

MINING, ENERGY AND LOW-CARBON ECONOMY IN SOUTH AFRICA: A PLATINUM CASE STUDY

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Abstract: The climate change agenda is increasingly prominent worldwide and has become an unavoidable factor in public policy, with drastic consequences for economic development. Carbon- and energy-intensive industries are prime examples of such effects. This paper reviews the implications of the transition to a low-carbon world on South Africa's platinum value chain, highlighting a complex interplay made of both risks and opportunities for the long-term development of the domestic industry.

The transition to a low-carbon world represents a fundamental transformation for platinum value chains. Despite weakening fundamentals, the South African economy, which plays a leading role in the global supply of platinum, is at the core of this new dynamic, which centred on energy issues. Indeed, the energy-intensive nature of the platinum industry in South Africa, coupled with the country's carbon-intensive energy system is a prime factor of vulnerability for the industry. The ability of firms to reduce risk factors is moreover limited due to the national control over South Africa's electricity supply industry and the nature of platinum mining activities. Firm-level interventions, in terms of energy efficiency and alternative use of energy, nevertheless exist to mitigate the risks associated with climate change response measures and improve the competitiveness of the sector. Furthermore, the global low-carbon transition may open the door to new markets for platinum through the development of fuel cells.

Whether or not, such a shift will be an opportunity or a threat to South Africa's platinum value chains is not definite at this stage. This will largely depend on the ability of the industry, in collaboration with the South African Government and other relevant stakeholders to position the local industry preferably in terms of supply, demand and competitiveness dynamics.

Keywords: low-carbon, mining, platinum, energy, South Africa

1. Introduction

The climate change agenda is increasingly prominent worldwide and has become an unavoidable factor in public policy, with drastic consequences for economic development. Carbon- and energy-intensive industries are prime examples of such effects. This paper reviews the implications of the transition to a low-carbon world on South Africa's platinum value chain, highlighting a complex interplay made of both risks and opportunities for the long-term development of the domestic industry.

Building on two decades of negotiations, the Paris Agreement, signed at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) by 195 countries, marked a definite step towards the political acknowledgement of the need to address the causes and consequences of climate change. South Africa has been an active stakeholder to the UNFCCC since the onset. The country has pledged to peak its greenhouse gas (GHG) emissions between 2020 and 2025 at 34% and 42% respectively, below a business-as-usual trajectory, then plateau for approximately a decade and decline in absolute terms thereafter; subject to the adequate provision of financial resources, technology transfer and capacity building support provided by developed countries (UNFCCC, 2011).

Against that engagement, South Africa's economy is historically structured around the affordable and abundant supply of coal-based electricity and the domination of energy-intensive mining value chains (Fine and Rustomjee, 1996). South Africa's electricity mix is heavily based on coal-fired power plants, which account for 90% of the generation capacity, constituting a major market for the local coal mining industry and a source of cheap electricity for other energy-intensive mining value chains. While this proportion is expected to decrease to 65% by 2030 according to the country's Integrated Resource Plan for Electricity 2010-2030 (IRP 2010), coal-based electricity generation will keep increasing over the period from 235 gigawatt-hour (GWh) to 295 GWh per annum (DoE, 2011). Over and above coal-fired electricity production, substantial support is still being unconditionally directed by the South African Government at energy- and carbon-intensive sectors (i.e. mining value chains) through fossil fuel subsidies and industrial policy (IEA, 2012a; IEA *et al.*, 2010; Koplow and Kretzmann, 2010).

Global dynamics in the climate regime and South Africa's domestic evolution therefore appear in frontal opposition. Going forward, the dichotomy between the global rise of the climate change agenda and the reliance on carbon-intensive activities is set to be an increasing stumbling block to socio-economic development. In the long run, climate change and industrial policies ought to be developed in a symbiotic fashion in order to embark on the transition towards a competitive, climate-compatible economy. "Industrial policy is at the cornerstone of any successful climate change mitigation policy while any successful industrial policy is intertwined with the transition to a low-carbon growth path, making a holistic view integrating both frameworks essential" (Montmasson-Clair, 2015a).

However, transitioning from the current conflicting situation to a more synergetic system is a long-lasting endeavour. It requires a strategic vision for the economy, based on an understanding of the short-, medium- and long-term costs and benefits as well as risks and opportunities associated with the

status quo and the transition. Indeed, the emergence of a new set of climate realities and policies raises the question of the role of industry, particularly mining value chains, in society. Climate change is not so much an environmental problem, but a socio-economic issue questioning the purpose, shape and features of industrial activities.

This paper investigates this matter through the lens of the platinum value chain in South Africa. It shows the complexity of the relationship between an energy-intensive economic activity and the transition to a low-carbon, resilient development pathway in a carbon-intensive energy system. It examines the implications, both positive and negative, of the transition on South Africa's platinum industry and the role of policy in maximising benefits and minimising fallouts.

