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THE IMPACT OF COPPER PRICE VARIATION ON THE ECONOMIC EFFICIENCY AND ENVIRONMENTAL SUSTAINABILITY OF KGHM OPERATIONS

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WPŁYW ZMIAN CEN MIEDZI NA EKONOMICZNĄ EFEKTYWNOŚĆ DZIAŁALNOŚCI KGHM W KONTEKŚCIE KRYTERIÓW ROZWOJU ZRÓWNOWAŻONEGO

STRESZCZENIE: Przedsiębiorstwa górniczo-hutnicze obecnie muszą sobie radzić z presją kosztową wynikającą z konieczności wydobycia rud z coraz gorszej jakości złóż oraz ze stagnacją cenową spowodowaną nadwyżkami produktów końcowych. W tym kontekście, w artykule przedstawiono możliwe reakcje firm górniczych na tę sytuacje na podstawie analizy danych operacyjnych KGHM. Firma KGHM została wybrana ponieważ poziom obrotów oraz profil firmy mogłyby sugerować, że jest bardziej narażona na przedstawioną sytuacje niż większe czy bardziej zdywersyfikowane firmy. Wyniki analizy wskazują, ze mimo tej pogarszającej się sytuacji firma podniosła wydajność operacyjną równocześnie zmniejszając uciążliwość środowiskową. KGHM mogłaby więc potencjalnie służyć jako wzór dla firm górniczych we wdrażaniu bardziej trwałych modeli biznesowych pod względem operacyjnym i środowiskowym.

KLUCZOWE SŁOWA: ceny miedzi, górnictwo i hutnictwo miedzi, ochrona środowiska, rozwój zrównoważony

Introduction

According to the World Bank, following the commodity boom of the first decade of the 21'st century, Mining Companies (or Miners in industry parlance) operate in a climate of longer-term stagnant prices[1]. This, is compounded by increasing costs due to weaker ore grades at existing or projected mines. The two forces combined mean that Miners are effectively "caught" between pricing pressure and cost pressure[2].

This is especially the case with Copper and, in this business context, the paper attempts to provide some insights into how Copper Miners respond to this situation based on an analysis of operational data for the Polish Copper Miner KGHM. KGHM was selected because a company of this size and profile could be more affected by this environment then larger or more diversified companies. A second reason for selecting KGHM was because of the knowledge available within the AGH Faculty of Management. In this context, this analysis is presented as a continuation of the contribution of the Faculty to a deeper understanding of the Copper Industry[3].

With 3.6% market share of Global Copper Production[4], KGHM volumes probably do not have significant pricing impact. Moreover, the company's largest volumes come from seams deep underground which, combined with declining ore grade quality, results in KGHM running a significantly more expensive operation than its competitors (data shown later in this paper). Therefore, an analysis of KGHM seemed appropriate to better understand how Copper Miners are responding to these challenges.

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1 World Bank Group, *Commodity Markets Outlook, July 2016*. License: Creative Commons Attribution CC BY 3.0 IGO – Commodity Index Tables Washington, DC. 2016.

2 A. Lala et al., *Productivity in mining operations: Reversing the downward trend*, "McKinsey Quarterly" 2015 no. 5.

3 T. Pindór, *Przemysł miedziowy w Polsce jako uczestnik rynku światowego*, in: Conf. Proc.: *Aktualia i perspektywy gospodarki surowcami mineralnymi,* Krakow 1992; B. Barchański, T. Pindór, *Bergbau und Metallurgie der NE-Metalle in Polen (I)*, "Erzmetall", Clausthal 1993; B. Barchański, T. Pindór, *Bergbau und Metallurgie der NE-Metalle in Polen (II)*, "Erzmetall", Clausthal 1993; B. Barchański, T. Pindór, *Kupferindustrie in Polen*, "Bergbau" Clausthal 1999; T. Pindór, *Restruktuierung der Kopferindustrie in Polen*, in: L. Preisner (ed.), *Umwelt- und* Ökonomischeaspekte *der Bergbaurestrukturierung*, Krakow 2002; T. Pindór, *Zrównoważony rozwój Legnicko-Głogowskiego Okręgu Miedziowego*, in: E. Lorek (ed.), *Zrównoważony rozwój regionów uprzemysłowionych*, Katowice 2009; T. Pindór, *Przekształcenia międzynarodowych rynków miedzi w latach 1980–2012*, Wrocław 2014.

