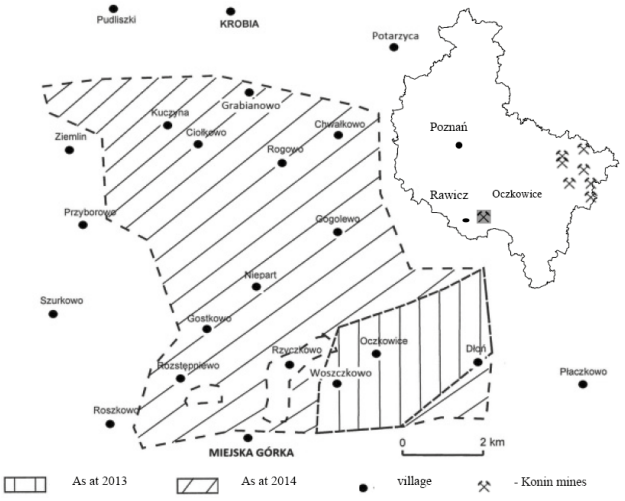

Fig. 1. Oczkowice lignite deposit in south-west Wielkopolska as specified in the MIDAS database of the Polish Geological Institute – Polish Research Institute.
Source: Przybyłek and Górski, 2016.

CHARACTERISTICS AND HYDROGEOLOGICAL CONDITIONS OF THE OCZKOWICE RESERVE

The Oczkowice lignite reserve was documented during geological works in the 1960s. The Poniec-Krobia reserve was documented in the 1970s. In 2011, the Minister of the Environment granted PAK Górnictwo Sp. z o.o. with a license for the exploration and prospection of lignite deposits in the "Poniec–Krobia" and "Oczkowice" zones. In 2014, pursuant to Appendix 1 (as approved), a part of the Poniec-Krobia reserve (Przybyłek and Górski, 2016) (Fig. 1) with a total area of 71.04 km^2 and a fully reliable estimation of 996 million tons of recoverable geological resources (531 million tons classified as C_1 and 465 million tons classified as C_2) (Przybyłek and Górski, 2016), with an estimated value of lignite ranging from PLN 75 billion to PLN 100 billion, was officially incorporated into the Oczkowice reserve.

The lignite deposit lies at a depth ranging from 111 to 134 m below ground level, in the area of the hydrotechnical system. The thickness of the deposit varies from 11 to 14 meters (Przybyłek, 2015). In this location, open-cast lignite extraction would have a devastating environmental impact. This results from the complex geological structure of the deposit itself, and from regional surroundings which include deep grabens (Deczkowski and Gajewska, 1980) and strongly mineralized (up to 100 g/dm^3 near Rawicz) underground water reservoirs located under the lignite deposit (Przybyłek and Górski, 2016). Also, the geological structure is conducive to underground water flow (Bojarski, 1996).

The Oczkowice reserve is located in a region with the lowest precipitation in Poland and the longest low-water periods in rivers of the right-bank catchment area of Barycz during summer and fall (Kępińska-Kasprzak, 2015). This is another crucial factor for the agriculture and potential losses in plant production. Also, the construction of the open-cast mine will result in destroying all hydrogeological structures in the quaternary layer, including underground water reservoirs with extreme importance for water management in this part of the Kalisz upland.

In 2015, ZE PAK did not yet have their own development concept for the lignite reserve, and therefore this paper is based on a preliminary development concept for Oczkowice by Kasztelewicz et al. (2012). According to the assumptions, there will be an excavation area of 5855 ha and the inevitable external dump with an area of 574 ha. However, operations are highly likely to extend over the entire area of the reserve (71.04 km^2). Thus, because of additional space occupied by external escarpments, the site will be extended to an area of 90 km^2 (Przybyłek and Górski, 2016). Note also that more agricultural land will be lost to accommodate the mining facilities and the power plant.

CHARACTERISTICS OF AGRICULTURE IN THE GOSTYŃ AND RAWICZ DISTRICTS

As regards land use, the planned excavation area is dominated by agricultural land (91%) with a negligible share of forests (4.7%) and buildings and roads (4.3%), which reflects the purely agricultural nature of this region. This is confirmed by the land use patterns in the Gostyń and Rawicz districts and in five neighboring districts where the share of forests is consistently lower than the average rate in the Wielkopolskie voivodeship (25.5%) (below 15% in the Gostyń, Kościan and Rawicz districts). The municipality of Górka has the best soil in the Rawicz district while the municipality of Krobia has the best soil in Wielkopolska (50% of land rated as class II or IIIa) (Raport o stanie…, 2000). This is one of the regions with the lowest precipitation in Poland, which would be a particularly detrimental feature if the area was deprived of a large part of subsoil water and surface water.