The paper proceeds as follows. Section 2 presents the platinum industry in South Africa. It highlights the central, although fragile, role of South Africa in the production of platinum and, in turn, the importance of the platinum industry in the South African economy. Section 3 unpacks the central role of energy systems in the interplay between South Africa's platinum mining value chain and the low-carbon transition, framing it as a key factor of risk and vulnerability. Section 4 discusses the opportunity to mitigate such a risk by investing at the firm level. Section 5 then turns to the potential of the low-carbon transition becoming a growth factor for platinum demand in the coming decades. Section 5 concludes with the formulation of policy implications, highlighting the key role of government policies in tipping the balance in favour of opportunities rather than risks.

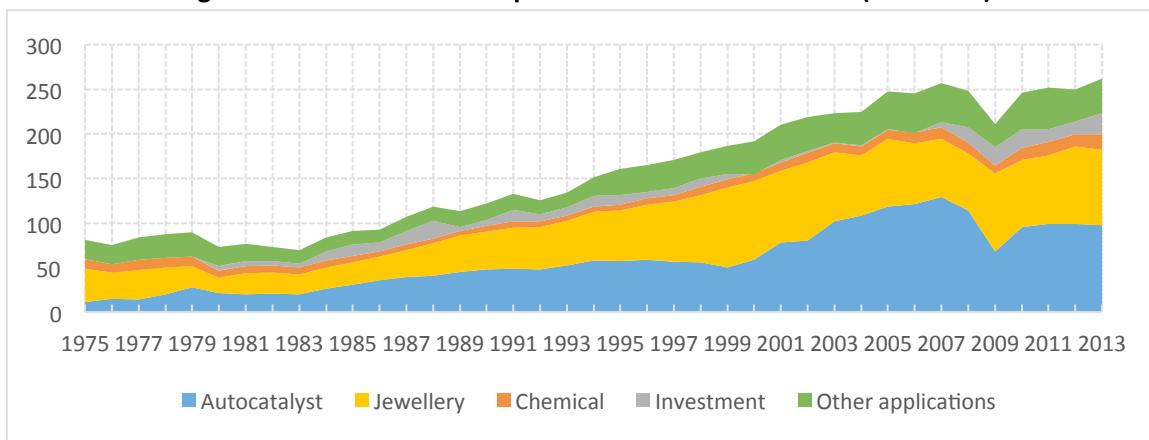
2. The platinum value chain in South Africa: A global but fragile positioning

Before exploring the interplay between the South African platinum industry and the transition to a low-carbon world in the following sections, Section 2 unpacks the close, although fragile relationship between platinum and the South African economy.

2.1. Platinum and South Africa: A close relationship

While platinum has been used in the petroleum industry as a catalyst from the 1950s and for jewellery-making from the 1960s, the demand for platinum has significantly grown from the 1970s with the introduction of air quality regulations for motor vehicles (with the exception of 2009 due to the global economic crisis). As illustrated in Figure 1, despite a decline in share from 50% in 2007 to 37% in 2013, the automotive catalyst industry constitutes the main driver of the platinum market (due to the use of PGMs to convert the noxious gases in vehicle exhausts into harmless substances) (McDonald and Hunt, 1982). Jewellery making and, more recently, industrial/medal and investment usages have also contributed to the growing demand for platinum.

Figure 1: Global demand of platinum from 1975 to 2013 (in tonnes)

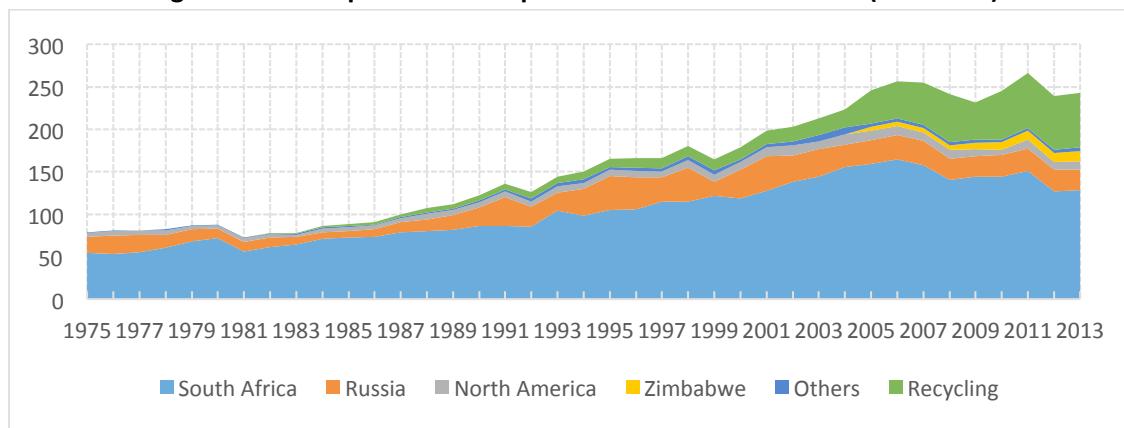


Source: Author's composition based on data from Johnson Matthey

Note: other applications include electrical, glass, medical and biomedical and petroleum.