4 KGHM. *2015 Annual Report,* Lubin 2016. Total KGHM Refined Copper Production (KGHM own sources plus. KGHM International plus purchased concentrate) = 697,1kt. World Bank Group. 2016. *Commodity Markets Outlook, July 2016*: Global Refined Copper Production = 19.308kt.

The results of the analysis indicate, that despite worsening business conditions, KGHM not only successfully improved efficiency but also reduced the environmental burden of its operations as well as reducing operating costs. Thus, the company may provide guidance to Miners or other companies in implementing more sustainable operation models from both a business and environmental perspective.

To present the subject the paper is divided in five sections. The first section is this introduction followed by an introduction to the Global Copper Market describing the challenges noted above and the position of KGHM in this market. The third section consists of an overview of KGHM while the forth section presents an analysis of the company's operational data and a discussion to try to identify the company's responses to this business environment. Based on the analysis in the fourth section, the paper ends with a Conclusion presenting some ideas on how Miners could effectively reconcile Business and Environmental goals.

Global Copper Industry Challenges

According to the World Bank[1], of the 6 Base Metals (Aluminium, Copper, Lead, Nickel, Tin, Zinc), Copper is by value, the largest global base metal market and has the second highest global refined production volume (Copper – 23,097Mt, Aluminium – 57,342Mt).

Copper is also a fairly plentiful mineral. Per the U.S. Geological Survey[5], global identified resources total 2.100 Mt (around 100 years supply at current volumes) and one can conclude the supply of Copper is assured so long as prices exceed Production Costs. This abundance is to some extent shown in the actual and forecast Copper prices[6] presented in figure 1 (World Bank Actual and Forecast prices 2006–2025 at constant 2010 US$).

Reviewing figure 1, it is evident that, after a turbulent period during the commodity boom, Copper prices fell sharply after 2011 and are forecast to recover slowly from 2016. Thus, for the medium term, Miners can expect much tougher market conditions.

However, although Copper is a fairly plentiful resource, average ore grades at existing mines and planned investment projects are weaker than their historical levels. This is for two main reasons; – firstly, ore deposits are

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5 USGS, *Estimate of Undiscovered Copper Deposits of the World 2013*, Washington DC 2014. Useful background information can also be found in: T. Pindór, L. Preisner, *Wycena zasobów rud miedzi*, in: Conf. Proc.: *Rachunek ekonomiczny w gospodarce surowcami mineralnymi*, Kraków 1990.

6 World Bank Group. 04.2016. *World Bank Commodities Prices (the Pink Sheet)/ World bank Commodities Price Forecast April 2016*. World Bank License: Creative Commons Attribution CC BY 3.0 IGO, Washington DC 2016.

of a defined size so ore grade diminishes as more ore is extracted and secondly, investment in new mine projects with lower ore grades becomes viable when Copper prices increase due to demand growth[7] (causing the "cyclical nature" of mine investments because of the 20–30 year lead-time between project start-up and start of economic exploitation).