In this region, farms demonstrate very high levels of animal production concentration. In the seven districts under consideration, with 79.33 bovine animals per ha (103.66 bovine animals per ha in the Gostyń district), the cattle population per 100 ha of agricultural land was more than twice as large as the national average as at 2010. For the cows, the ratio was 63% higher than the national average, or 157% higher in the Gostyń district (44.01 cows per ha). When it comes to swine and sows, the gap between the regional and national average figures is even larger. The stocking density was 266–275% higher than the national average, and as much as 4.0–4.5 times the national average in the Gostyń and Rawicz districts (respectively: 445.12 pigs per ha and 397.12 pigs per ha; and 39.25 sows per ha and 37.69 sows per ha) (Charakterystyka gospodarstw…, 2012). Districts in this region also experience positive changes in livestock population. According to Table 1, from 2002 to 2010, the livestock population growth rate recorded in each of the districts was above the national average and reached 33.3%, or 17.6% in the case of cows (the cow population declined by more than 40% only in the Jarocin district). As regards the swine population, the decline rates reported in the region under consideration were below the national average. The most outlying results were recorded in the Rawicz district where the pig and sow population grew by 20.3% and 17.2%, respectively.

Table 1. Characteristics of selected districts of the Wielkopolskie voivodeship as at 2010

Specification	Share of agricultural land in total area (%)	Agricultural land area (ha)	Animal population (unit)				Change in population (2002 = 100%)			
			cattle	cows	pigs	sows	cattle	cows	pigs	sows
Poland	49.58	15 502 969	5 760 585	2 657 365	15 278 051	1 426 575	104.1	92.5	82.0	74.4
Wielkopolskie voivodeship	60.01	1 789 875	844 289	304 467	4 819 561	383 753	117.2	102.9	100.3	82.2
Gostyń district	77.27	62 608	59 562	25 288	255 776	22 551	138.8	130.9	86.0	81.7
Rawicz district	76.60	42 400	40 682	12 206	223 360	21 195	125.8	107.1	120.3	117.2
Jarocin district	74.80	43 928	23 299	5 132	108 172	12 887	104.4	59.5	89.8	106.8
Kościan district	73.00	52 737	44 218	15 469	163 132	15 321	138.5	131.0	94.2	89.9
Krotoszyn district	73.00	52 099	53 882	20 125	185 658	17 521	135.1	117.0	81.8	77.8
Leszno district	66.66	53 713	29 731	10 106	182 445	17 238	131.0	114.8	80.5	75.0
Śrem district	65.98	37 877	22 608	8 191	127 184	12 577	168.7	165.5	106.1	115.0
Total 7 districts	72.45	345 361	273 982	96 517	1 245 727	119 290	133.3	117.6	92.3	90.9

Source: Charakterystyka gospodarstw…, 2012; Raport z wyników…, 2003.

METHODOLOGICAL ASSUMPTIONS

In 2017, the project to operate the Oczkowice reserve was not developed yet. Therefore, in this paper, external costs are calculated based on the development concept presented by Kasztelewicz et al. (2012). Accordingly, the open-cast mine is supposed to cover an area of 5855 ha, including 5324 ha of agricultural land. An additional area of 574 ha will be used by the external dump. During the 50-year lifecycle of the mine, an average of 60% of that area will be out of agricultural use. This is why the calculations assume that losses in crop and animal production will reach 60% in the area of the open-cast mine. From the agricultural perspective, most of that land will be irrecoverably lost. After environmental rehabilitation, former mining sites are dominated by forests and leisure sites (Gilewska and Otremba, 2013). Note also that remediated agricultural land is an anthrosol which often largely differs from natural soils in a number of properties: absence of the accumulation horizon, low content in nutrients, unstable yields (Gruszczyński, 2010).

