

Supplementary Material:

## PGM Production in Southern Africa, Part II: Environmental Aspects

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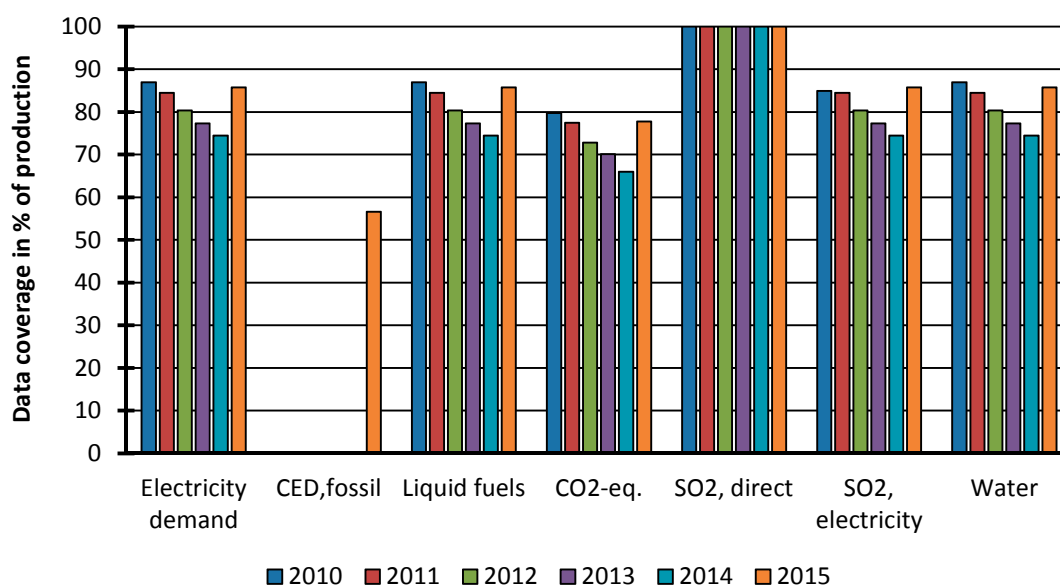
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### Data coverage

The current assessment of environmental aspects of PGE production covers most of the PGE production in Southern Africa (Figure S1). The data coverage is defined here as the share of production for which data are available to overall production. For all indicators except CED<sub>fossil</sub>, at least 66 % of the production is covered. It should be kept in mind that not all companies report data and data reporting is not consistent throughout the years of the assessment (cf. [1]). Scopes and assessment/reporting boundaries might differ among companies.



### Additional Tables

The CED<sub>fossil</sub> of the South African and Zimbabwean electricity mixes were determined based on the CED<sub>fossil</sub> of the respective energy form derived from the Ecoinvent Database [3]. The share of each energy carrier of the total electricity production was obtained from [2].