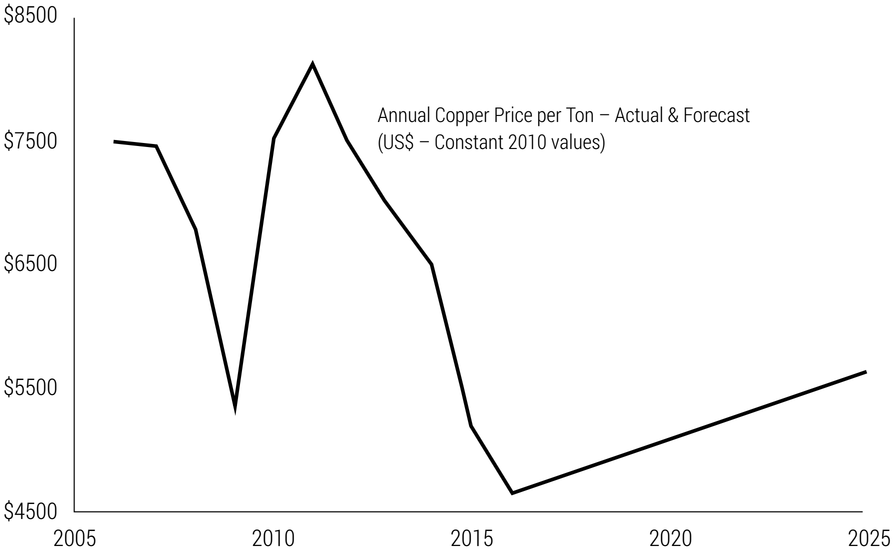

Figure 1. Actual & Forecast US$ Copper Prices (annual averages)

Source: World Bank – Pink Sheet Data & Commodity Forecast.

This weakening in ore grade is visible in the data shown in figure 2 based on data from two industry consulting companies originally presented in a report by the Investment Banking Arm of a leading international Bank[8]. Figure 2 presents on a global level over time, average ore grade combining existing mines and new mine projects.

The conclusion from figure 2 is that the steady downward ore grade trend means extraction volumes have to increase to maintain similar levels of refined Copper. This cannot but result in higher extraction costs per ton. Thus over time, Copper Miners can expect the Operating Costs of their mining activities to steadily increase.

In this context, what is the situation of KGHM compared to other Copper Miners?

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7 P. Gait, *The Growth of Productivity in Copper Mining and The Long Term Evolution of The Reserve Base*, Presentation to the ICSG Environmental & Economics Committee, Lisbon 2015

8 A. Bukacheva et al., *Copper Industry Strategy*, BDO Capital Markets, Montreal/ London 2014.

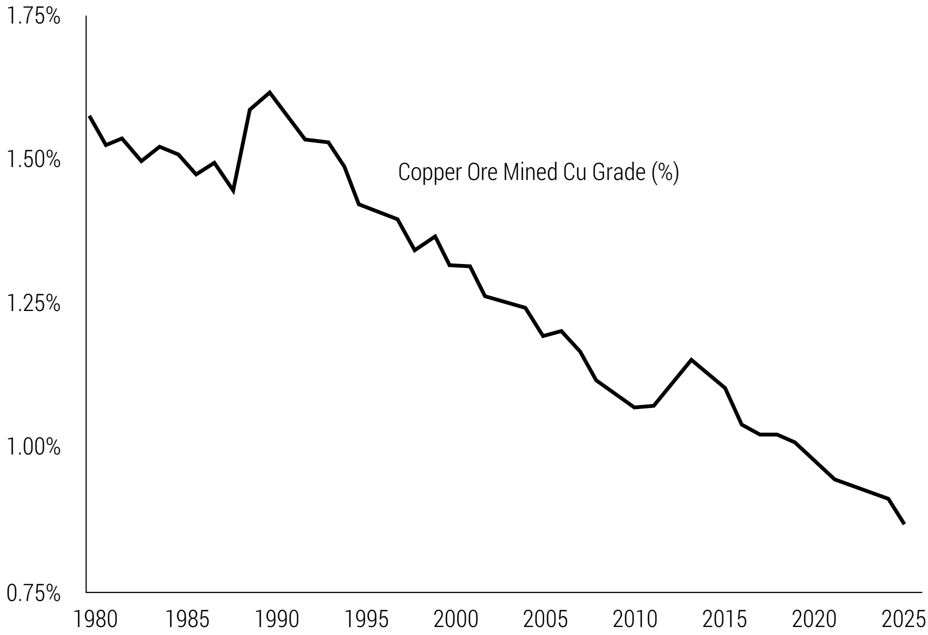

Figure 2. Global Average Percentage Refined Copper in Mined Copper Ore

Source: BMO Global Mining Research(based on Brook Hunt / Freeport McMoRan data).