South Africa is by far the largest producer, as depicted in Figure 2. In 2013, South Africa indeed accounted for 72% of the world production excluding recycling (and 53% including recycling). South Africa benefits from the world's largest deposits of platinum group metals (PGMs), with 63 000 tonnes or 96% of known global reserves (Chamber of Mines, 2014). Three reefs (the Merensky Reef, UG2 Chromitite and the Platreef) make the South African Bushveld Igneous Complex, in the North-Eastern part of the country, the largest platinum resource in the world (McDonald and Hunt, 1982). The global top three producers (Anglo American Platinum, Impala Platinum and Lonmin) are all operationally based in South Africa and are responsible for the majority of global platinum production (between 70% and 85% of primary production depending of the years.¹ Other smaller South Africa-based companies include *inter alia* Aquarius Platinum, Northam Platinum, Royal Bafokeng Platinum, Jubilee Platinum and Wesizwe Platinum.

Figure 2: Global production of platinum from 1975 to 2013 (in tonnes)



Source: Author's composition based on data from Johnson Matthey

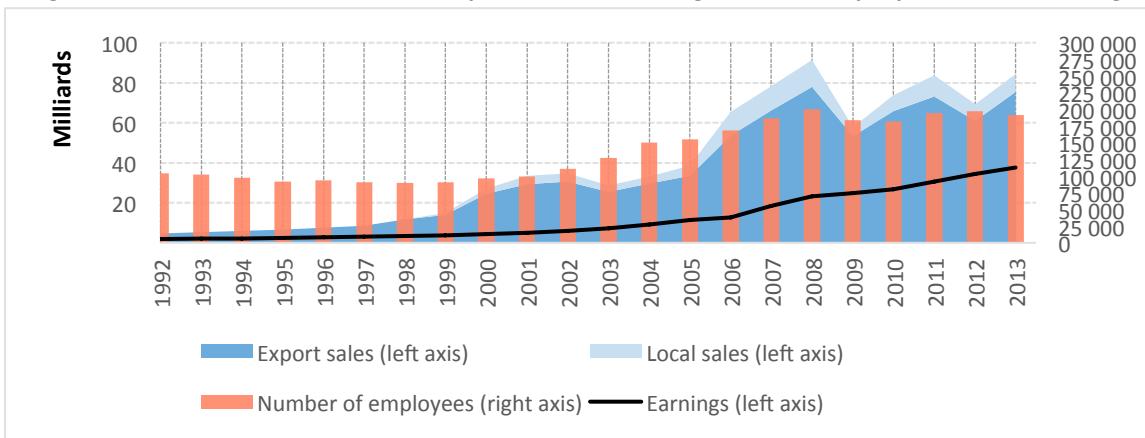
¹ Calculations based on data from Johnson Matthey and companies' annual reports.

Note: movements in stocks explain the discrepancies between global supply and demand. Due to price volatility and demand patterns, annual movements in stocks have reached up to 20 tonnes, such as in 2009 (accumulation).

While demand for platinum has historically increased over time, the global primary production of platinum reached an all-time high in 2006 and has been declining since then, particularly in South Africa. This is largely explained by a steady and continual increase in platinum recycling, which accounted for 27% (i.e. 65 tonnes) of global supply in 2013 (compared to less than 10% in 2004). Over the last two decades, South Africa's platinum industry has in fact lost 16 percentage points of its global market share. The South African industry slid from a position in 2004, when it accounted for two-thirds of the global platinum supply, to providing just over half in 2013. On top of an increased secondary supply of recycled platinum, other structural changes inherent to the platinum market, such as increased stockpiling in recent years, the need for deeper mining, the reduced grade quality of ores, productivity losses as well as increased costs to mine, have all contributed to a slow-down in output (Chamber of Mines, 2014). Global primary supply, led by South Africa, however picked up in 2015 to meet the increased demand (notably as a result of the stagnation of recycling), a trend that should be confirmed in 2016 (Johnson Matthey, 2016).