The sowing pattern was determined based on data from the 2010 general agricultural census (Charakterystyka gospodarstw…, 2012). The yield level was determined based on data from yearbooks published by the Central Statistical Office in the 1976–1995 period. Accordingly, yields recorded in the Leszczyńskie voivodeship were, on average, 15% above the average level reported within the modern territory of Wielkopolskie voivodeship. As the excavation area is best quality agricultural land, it is conservatively assumed to produce 30% higher yields than the average figures recorded in the Wielkopolskie voivodeship. The buying-in prices of agricultural products were calculated based on average prices recorded in the Wielkopolskie voivodeship over the 2011–2015 period. The value of remaining production was calculated using the share of specific crops in the sowing pattern in proportion to the share of cereals, rape and beet (and the value thereof).

Losses in livestock population were calculated in proportion to the mine's share in the agricultural land area of districts under consideration. The following yield rates were used: 300 kg of live cattle per bovine animal (other than cows); 6283 liters of milk per cow (2015 average for the Wielkopolskie voivodeship) (Fizyczne rozmiary…, 2016); 180 kg of live pig per porcine animal; and 18.7 piglets per sow (2015 average for the Wielkopolskie voivodeship) (Zwierzęta gospodarskie…, 2016).

The estimation of production losses and external costs around the open-cast mine is much more complicated as it involves the following factors that are difficult to quantify:

- the development and reach of the depression crater and its impact on declining yields,
- the restrictive impact of lower yields on animal production (in the case of bovine animal production – which almost totally depends on the farms' own feedstuffs – the impact will be more severe than in the case of porcine animal production with a share of own feedstuffs at a level of around 50%) (Pepliński et al., 2004),
- the impact of lower profitability of agricultural production on the farms' investments (this will result in reduced productivity and lower performance levels compared to other regions),
- the impact of lower production profitability on the farmers' decisions to discontinue livestock production (lower volumes of own feedstuffs will reduce the animal population; this will lead to an increase in fixed costs; a total depopulation of the herd will be the ultimate consequence),
- the impact of lower agricultural production volumes on the turnover of agri-food companies and regional suppliers of productive inputs.

The dewatering of the aquifer will result in the creation of a deep, extended depression crater. As calculated by Dąbrowski et al. (2015) and Przybyłek and Górski (2016), the planned drainage crater will result in a decline in groundwater table (which is of key importance to agriculture) in the area located within 3–5 km (or more) from the boundaries of the reserve (or even up to 10 km alongside the excavations). The area of the planned low-pressure crater will be multiple times larger than that of the documented lignite reserve (with a radius of up to 20–25 km). This analysis assumes that the drainage crater will extend over an area of 300 km^2 approximately, with a 75% share of agricultural land. Therefore, the impact area of the drainage crater will be around 22,500 ha of agricultural land (scenario 1).

Note that the depression crater includes the zone where dewatering will cause a permanent decline in groundwater table (by 1 meter or more). A prolonged decline in groundwater table, even by several dozen centimeters, has a strong impact on yields, especially

as regards meadows and pastures which demonstrate a strict relationship between yields and a high groundwater table (Malewski, 2011). Therefore, the mine's impact on the environment and arable crops is likely to extend over a larger area. To determine that impact, the evolution in crop yield and animal population in the former Konińskie voivodeship was benchmarked against corresponding data from the remaining part of today's Wielkopolskie voivodeship in 1956–1970 and 1976–1995 periods (Table 2). In the second (most realistic) scenario, the mine's impact area was extended to cover the entire area of Gostyń and Rawicz districts and two thirds of neighboring districts from the Wielkopolskie voivodeship (i.e. Jarocin, Kościan, Krotoszyn, Leszno and Śrem districts) with a total farming area of 260,000 ha (ca. 66% of agricultural land of the former Konińskie voivodeship). This area coincides with that of the planned low pressure crater which will adversely affect groundwater through numerous hydraulic windows.

Table 2. Cereal yields in today's Wielkopolskie voivodeship (not including the former Konińskie voivodeship) and in the former Konińskie voivodeship in 1956–1995 (dt/ha)

Specification	Wielkopolskie	Konińskie	Wielkopolskie = 100%
1956–1960	16.85	15.72	93.35
1961–1965	19.96	18.66	93.49
1966–1970	18.61	16.93	90.98
1976–1980	25.88	20.98	81.06
1981–1985	27.47	23.14	84.24
1986–1990	36.29	27.16	74.86
1991–1995	32.30	24.46	75.73

Source: own elaboration based on Central Statistical Office data.