Table 1, taken from a relevant article on the subject[9], presents this using data for the 10 largest Copper mine entities[10]. Mine entities are presented and not Miners (eg. the data on KGHM presents only its Polish Operations not including its Chilean or Canadian operations) because it allows a comparison across operating units (for instance: data on Daily Ore Volume Extracted from the Mine or Operational Cost of producing One Ton of Refined Copper) rather than macro level data where each Miner has a specific (and quite different) operational profile[11].

9 V. Peckham, *These 10 mines will set the Copper price for the next decade*, www.Mining.com [03–11–2015].

10 Mine Entities in this context are distinct operating units consisting of one or several mines forming a separate legal entity which may (or may not) be part of a conglomerate.

11 For instance CODELCO the largest global Copper Miner (10% global production) concentrates on mining and production of Copper Concentrate. KGHM mines and also refines all its production.

Table 1. 10 Largest Copper Mine Entities

Order	Mine Operation	Start Year	Country	Owners	Open Pit / U.grond	Exracted Ore Vol. / Day	Refined Cu Production Vol. / Yr.	Refined Cu Cash Cost	Mine Reserves	Reserve Ore Grade (Cu)	Mine Life
					OP / UG	kt	kt	US$/t	Bt	%	yrs.
1	Escondida	1990	Chile	BHP Biliton	OP	1 300	1 140	**2 440**	26.20	**0.52%**	54
2	Collahuasi	1880	Chile	Anglo American, Glencore	OP	705	470	**3 238**	3.25	**0.80%**	70
3	El Teniente	1905	Chile	CODELCO	UG	137	452	**2 622**	1.67	**0,93%**	50
4	KGHM Poland in Operations	1968	Poland	KGHM	UG	88	420	**4 391**	1.15	**1.52%**	45
5	Los Bronces	1867	Chile	Anglo American	OP	397	405	**2 052**	2.06	**0.51%**	35
6	Los Pelambres	2000	Chile	Antofa-gasta	OP	400	391	**2 690**	1.49	**0.52%**	24
7	Morenci	1872	USA	Morenci	OP	816	369	**N/A**	9.70	**0.25%**	23
8	Antamina	2000	Peru	BHP Biliton, Glencore	OP	532	345	**N/A**	0.65	**0.94%**	13
9	Chuquicamata	1911	Chile	CODELCO	OP	N/A	340	**2 166**	0.90	**0.83%**	40
10	Radomiro Tomic	1997	Chile	CODELCO	OP	N/A	327	**2 896**	2.06	**0.47%**	40

Source: Investing News: www.investingnews.com (12.10.2016).

Comparing the position of KGHM to the other mine entities, Reserve Ore Grade (1.52%) and Mine Life (45 years) are both positive factors which show the ore quality of KGHM's operations in Poland. What is less positive (compared to other mine entities), is the high extraction cost. At US$ 4,391.= per ton the cost is over 100% more than the lowest cost producer. One reason is that the mines forming the Polish KGHM Entity are deep underground with intrinsically high operating costs. However, another reason is the relatively low daily extraction rate ("Extracted Ore Vol. / Day" column) which, among other factors, is due to the lower number of work days at Polish mines[12].

This Production Cost factor will be discussed in more detail in the next section which presents an overview of KGHM with a review of some challenges the company faces.

KGHM Overview

As presented in table 1, in 2015, KGHM's operations in Poland formed the World's fourth largest Copper mining entity. In that year, the entire company (Poland plus KGHM International) extracted 562kt of Copper making KGHM the sixth largest global Copper Miner (just before the mining operations of Rio Tinto with 555kt.)[13].

As well as Copper, KGHM produces extensive quantities of Silver and in 2014 was the World's number one Silver Miner[14]. Reserves (estimated at 85kt.) place the company on a par with Australia as having the World's second largest Silver reserves[15].

There are however some challenges. The first one is ore depletion affecting the Polish mines of KGHM. This is illustrated in figure 3 which presents the volumes of ore extracted from these mines to produce broadly similar volumes of refined Copper. Figure 3 is based on data from the company's Annual Reports[16].