**Table S1.** Results allocated by average price (2010–2015—prices as reported in Part I).

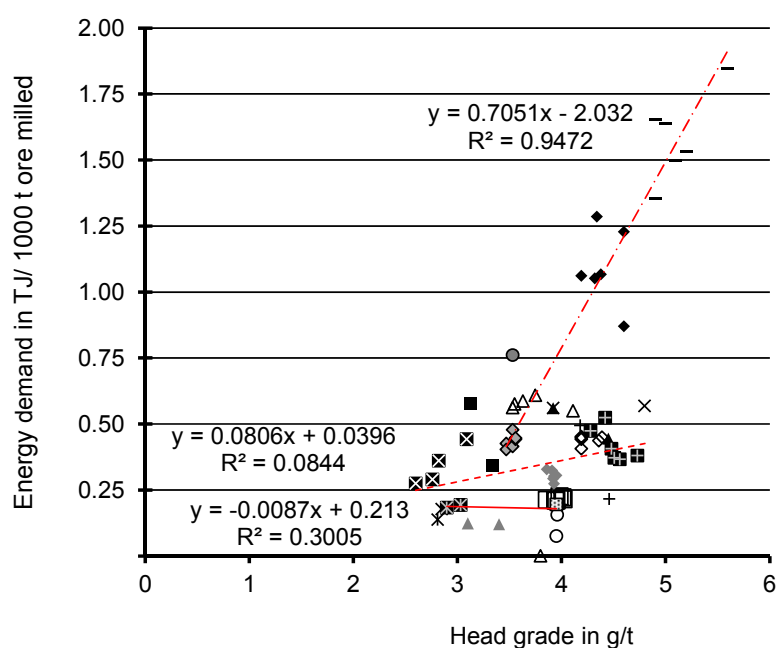
Indicator		2010	2011	2012	2013	2014	2015	Average
Electricity demand in GJ/kg	Pt	77.86	80.49	85.04	83.58	89.44	82.75	83.19
	Pd	20.51	21.20	22.40	22.01	23.56	21.79	21.91
	Rh	10.09	10.43	11.02	10.83	11.59	10.73	10.78
	Au	7.31	7.56	7.98	7.84	8.40	7.77	7.81
	Ru	0.57	0.59	0.62	0.61	0.66	0.61	0.61
	Ir	0.83	0.86	0.91	0.89	0.95	0.88	0.89
	Ni	10.15	10.50	11.09	10.90	11.66	10.79	10.85
	Cu	2.88	2.98	3.14	3.09	3.31	3.06	3.08
Liquid fuels in L/kg	Pt	367.07	389.55	417.81	424.67	501.92	394.82	415.97
	Pd	96.68	102.60	110.04	111.85	132.19	103.99	109.56
	Rh	47.58	50.50	54.16	55.05	65.06	51.18	53.92
	Au	34.45	36.56	39.22	39.86	47.11	37.06	39.04
	Ru	2.69	2.86	3.06	3.11	3.68	2.90	3.05
	Ir	3.91	4.15	4.45	4.53	5.35	4.21	4.43
	Ni	47.87	50.80	54.48	55.38	65.45	51.48	54.24
	Cu	13.57	14.40	15.45	15.70	18.56	14.60	15.38
CED fossil in GJ/kg	Pt						361.83	
	Pd						95.30	
	Rh						46.90	
	Au						33.96	
	Ru						2.65	
	Ir						3.86	
	Ni						47.18	
	Cu						0.013	
CO <sub>2</sub> -eq. in t CO <sub>2</sub> -eq./kg	Pt	24.90	26.37	28.61	28.34	33.85	26.77	28.14
	Pd	6.56	6.94	7.54	7.46	8.92	7.05	7.41
	Rh	3.23	3.42	3.71	3.67	4.39	3.47	3.65
	Au	2.34	2.48	2.69	2.66	3.18	2.51	2.64
	Ru	0.18	0.19	0.21	0.21	0.25	0.20	0.21
	Ir	0.27	0.28	0.30	0.30	0.36	0.29	0.30
	Ni	3.25	3.44	3.73	3.70	4.41	3.49	3.67
	Cu	0.92	0.97	1.06	1.05	1.25	0.99	1.04
SO <sub>2</sub> in kg SO <sub>2</sub> /kg	Pt	232.09	237.18	252.55	257.87	324.78	275.70	263.36
	Pd	61.12	62.47	66.51	67.92	85.54	72.61	69.36
	Rh	30.09	30.75	32.74	33.43	42.10	35.74	34.14
	Au	21.78	22.26	23.71	24.20	30.48	25.88	24.72
	Ru	1.70	1.74	1.85	1.89	2.38	2.02	1.93
	Ir	2.47	2.53	2.69	2.75	3.46	2.94	2.81
	Ni	30.26	30.93	32.93	33.63	42.35	35.95	34.34
	Cu	8.58	8.77	9.34	9.53	12.01	10.19	9.74
Water in 10 <sup>3</sup> L/kg	Pt	141.37	147.82	165.30	159.80	172.94	162.49	158.29
	Pd	37.23	38.93	43.54	42.09	45.55	42.79	41.69
	Rh	18.33	19.16	21.43	20.72	22.42	21.06	20.52
	Au	13.27	13.87	15.52	15.00	16.23	15.25	14.86
	Ru	1.04	1.08	1.21	1.17	1.27	1.19	1.16
	Ir	1.51	1.58	1.76	1.70	1.84	1.73	1.69
	Ni	18.43	19.28	21.56	20.84	22.55	21.19	20.64
	Cu	5.23	5.47	6.11	5.91	6.39	6.01	5.85