In the 1956–1960 period, at the very beginnings of lignite extraction operations near Konin, crop yields in the former Konińskie voivodeship were only 6.65% lower than average figures for the then-existing Poznańskie voivodeship. However, already in the 1991–1995 period, they were ca. 24% below the average level. The reduction in crop yields is probably stronger in the immediate vicinity of open-cast mines. It will take many decades to reverse this trend, as the recovery of groundwater table in decommissioned Konin mines (much shallower than the Oczkowice open-cast mine) is supposed to take 30 years or more (Stachowski, 2007). In the case of Oczkowice, that period may even extend beyond 50 years. Southern Wielkopolska may be expected to experience similar rates of crop yield decline due to the depression crater. In view of the above, the loss in yields is assumed to be the same as in the former Konińskie voivodeship, i.e. 18.9% (scenario 2) or 25% within the depression crater (scenario 1).

The changes in livestock concentration in the former Konińskie voivodeship was compared to the evolving situation in today's Wielkopolskie voivodeship (not including the former Konińskie voivodeship). The analysis failed to provide any consistent clues as to the impact of open-cast mines on animal population (Table 3). Compared to 1959, in 2010, cattle concentration in the area of the former Konińskie voivodeship was 36% higher while pig concentration was 25% lower; in the remaining part of the Wielkopolskie voivodeship, the respective concentration rates were 5% higher and 46% lower. In the area of the former Konińskie voivodeship, the increase in concentration of pig livestock and sows was significantly lower than in the remaining part of Wielkopolska. The rates were 43% and 15%; and 312% and 173%, respectively. During the analysis period, in the former Konińskie voivodeship, the animal population (converted into livestock units) increased by 20% while an increase by 47% was recorded in the Wielkopolskie voivodeship (not including the former Konińskie voivodeship). In view of the above, the estimated decline rates of livestock production within the depression crater area are as follows: in the case of cattle, 20% in scenario 1 and 15% in scenario 2 (the shortage of feedstuffs is supposed to be partially offset by an additional forage area); in the case of pigs, 12.5% and 9.5%, respectively (the share of own feedstuffs is assumed to be 50%). In the optimistic scenario, the decline rates were calculated based on the estimated losses in crop yields. In the pessimistic scenario, a decline rate of 30% was used for each group of livestock, though it may reach even 50% in several decades.

Table 3. Concentration of livestock population in today's Wielkopolskie voivodeship (not including the former Konińskie voivodeship) and in the former Konińskie voivodeship 1959–2010 (animals / 100 ha of agricultural land)

Specification	Wielkopolskie				Konińskie				Wielkopolskie = 100%			
	cattle	cows	pigs	sows	cattle	cows	pigs	sows	cattle	cows	pigs	sows
1959	43.64	30.28	72.79	8.60	39.16	28.78	68.35	8.82	89.73	95.03	93.91	102.63
1965	52.32	28.26	102.18	11.08	43.60	27.43	90.98	11.61	83.35	97.07	89.04	104.79
1975	71.32	29.47	155.92	14.54	74.90	29.40	89.56	10.56	105.02	99.76	57.44	72.60
1985	59.23	26.75	153.25	15.38	58.16	28.54	82.96	10.33	98.19	106.70	54.14	67.14
1996	44.22	16.79	252.15	23.40	45.11	21.12	118.85	12.02	102.02	125.74	47.13	51.36
2002	38.91	15.45	285.65	27.55	43.38	20.66	148.78	15.56	111.48	133.72	52.09	56.51
2010	46.08	16.18	299.89	23.46	53.27	21.67	97.60	10.12	115.61	133.94	32.54	43.14

Source: own elaboration based on Central Statistical Office data.

The external costs of launching the open-cast mine were calculated as follows:

$$K_z = \sum A \times P \times S \times C \times R + \sum Po \times W \times S \times C \times R,$$

with:

K_z – external costs (PLN),
A – cultivation area of the crop concerned (ha),
P – yields (t/ha),
S – level of losses (%),
C – buying-in price (PLN/t, PLN/l, PLN/unit, PLN/kg),
R – profitability (%),
Po – population of livestock concerned (animals),
W – performance or output (l, unit, kg/unit).

The estimation of external costs for the agri-food industry makes the following assumptions: the share of agricultural raw materials in the sales value of the agri-food industry is 50%; 80% of pig and cattle livestock and of milk is intended for processing. For crop production estimations, the average value of bought-in crop products in the 2011–2015 period, which is PLN 1642.8 per ha of agricultural land (GUS, 2012–2016), was used.