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12 W. Bogdan et al., *Poland 2025: Europe's new Growth Engine*. 2015, McKinsey & Co, Warszawa, page 52 of this report presents a comparison of "Effective Working Time" in mines in Poland, Czech Republic, USA and Canada. Mines in Poland operate for 256 days per year, mines in the Czech Republic 355 days, mines in the U.S. and Canada 365 days.

13 Investing News, *10 Top Copper-producing Companies*, www.investingnews.com [12–10–2016].

14 The Silver Institute, *World Silver Survey 2015*, www.silverinstitute.org [12–10–2016].

15 Sources: Data on Global Silver Reserves; – USGS, *Mineral Commodity Summaries – Silver: 2016*, 2016, www.minerals.usgs.gov [12–10–2016]. Data on KGHM Silver Reserves; – KGHM, *Mineral Resources and Reserves Report – as at 31.12.2014*, 2015, www.kghm.com [12–10–2016].

16 KGHM, *KGHM Annual Reports 2000–2015*, Lubin 2001–2016.

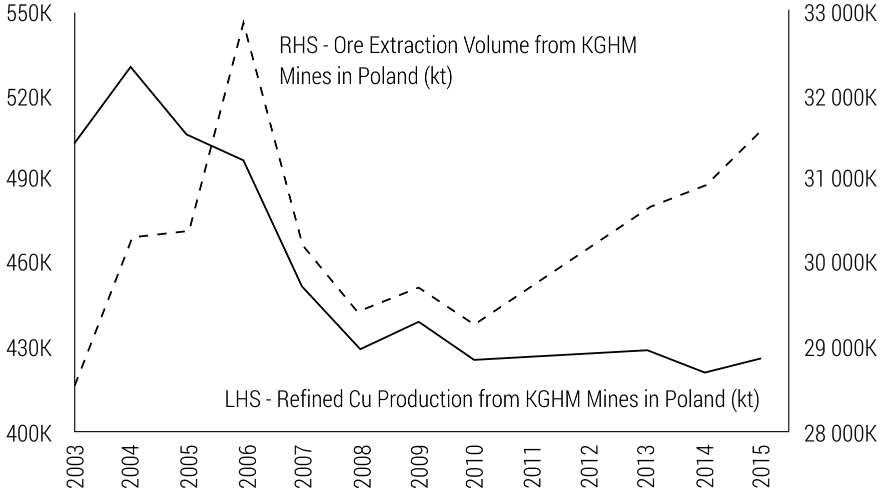

Figure 3. Refined Copper Production from KGHM Mines in Poland (LHS) / Ore Extraction Volumes from KGHM Mines in Poland (RHS)

Source: KGHM Annual Reports 2005 – 2015.

The additional extraction requirement shown in figure 3 can be seen comparing 2003 against later years. In 2003, KGHM used 28,515 kt. ore to produce 503,213 t. refined Copper. In 2010, it extracted 29,303 kt. ore from which it produced almost 78,000 t. less Copper. In 2015, the company, with 8% more ore than in 2010 (almost 2,300 kt.), produced a similar Copper volume. Thus, whilst KGHM ore grades are better than its competitors, over time Copper ore yields become significantly poorer which, combined with the low mine working days, cannot but have a negative Production Cost impact.

This impact is presented in figure 4 which plots the costs (in PLN) of producing one ton of refined Copper against annual KGHM ore grade. the Production cost is shown in PLN to more accurately reflect the cost structure of the Polish mines. This figure is also based on data from KGHM Annual Reports[17].

The visual trend over time of declining ore grade and increased Production Costs evident in figure 4 was confirmed by a Pearson Correlation Analysis of -0.94.

This Production Cost increase is despite Cost Reduction initiatives (impact evident from 2013 onwards) which resulted in a reduction of around 10% per ton refined Copper[18].

17 Ibidem.

18 Reviewing the data for 2014 and 2015, this 10% reduction in KGHM Production Costs is maintained despite the need to extract an additional 665kt. ore because of worsening grades.