**Table S2.** CED<sub>fossil</sub> of different energy carriers.

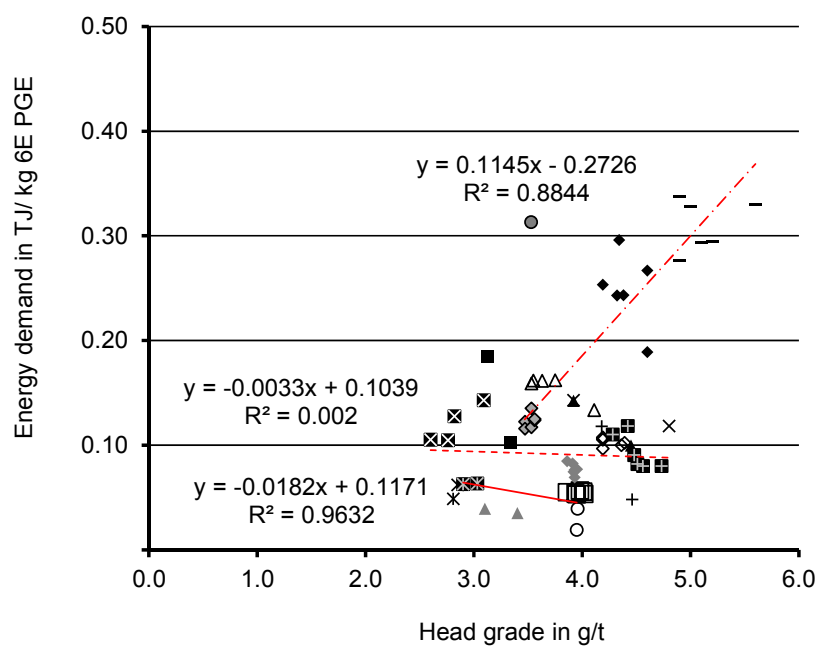
Energy Carrier <sup>a</sup>	Value	Unit	Source
Coal provision, ZA	25.91	MJ/kg	[3]
Natural gas provision, ZA	40.77	MJ/m <sup>3</sup>	[3]
Diesel provision, global	56.98	MJ/kg	[3]
Electricity <sup>b</sup> , nuclear, ZA	0.14	MJ/kWh	[3]
Electricity <sup>b</sup> , coal, ZA	12.86	MJ/kWh	[3]
Electricity <sup>b</sup> , hydropower, ZA	0.05	MJ/kWh	[3]
Electricity mix, ZA	12.06	MJ/kWh	Own calculation based on shares of energy carriers
Electricity mix, ZWE	5.49	MJ/kWh	Own calculation based on shares of energy carriers

<sup>a</sup> 1 MJ is added per MJ of each energy carrier for its combustion; <sup>b</sup> The CED<sub>fossil</sub> of the South African (ZA) and Zimbabwean (ZWE) electricity mix are determined based on the share of the respective energy source in the electricity mix [2].