COSTS OF THE POSSIBLE CONSTRUCTION OF THE OPEN-CAST MINE

The construction of an open-cast mine involves multiple environmental, social and economic impacts. In the case of agriculture and agri-business, the key drivers of external costs include:

- permanent and temporary exclusion of agricultural land and forests from agricultural production (approximately 70 km^2 of land to be occupied by the mine and the external dump),
- permanent disturbance to hydrological regimes around the mine caused by the depression crater and the low-pressure crater,
- liquidation of all farms located within the area of the planned mine, and of many farms that will lose a large part of their land for the construction of the mine,
- decrease in livestock production in liquidated farms (to a known extent), and decrease in production volumes in farms that will lose a large part of their land for the construction of the mine or will be located within the depression crater, due to decrease in production of own feedstuffs,
- disturbance to the raw material base used by the agri-food industry.

The value of unrealized agricultural production within the open-cast mine area depends on the cultivation area, yields and buying-in prices of specific plants and – as regards livestock production – on the number, productivity and buying-in prices of animals.

The value of unrealized plant and livestock production within the area occupied by the open-cast mine (including the external dump) is estimated at PLN 48.0 million per year. During the 50-year lifecycle of the mine

Table 4. Annual costs for crop and animal production

Specification		Mine	Scenario 1	Scenario 2
Plant production				
Area (ha)		5,898.0	22,500.0	260,000.0
Losses (%)		60.0	25.0	18.9
Cultivated area (ha)	cereals	3,151.4	12,022.0	138,921.2
	potatoes	116.5	444.4	5,135.4
	sugar beets	141.8	540.8	6,249.5
	rape	369.2	1,408.6	16,277.1
	others	2,119.1	8,084.1	93,416.8
Yield (t/ha[1])	cereals	5.3	5.3	4.7
	potatoes	32.7	32.7	28.9
	sugar beets	78.8	78.8	69.7
	rape	3.7	3.7	3.3
Buying-in price (PLN/t)	cereals		672.8	
	potatoes		616.0	
	sugar beets		131.4	
	rape		1623.7	
Production losses (PLN million)	cereals	6.8	10.8	83.1
	potatoes	1.4	2.2	17.3
	sugar beets	0.9	1.4	10.8
	rape	1.3	2.1	16.6
	others	5.8	9.3	71.6
	total	16.2	25.8	199.4
Total external cost		4.1	25.8	199.4

Animal production						
Specification		mine	optimistic scenario	pessimistic scenario	optimistic scenario	pessimistic scenario
Area of districts (%)		5.62	21.43*		75.28**	
Losses (%)	cattle	60.0	20.0	30.0	15.0	30.0
	milk	60.0	20.0	30.0	15.0	30.0
	pigs	60.0	12.5	30.0	9.5	30.0
	sows/piglets	60.0	12.5	30.0	9.5	30.0
Population (animals)	cattle	100,244.0	100,244.0		273,982.0	
	milk	37,494.0	37,494.0		96,517.0	
	pigs	479,136.0	479,136.0		1,245,727.0	
	sows	43,746.0	43,746.0		119,290.0	
Buying-in prices	cattle (PLN/kg)		6.21			
	milk (PLN/l)		1.25			
	pigs (PLN/kg)		4.90			
	piglets (PLN/animal)		150.72			
Production losses (PLN million)	cattle	3.9	5.0	7.5	37.3	74.6
	milk	9.2	11.7	17.6	79.6	159.2
	pigs	14.2	11.3	27.2	78.6	248.1
	piglets	4.3	3.4	8.3	25.1	79.2
	total	31.7	31.5	60.5	220.6	561.1
Total external cost		7.9	7.9	15.1	55.1	140.3

Source: own elaborations based on purchase volumes and prices of agricultural products (Central Statistical Office, 2012–2016).
*Share of the mine and depression crater in the total area of Gostyń and Rawicz districts.
**Share of dehydrated area in the total area of Gostyń, Rawicz, Jarocin, Kościan, Krotoszyn, Leszno and Śrem districts.

and the subsequent 50-year period of hydrological recovery, this provides a total of PLN 4.8 billion (the share of plant production is 34%). With a gross margin of ca. 25%, this results in external costs of ca. PLN 1.2 billion (Table 4).