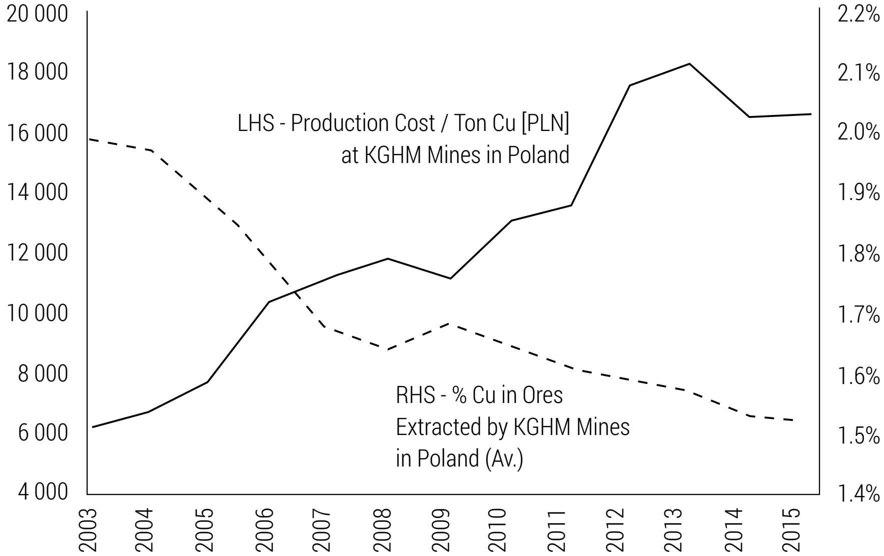

Figure 4. Refined Copper Production Cost in PLN at KGHM Mines in Poland (LHS) / Copper ore grades from KGHM Mines in Poland (RHS)

Source: KGHM Annual Reports 2005 – 2015.

However, with worsening ore grades and restrictions on the number of mine working days, there are limits to the steps KGHM can take to reduce costs. In this situation, additional steps were needed to support a viable long-term business and this aspect will be discussed in more detail in the next section of the paper.

Analysis of KGHM Polish Mine Production of Precious Metals and Co-products

The analyses presented in this section were carried out on yield data for the additional metals or other products KGHM extracts from Copper ore. The purpose was to try to identify whether the weak business environment had a positive or negative impact on process efficiency or environmental sensitivity.

The products analysed are co-products from processes for producing Copper (KGHM's primary product). Thus, comparison of co-product yields per ton of primary product yield should give an indication whether KGHM has become more or less operationally efficient. Moreover, as some co-products (such as Sulphur Dioxide or Lead) have a deleterious environmental impact, analysing co-product yield/ primary product yield for these products should also give an indication whether lower prices and higher costs were coincident with a better or worse environmental control.

Table 2 shows KGHM's extraction volumes of rare and precious metals over time. These are usually extracted from anode slime which accumulates in the final stage of the Copper refining process. Anode slime output relates to Copper volumes whereas yield for specific co-products depends on the efficacy of a specific extraction process. In this context table 2 shows; – total output volume, output volume per ton refined Copper produced and percentage change of output volume compared to 1995 as base year.

Reviewing table 2, what is immediately apparent is the increased efficiency of the Gold extraction processes. Between 1995 and 2015 Gold output improved by 441%. What is especially significant is the "jump" of just over 300% between 2013 and 2014 and this high output being maintained in 2015 (implying a process change and not a "one-off"). Whilst the quantity of Silver in the KGHM Polish mines was known from the start, it is an open question whether so much Gold was identified when the mines commenced commercial life 50 years ago. With regard to Silver, the improvement (28%) from 1995 is lower but still significant given the value of the metal. In this context, the evident conclusion reviewing table 2 has to be that, over time, KGHM has significantly improved the efficacy of its precious metal extraction processes.

Table 2. Precious Metal Extraction per ton Refined Copper from KGHM Mines in Poland

	1995	2000	2005	2010	2011	2012	2013	2014	2015
Refined Copper [kt]	405 739	486 002	506 248	425 344	426 665	427 064	428 879	421 300	420 500
Refined Silver [t]	964	1 110	1 244	1 161	1 260	1 274	1 161	1 256	1 283
Refined Gold [t]	0.474	0.367	0.713	0.776	0.704	0.916	1.066	2.530	2.660
Refined Silver [kg] per ton Refined Copper	2.3759	2.2839	2.4573	2.7296	2.9531	2.9832	2.7071	2.9812	3.0511
Refined Gold [kg] per ton Refined Copper	0,0012	0,0008	0,0014	0,0018	0,0017	0,0021	0,0025	0,0060	0,0063
Refined Silver Improvement [%]	100%	96%	103%	115%	124%	126%	114%	125%	128%
Refined Gold Improvement [%]	100%	65%	121%	156%	141%	184%	213%	514%	541%

Source: KGHM Annual & Environmental Reports 2000–2015 / KGHM Web Site Historical Data.