As a result of South Africa's natural comparative advantage, the platinum value chain plays a unique role in South Africa's economic development. The PGM sector is the largest component of the South African mining sector and, as illustrated in Figure 3, trends in sales and earnings demonstrate a steady growth of the local industry, driven by international markets. Platinum mining contributed 4.1% to South Africa's gross domestic product (GDP) (1.9% directly and 2.2% indirectly) in 2012. In 2012, mineral sales growth accounted for 5.2% of GDP growth, of which 43% came from the platinum sector. PGMs are the largest revenue generator of South Africa's mineral exports, with ZAR 75 billion in 2013, making up 27% of mineral export earnings and between 7% and 15% of total exports (expressed in US dollar) over the last 15 years (Baxter, 2014; Chamber of Mines, 2014). Platinum is also the largest employer in the South African mining sector and a source of growing earnings. It accounted for 26% of all mining employment in the country in 2013, supporting around 325 000 jobs, including 190 000 direct jobs (Chamber of Mines, 2014).

Figure 3: Evolution of South Africa's production (in kilogramme), employment and earnings



Source: Author's composition, based on data from the Department of Mineral Resources

South Africa's platinum industry also contributes to the country's development through its numerous economic linkages with the rest of the economy. South Africa's platinum value chain include backward (such as input suppliers, original equipment manufacturers, engineering and project management firms), forward (such as fabricators, industrial manufacturers, especially the catalytic converter industry, and jewellery producers) and sidestream (such research and development (R&D), skills development and infrastructure development) linkages (Jourdan, 2015; Kaplan, 2012, 2011; Lydall, 2009; Steinweg, 2008; Walker and Minnitt, 2006).

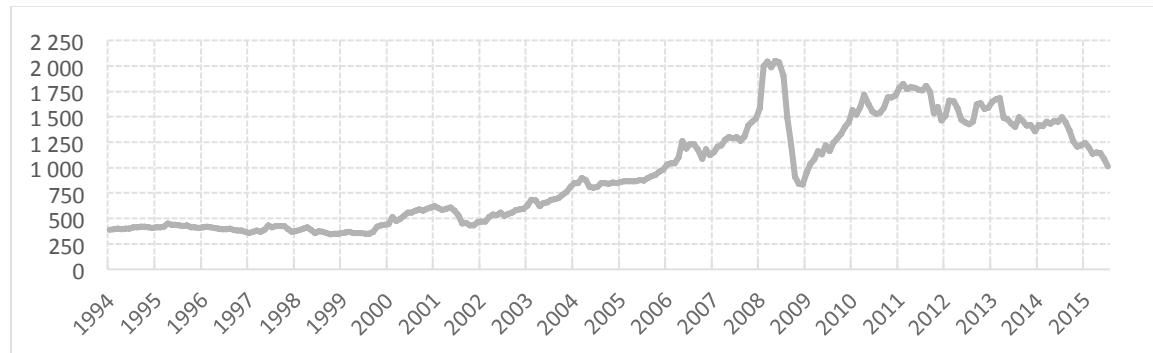
Most importantly, at the downstream level, the platinum value chain contributes to the South African economy through the production of catalytic converters. South Africa's catalytic converter industry beneficiaries 15% of locally-mined platinum and 38% of locally-produced stainless steel (Dewar, 2012). In 2014, the South African industry produced 13 million catalytic converters, accounting for 10% of the global market. Catalytic converters constitute high-value exports, accounting for 20% of South Africa's total automotive exports. Furthermore, the industry employs around 6 500 people directly in South Africa, along with 20 000 indirect workers (Dewar, 2014). The two main companies present in South Africa (and the only two disposing of a ceramic substrate plant necessary to the production process) are NGK Ceramics (a Japanese-owned company) and Corning (an American-owned company). Across their operations, these two firms account for 90% of global supply and 95% of South African supply. Locally-based fabricators, such as Umicore, BASF, Heraeus and Johnson Matthey, also play a role in the production process.

2.2. A fragile situation: Changing international and domestic dynamics

Despite a strong position, the South African platinum industry has experienced difficult conditions over the last few years. As showed in Figure 4, a downturn in the platinum price has occurred since 2012 as weak market fundamentals have kept the platinum price depressed. Going forward, commodity prices seem likely to recover only between 2020 and 2025 at best. Moreover, despite some platinum mining companies, particularly Anglo American Platinum and Impala Platinum, displaying some ability to pass

on higher costs to global car manufacturers and industrial fabricators (Deloitte, 2012; Montmasson-Clair and Ryan, 2014), South African platinum mining companies have limited control over price volatility, which is largely determined by macroeconomic factors (Seccombe, 2013).