Also, significant costs will be caused by the depression crater. In the first scenario, where only the depression area is covered, the annual costs for crop production are estimated at the level of PLN 25.8 million. However, if the impact of dewatering on agricultural land in neighboring districts (scenario 2) is taken into account, the costs may reach as much as PLN 199.4 million per year (PLN 2.6–19.9 billion over the entire period of impact). In this case, the decrease in crop yields means an almost total reduction of the farmers' profits which will be neither invested nor consumed. Therefore, it will also have an impact on the sales figures of local companies, whether related to the agricultural sector or not.

Because of the high concentration of livestock production, production losses related to the decrease in animal population are significantly higher than in the case of crop production. Within the area of the estimated depression crater (scenario 1), the estimated decline in livestock production ranges from PLN 31.5 million to PLN 60.5 million per year (or from PLN 220.6 million to PLN 561.1 million in scenario 2). With a gross margin of 25%, the external costs, spread over a 100-year period, result in a total ranging from PLN 0.8 billion to PLN 1.5 billion and from PLN 5.5 billion to PLN 14.0 billion, respectively.

During the 100-year period, the unrealized production of agricultural raw materials in the area concerned will amount to a total ranging from PLN 10,5 billion to PLN 80.8 billion (including losses incurred within the open-cast mine site); the most realistic amount of losses is PLN 46.8 billion. External costs, defined as income foregone, will account for PLN 4.6–35.2 billion, and the most realistic cost level will be PLN 26.6 billion.

Significant costs will be incurred by the agri-food industry. This is largely due to the restricted ability to import unprocessed raw materials such as pig and cattle livestock, industrial fruits and vegetables, and milk. Depending on the scenario used, the estimated annual

Table 5. Annual costs for the agri-food industry and decline in yearly sales

Specification		Mine	Scenario 1		Scenario 2	
Crop production						
Area (ha)		5,898.0	22,500.0		260,000.0	
Loss (%)		60.0	25.0		18.9	
Buying price (PLN/ha)			1,642.8			
Losses (PLN million)		11.6	18.5		161.5	
Animal production						
Specification		mine	optimistic scenario	pessimistic scenario	optimistic scenario	pessimistic scenario
Production losses (PLN million)	cattle	6.3	8.0	12.0	59.7	119.4
	milk	14.8	18.8	28.2	127.3	254.7
	pigs	22.8	18.1	43.5	125.7	397.0
	total	43.8	44.9	83.6	312.8	771.1
Loss in crop and animal production (PLN million)		55.5	63.4	102.1	474.2	932.6
External costs for crop and animal production (PLN million)		2.4	2.7	4.4	20.4	40.1

Source: own elaborations based on purchase volumes and prices of agricultural products (Central Statistical Office, 2012–2016).

decrease in the processing companies' sales turnover may range from PLN 11.9 billion (the most optimistic scenario) to PLN 93.3 billion (the second, pessimistic scenario). The author believes that in the most probable scenario, the sales volume of Polish processors will decline by PLN 53.0 billion. The decrease in sales turnover will also have an adverse effect on profits. With a sales profitability ratio of 4.3% (Rocznik..., 2017), the yearly decline in investments and dividends will range from PLN 0.51 billion to PLN 4.25 billion (most of these costs will be incurred by companies located near the planned mine). Costs borne by wholesale and retail trade operators will be of minor importance because either the food shortages will be covered by imports, or the volume of exports from Poland will be reduced.

SUMMARY

Oczkowice is located in a region which demonstrates the highest concentration levels of livestock production and is maintained in the best agricultural condition of all Polish regions. Therefore, the launch of an open-cast lignite mine in that location will imply extremely high external costs for the agricultural production and for the agri-food sector during the mining operations and hydrological recovery (100 years approximately). In the most realistic scenario, the costs are estimated to reach around PLN 28.9 billion while the value of unrealized production in the agricultural and agri-food sectors is estimated to be PLN 99.8 billion. In a pessimistic scenario, the external costs and production losses may reach PLN 39.5 billion and PLN 174 billion, respectively. This will translate into lower investments and a reduced sales turnover in companies from the agricultural and agri-food sectors. The employment level will also be adversely affected.

Compared to the value of lignite from the Oczkowice reserve, the level of external costs and production losses in the agricultural and agri-food sectors make open-cast lignite mining at that location an economically unviable project.

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