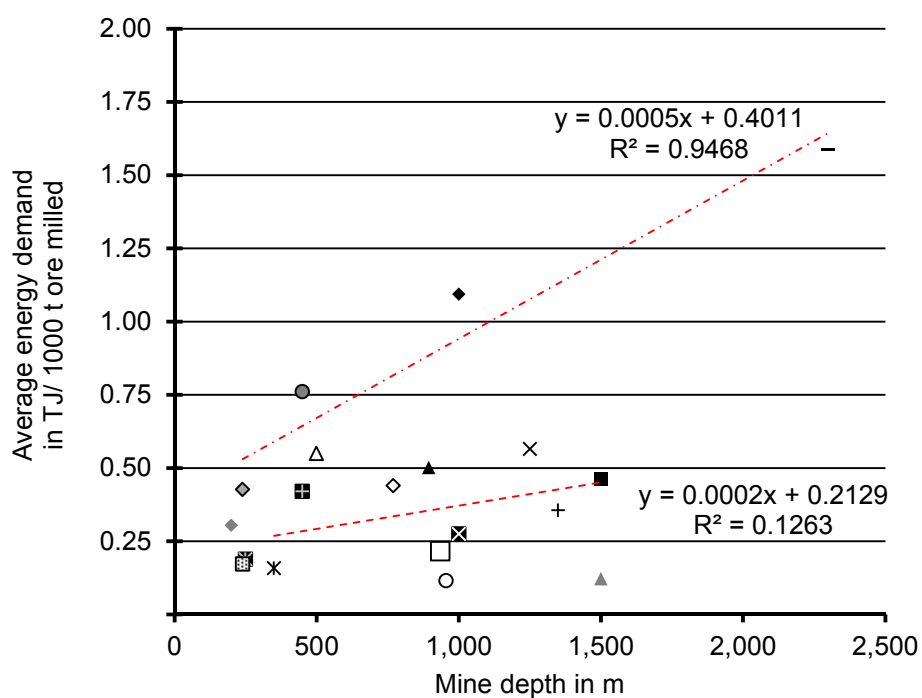
## Figures



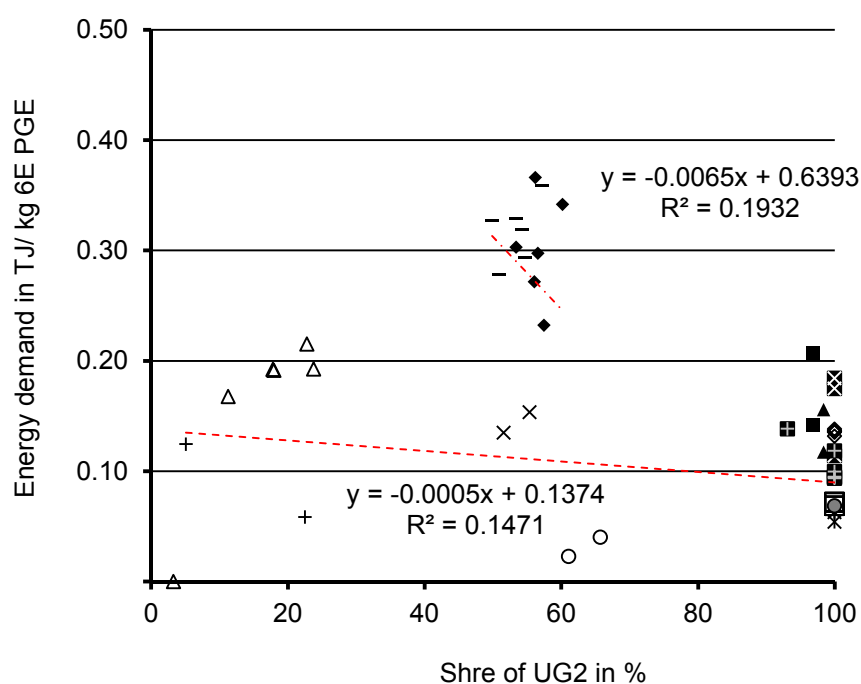
**Figure S2.** Linear regression of data points depicted in Figure 6a. See below for legend (Figure S7). Based on data from [4–16].



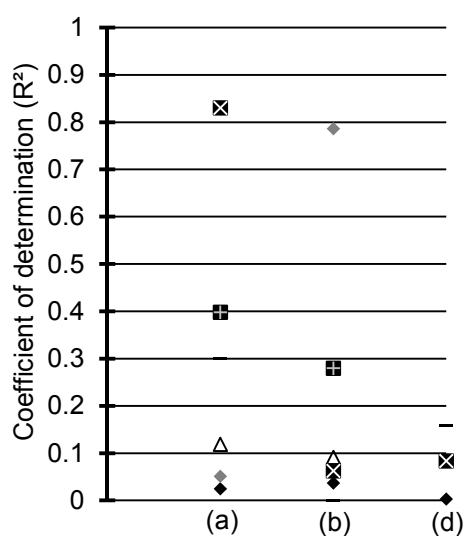
**Figure S3.** Linear regression of data points depicted in Figure 6b. See below for legend (Figure S7). Based on data from [4–16].



**Figure S4.** Linear regression of data points depicted in Figure 6c. See below for legend (Figure S7). Based on data from [4–16].