Figure 4: Evolution of platinum prices from 1994 to 2015 at the London Metal Exchange



Source: Author's composition, based on data from kitco

Compounding the effect of falling prices, the average cost of producing an ounce of platinum in South Africa has increased by 18% annually over the past five years. Higher operating costs for platinum producers in South Africa are attributed to structural changes, including declining head grades, increasing mine depths, reduced productivity and increasing capital intensity, as well as cost increases for labour, materials and energy. Labour and wages, which represent the most significant operating cash cost (around half on average), have rapidly increased over the last few years. Average remuneration paid per worker employed in the South African mining sector grew by 12% per annum over five years. Furthermore, stoppages and labour unrest have deeply impacted production over the last few years. Input costs for materials and consumables, which constitute the second largest operating cost item, have also increased over the years. For example, reinforcing steel prices have increased by an average of 15.3% per annum between 2007 and 2012 (Baxter, 2014), specifically due to a cartel operating in long steel products at the time. Last but not least, energy, which makes up for a sizeable share of operating costs,² has also seen rising prices. According to the Chamber of Mines, electricity is the cost component which witnessed the largest inflation over the 2007-2012 period, with average annual cost increases above 25%. Diesel costs follow, at more than 15% per annum, on the back of high international oil prices at the time.³

In addition, key infrastructure-related constraints are impacting the development of the industry. As such, South Africa allegedly failed to take full advantage of the commodity boom in the 2000s as to

² Different studies suggest diverging estimates of electricity costs as a proportion of total or operating costs. For instance, (Altman *et al.*, 2010) assesses that electricity costs account for 15% of the platinum value chain costs. According to a (Deloitte, 2012) study, the share of total costs attributed to electricity for platinum mining companies ranges between 3% and 7%. Analysing recent company financial reports, (Montmasson-Clair and Ryan, 2014) show that electricity costs as a share of total costs stand respectively between 10-11% on average.

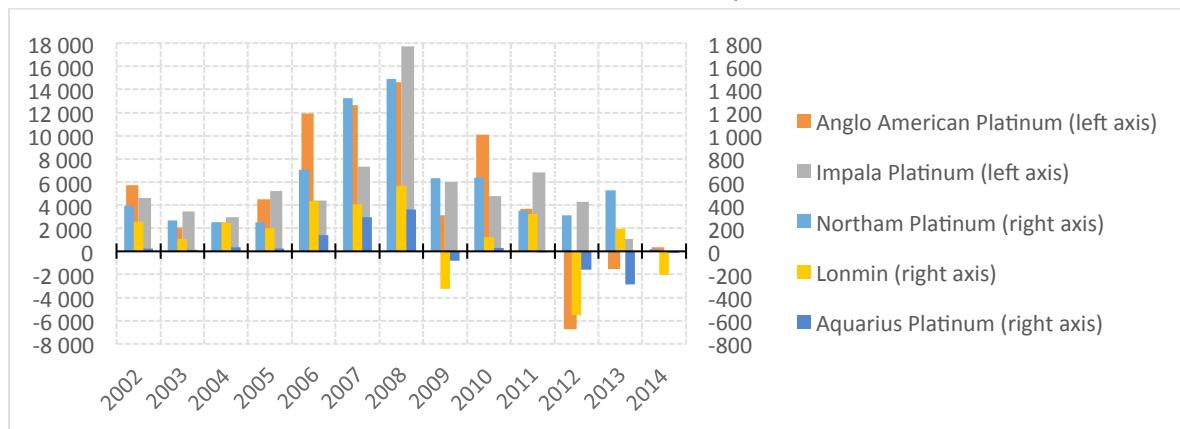
³ The cost of liquid fuels remains however a secondary concern for most platinum mining companies given the deep shaft nature of mining operations. The recent drop in international oil prices has moreover provided some relief to companies on this front.

water availability limited the development of the PGM industry (ANC, 2012). Energy supply constraints experienced since 2008, symbolised by electricity rationing for large users, rotational load shedding for smaller firms and rapid increases in electricity prices to finance the construction of new power plants, have also slowed the growth of the industry (Das Nair *et al.*, 2014; Montmasson-Clair and Ryan, 2014).

Moreover, the South African mining sector suffers from a lack of policy and regulatory certainty. Since 1994, the legislative framework for mining and industrial activities has undergone massive changes in terms of ownership, labour relations and conditions, environmental management, taxation, industrial policy, innovation, skills development and infrastructure development. Recent evolutions pertaining to the Mineral and Petroleum Resources Development Act 28 of 2002, the Mining Charter and environmental regulations have notably destabilised the growth of the local industry (Davenport, 2015, 2014; Peyper, 2015; TIPS, 2015).

The combination of policy uncertainty, increased cost pressures, lower demand and downward prices has had a drastic impact on the sustainability of the industry. Overall, reported profits have largely declined in recent years, with operating profits and returns on investments even entering negative territory in some years. Figure 5 illustrates this point for profit after taxation at a firm level.