A point about table 2 that should be noted is that KGHM also refines other metals and products from Slime (such as Pl / Pt Concentrate or Selenium) however, the quantities so far seem to be not yet fully stabilised[19] and thus are not presented in this table.

Table 3 is similar in construction to table 2 and presents two products; – Sulphuric Acid and Lead[20]. Sulphuric Acid is produced from Sulphur Dioxide, a co-product of the smelting operation, whereas Lead is a co-product of smelting which also occurs in anode slime. Thus, production volumes for these products are related to Copper production volumes permitting a similar analysis to that presented in table 2. Some additional products are also produced as part of the smelting or concentrating operations (eg. Copper Sulphate, Nickel Sulphate) but their volumes are lower and more variable so they were not included in this analysis.

Table 3. Sulphuric Acid and Lead production per ton Refined Copper from KGHM Mines in Poland

	1995	2000	2005	2010	2011	2012	2013	2014	2015
Refined Copper [kt]	405 739	486 002	506 248	425 344	426 665	427 064	428 879	421 300	420 500
Sulphuric Acid [t]	447 100	544 400	621 570	559 668	636 248	630 837	609 019	646 074	650 000
Refined Lead [t]	12 100	12 527	21 050	20 892	25 234	27 511	26 631	26 128	30 400
Sulphuric Acid [t] per ton Refined Copper	1.10	1.12	1.23	1.32	1.49	1.48	1.42	1.53	1.55
Refined Lead [kg] per ton Refined Copper	29.82	25.78	41.58	49.12	59.14	64.42	62.09	62.02	72.29
Sulphuric Acid Improvement [%]	100%	102%	111%	119%	135%	134%	129%	139%	140%
Refined Lead Improvement [%]	100%	86%	139%	165%	198%	216%	208%	208%	242%

Source: KGHM Annual & Environmental Reports 2000–2015 / KGHM Web Site Historical Data.

From an efficiency improvement perspective, table 3 presents a similar picture to table 2. Over the 20 year period since 1995, KGHM has improved Sulphuric Acid output by 40% and Lead output by 142%. The efficiency gain reflects an additional 450kg Sulphuric Acid per ton (of Copper) and over 42kg of Lead. These quantities, multiplied by Copper volumes, come to almost 190kt p.a. Sulphuric Acid and 18kt. p.a. Lead. These are significant

19 KGHM, *KGHM Annual Reports 2000–2015*, op. cit.

20 Some useful background information can be found in: L. Preisner, T. Pindór, *Heavy Metals Emission in the Copper Region in Poland*, in: Mining and Environment Research Network (MERN) "Research Bulletin and Newsletter", Bath 1995.

volumes, that previously "disappeared" into the environment and which now provide additional value as a result of improved process efficiency.

To finish the analysis, table 4 was developed to identify additional turnover KGHM generated by the extra co-product volumes shown in tables 2 and 3. Table 4 is thus based on the quantity data in tables 2 and 3 combined with price data from several sources (World Bank Commodity Prices[21], U.S. Dept. of Labor – Sulphuric Acid Price Indexes[22], CRU Consulting Group – Sulphuric Acid Price Data[23]). Included in the table 4 Precious Metal figures are the "trace quantities" of Selenium (of which KGHM occasionally produces up to 90 tons / year) and, in the Co-Product figures, the fairly low quantities of Copper and Nickel Sulphates (about 6,500 and 2,500 tons respectively) which the company sometimes produces:

Table 4. Volumes, Turnover (in 2010 US$) and % Value Contribution of Copper, Precious Metals (mainly Ag and Au) and other Co-Products (mainly Pb, H_2SO_4) from KGHM Mines in Poland

	1995	2000	2005	2010	2011	2012	2013	2014	2015
Pl Production – Precious Metals Turnover [K.US$]	181 709	226 321	344 908	782 804	1 354 832	1 241 859	891 378	829 911	710 890
Pl Production – Other Co-Products Turnover [K.US$]	58 433	61 894	119 630	97 244	146 008	163 633	162 441	155 740	144 245
Total Pl Production Turnover [K.US$]	1 535 932	1 396 001	2 588 064	4 084 921	4 958 387	4 565 894	4 018 794	3 716 663	3 048 354
Pl Production – Copper [% Total Turnover]	84%	79%	82%	78%	70%	69%	74%	73%	72%
Pl Production – Precious Metals [% Total Turnover]	12%	16%	13%	19%	27%	27%	22%	22%	23%
Pl Production – Other Co-Products [% Total T.O.]	4%	4%	5%	2%	3%	4%	4%	4%	5%

Source: KGHM Annual & Environmental Reports 2000–2015 / KGHM Web Site Historical Data / World Bank Group / U.S.Bureau of Labor Statistics / CRU Consulting Group.

Reviewing table 4, an immediate conclusion is the increasing significance of the non-Copper turnover where, over the 20 years presented above, it has

21 World Bank Group. 04.2016. *World Bank Commodities Prices (the Pink Sheet)/ World Bank Commodities Price Forecast April 2016*. op. cit.

22 Bureau of Labor Statistics – Databases Tables & Calculators by Subject, 25.10.2016, *Producer Price Index – Series id: WPU0613020T1 / Sulfuric Acid*, U.S. Dept. of Labor – Bureau of Labor Statistics.

23 J. Peacock, *Sulphuric Acid Market Outlook – Demand for Fertilizers, Metal and Uranium*, London 2009.

increased from 16% to 28% of turnover. In Silver, the figures reflect KGHM's progress from an important Silver producer to Number 1 Global Miner in 2014. In Gold, where KGHM currently produces 2.6 tons, there was a 137% volume increase between 2013 and 2014 / 2015.

With regard to the other co-products KGHM produces, the turnover impact (around 5%) is much lower, however it is still significant and equates to around 15% EBITDA[24]. This EBITDA impact is important, but so also is the effect of lower quantities of harmful products (such as Sulphur Dioxide or Lead) released into the environment.

Because of fluctuations in prices of specific metals or products not all improvements are reflected linearly in the above data, however, a general conclusion from table 4, for KGHM's shareholders, would be that without the non-Copper volumes, turnover would be almost 30% lower in 2015. The general conclusions from this "operating impact" are reviewed in the next and final section of the paper.

Conclusion

This paper presents an example of the steps a company can take in a declining market situation coupled with increasing production costs. This is a situation which, from a business perspective, is quite common. Most companies, because of their size, volume or marketing power, have little influence on prices for the products they produce. On the other hand these companies are most often under cost pressure because of rising real wages (e.g. as currently in Poland) and / or because of the "sunk cost" needed to keep up with market developments (e.g. new technology investments). In the author's opinion a company such as KGHM is an example of what businesses can do in this situation by applying their internal skills and know-how to review and optimise the product base.

A company which is "squeezed" between prices and costs does not always have to search for new markets or develop new products. Maybe the best potential for development is by harnessing these internal capabilities and KGHM is an example of this.

Moreover, at the same time as increasing volumes of its highest value products (Gold, Silver), KGHM reduced environmental impact by lowering Sulphur Dioxide and Lead emissions by many thousand tons. All this taking place whilst the company was implementing a cost reduction programme and reducing costs by 10%.

24 KGHM, *KGHM 2015 Annual Report*, Lubin 2016.

The data presented in this paper thus shows that the triple goals of; – increased turnover, reduced environmental impact, internal cost reduction, are not incompatible with each other and perhaps this is the major conclusion from the analysis presented above which is a conclusion that may be relevant not only for Miners in other mineral areas but also for many companies operating in similar business environments to KGHM.

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