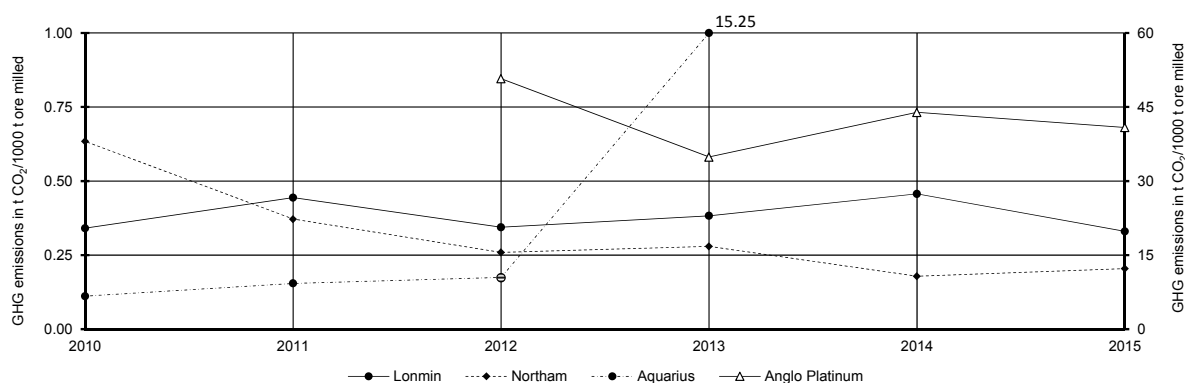
**Figure S5.** Linear regression of data points depicted in Figure 6d. See below for legend (Figure S7). Based on data from [4–16].



**Figure S6.** Linear regression of data points for individual mines depicted in Figure 6b. See below for legend (Figure S7). Based on data from [4–16].

- ◆ Impala Rustenburg [MCS]
- Union [MC]
- ▲ Tumela [MC]
- × Dishaba [MC]
- ✱ Bathopele [MC]
- Thembelani + Khuseleka [MC]
- + Siphumelele + Khomania [MC]
- △ Bafokeng [MC]
- Zondereinde [MCS]
- ◇ Marula [MC]
- Two rivers [MC]
- ⊠ Booyse dal (Everest) [MC]
- ◆ Zimplats [MCS]
- ▲ Unki [MC]
- ◆ Mimosa [MC]
- ⊠ Mogalakwena [MC]
- ⊠ Nkomati [MC]
- Modikwa [MC]
- Kroondal [MC]
- Linear (Trend MC)
- Linear (Trend MCS)
- Linear (Trend OC)

**Figure S7.** Legend of Figure S1–S6. Abbreviations: MC: Mine and concentrator; MCS: Mine, Concentrator and Smelter.



**Figure S8.** Scope 3 GHG emissions. Data points of Anglo Platinum refer to the right axis. All other data points refer to the left axis.

### Comparison to other studies

Results presented in the present paper were compared to reported values of Glaister and Mudd [17] and the Ecoinvent database [3,18] (Figure 15, Table S1). To extrapolate values reported by Glaister and Mudd [17], it was assumed that reported values present the data in 2008. The average annual growth rates of GHG emissions, electricity demand and water withdrawal are 2.40%, 2.73% and 3.05%, respectively (based on data presented in the present work). The annual average growth rate for electricity was taken for energy demand.

**Table S3.** Comparison to other studies.

Study	Year	GHG	Energy	CED <sub>fossil</sub>	SO <sub>2</sub>	Water Withdrawal
		t CO <sub>2</sub> -eq./kg PGE	GJ/kg PGE	GJ/kg PGE	kg SO <sub>2</sub> /kg PGE	m <sup>3</sup> /kg PGE
This work	Average	105.11	102.92		95.53	97.42
	2015	100.00	100.00	100.00	100.00	100.00
Ecoinvent	before 2000 <sup>a</sup>	92.43		79.50	117.55	140.60
Glaister and Mudd	2000–2008	88.01	94.08	85.08 <sup>b</sup>		144.09
Glaister and Mudd	Extrapolated 2008 → 2015	103.90	113.62			177.79

<sup>a</sup> Data of the ecoinvent datasets stem from reports published before 2000 [18]; <sup>b</sup> The reported energy demand of Glaister and Mudd was converted to CED<sub>fossil</sub> using conversion factors, reported in Table S2, and the share of energy sources reported in the current paper (Figure 7).

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