Figure 5: Profit after taxation from 2002 to 2014 for Anglo American Platinum, Impala Platinum and Northam Platinum (in ZAR million) and Lonmin and Aquarius Platinum (in USD million)



Source: Author's composition, based on data from companies' annual reports

At the fabrication level, the catalytic converter industry is also facing difficult conditions. The local industry is capacitated to produce up to 23.7 million units per year, about 18% of global production. However, this potential is not fully exploited and production has been declining over the years. At its peak in 2008, the local industry earned ZAR 24.3 billion in exports. This has been significantly reduced over the last few years. South Africa's catalytic converter exports dropped to ZAR 19.6 billion and ZAR 16.3 billion in 2011 and 2012 respectively (Dewar, 2014, 2012). Some small players in the industry have struggled in recent years, as illustrated by the closure of the South African subsidiary of Italian catalytic converter manufacturer Magneti Marelli in 2014. Larger fabricators are only managing to pursue operations through specific deals. For example, General Motors South Africa, in partnership with

component manufacturer Tenneco South Africa, clinched in 2015 a ZAR 6-billion contract to export catalytic converters to North America (Venter, 2014).

This situation can largely be explained by an increase in international competition combined with a progressive reduction in the industrial support provided to the sector in South Africa. Industrial support is considered vital to the viability of the local industry in order to cover the locational disadvantage of South Africa-based manufacturing and therefore attract contracts from international original equipment manufacturers. Over the years, the domestic industry has progressively lost industrial support from the South African Government, a trend that the recent industrial policy shift from the export-focused Motor Industry Development Programme to the value-added Automotive Production Development Programme is set to amplify (Venter, 2014). This is particularly important as the local industry is also at a huge technological risk of losing its main export market. Since 1 September 2015, all new petrol and diesel cars sold in the European Union must be compliant with the 'Euro 6' emission standards. The European Union accounts for 85% of South Africa's catalytic converter exports and the South African industry is largely not designed to produce autocatalysts of such standards (Parker and Mathews, 2013). It remains to be seen whether the industry will be able to sustain demand and/or adapt to new requirements.

Overall, South Africa is well positioned to shape and benefit from worldwide dynamics in the platinum value chain. Recent developments have however weakened the position of South African industries. New considerations arising from the global transition to a low-carbon economy put additional pressure on the sector while also providing significant growth opportunities in the long run, as investigated in the following sections.

3. Energy: a factor of vulnerability to climate change response measures

Against the background provided in Section 2, the transition to a low-carbon world comes as an additional variable in the platinum industry equation. Section 3 investigates the direct implications, highlighting the energy systems as a key factor of vulnerability for the industry.

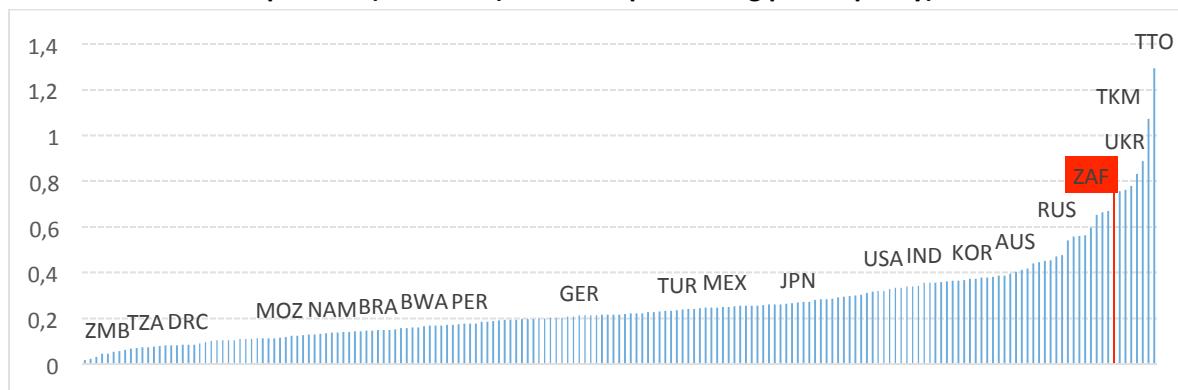
3.1. A lose-lose starting point: An energy-intensive industry in a carbon-intensive energy system

The energy-intensive nature of South African mining value chains, coupled with the high carbon intensity of the country's energy supply industry, carries underlying risk factors for the domestic platinum value chain. The implementation of local as well international climate change mitigation measures is indeed a prime factor of risk for South African mining and linked manufacturing companies. A number of macro-economic factors make the South African economy particularly vulnerable to climate change-related risks.

Firstly, South Africa is one of the most carbon-intensive economies in the world, as showed in Figure 6. This is largely the result of South Africa's fossil fuel-based energy supply industry. Energy supply systems account for the bulk of South Africa's GHG emissions. The energy sector indeed accounted for about 87% of South Africa's GHG emissions over the 2000-2010 period. This largely results from coal-fired electricity generation, followed by road transportation. Overall, electricity generation (i.e. the national utility Eskom) accounted for more than 60% of the country's GHG emissions over the period.

In contrast, industrial activities, including mining, only contributes to slightly more than 6% of South Africa's GHG emissions over the 2000-2010 period. Industrial activities are however significant energy consumers, indirectly driving GHG emissions. The mining sector alone consumes about 15% of Eskom's annual electricity output, with gold (47% of the total) and platinum (33%) mining (i.e. the two main underground mining industries in the country) being the heaviest users. At the downstream level, industrial sectors account for a further 25% of the utility's generation. Most significantly, fabrication activities require a large and uninterrupted supply of energy, consuming a considerable share of the country's electricity. In addition, the sector is partly accountable for GHG emissions from Transnet, South Africa's rail, port and pipeline state-owned enterprise.

Figure 6: Carbon intensity per country (in kilogramme of carbon dioxide-equivalent per gross domestic product (2011 USD) based on purchasing power parity)



Source: Author's composition based on data from the World Bank

Note: TTO: Trinidad and Tobago; TKM: Turkmenistan; ZAF: South Africa; RUS: Russia; AUS: Australia; KOR: South Korea; IND: India; USA: United States of America; JPN: Japan; MEX: Mexico; TUR: Turkey; GER: Germany; PER: Peru; BWA: Botswana; BRA: Brazil; NAM: Namibia; MOZ: Mozambique; DRC: Democratic Republic of the Congo; TZA: Tanzania; ZMB: Zambia

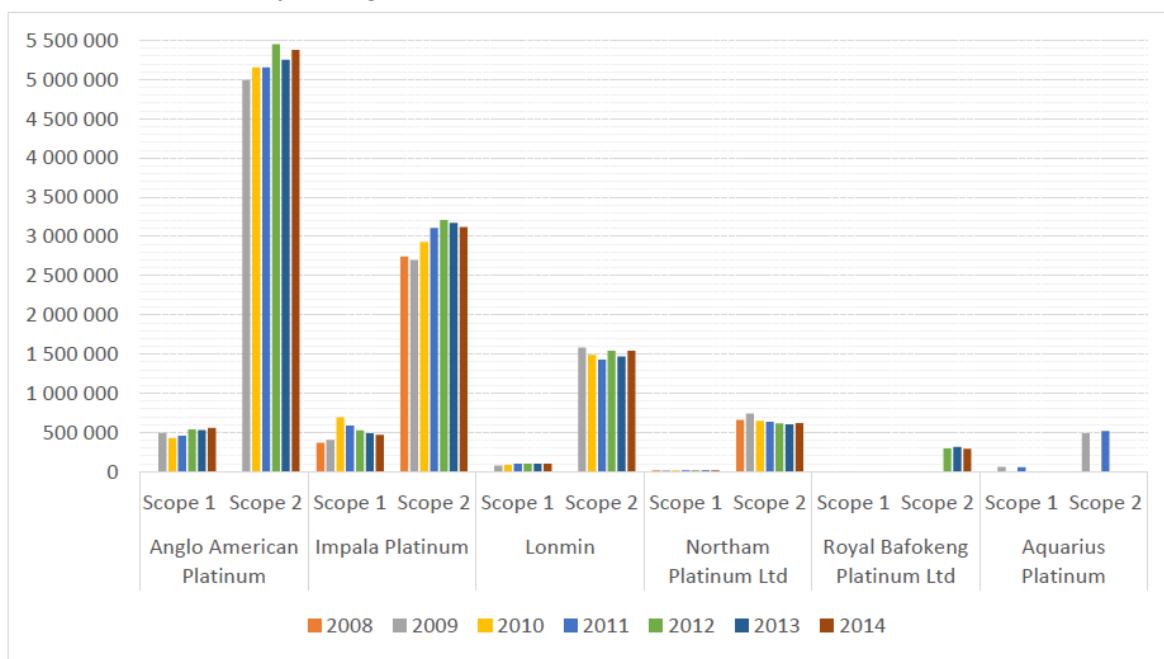
As shown in Figure 7, looking at South Africa's main platinum companies confirms this analysis. Scope 2⁴ emissions account for the vast majority (i.e. more than 90%) of companies' GHG emissions, highlighting

⁴ Scope 1 emissions are all direct GHG emissions, i.e. emissions from sources that are owned or controlled by the reporting entity. Scope 2 emissions are indirect GHG emissions from consumption of purchased electricity, heat or steam. Scope 3 emissions covers other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. transmission and distribution losses) not covered in Scope 2, outsourced activities, waste disposal, etc. (Greenhouse Gas Protocol, 2012).

the significant impact of electricity consumption. Interestingly, scope 1 emissions also result from energy use as they are essentially driven by the use of coal for heating and energy (65%) and diesel (31%) in the case of Anglo American Platinum (2014) and by stationary (53%) and mobile (43%) combustion in Lonmin's (2015) case. Indeed, due to the underground nature of platinum mining operations, electricity represents a considerable share of platinum mining companies' energy consumption. Electricity accounts for 72% and 81% of Anglo American Platinum's (2014 data) and Lonmin's (2013 data) energy use, well ahead diesel (10-11%), coal (16% of Anglo American Platinum and 6% of Lonmin) and gas (about 1%).

Second, in the short to medium term, the ability of the platinum mining houses to deeply transform their emissions profile is moreover limited. Energy consumption is largely considered an 'uncontrollable' factor of competitiveness by companies in South Africa. Energy supply in South Africa is essentially determined at the national level by the Department of Energy and Eskom, the electricity utility. The embryonic and slow-paced decarbonisation of South Africa's electricity system, which would address the bulk of GHG emissions from platinum mining companies, is largely out of the control of industries.

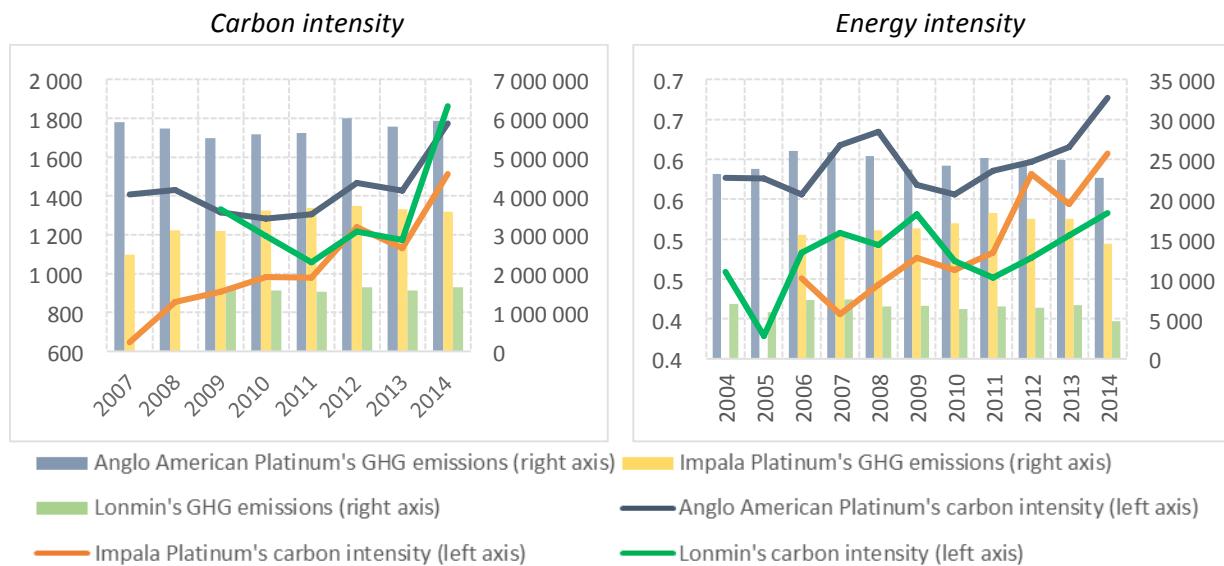
Figure 7: Global greenhouse gas emissions (Scope 1 and Scope 2) for main platinum companies operating in South Africa from 2008 to 2014 (in tCO2e)



Source: Author's composition, based on data from the Carbon Disclosure Project

Note: data for Aquarius Platinum are only available for 2009 and 2011. Scope 1 data for Northam Platinum and Royal Bafokeng (2012, 2013 and 2014) are reflected but too small to appear in the graphic representation. 2008 data for Anglo American Platinum are not available.

Figure 8: Global greenhouse gas emissions (Scope 1 and 2) (in tCO₂e and tCO₂e per ounce of PGM) from 2007-2014 and energy intensity from 2004-2014 (in gigajoule per ounce of PGM) from South Africa's top three platinum companies



Source: Author's composition, based on data from the Carbon Disclosure Project and companies' annual and sustainable development reports

Note: performance is not directly comparable from one year to the other due to the impact of strikes and stoppages. Even in the event of a prolonged strike and the absence of production, essential equipment, such as ventilation fans and pumps, and services still consumes approximately half of normal electricity load.

Trends are however relevant for the analysis.

Unchanged energy systems, notably in terms of electricity generation, combined with the declining ore grade and the need to mine deeper and further away from the main shaft over time, by consequence increasing refrigeration needs and energy use, largely explains why the energy and emission intensity of main companies have increased over time, as illustrated in Figure 8. The parameters around the variability of power supply required in specific operations are also a key consideration. Overall, a large share of power requirements is fixed. While this does not prevent efficiency improvements, the nature of power consumption variability reduces to some extent the ability to decrease consumption. For instance, at the mining phase, which accounts for a third of energy use (35% based on Anglo American Platinum's 2014 data), largely due to electricity consumption, 80% of the power requirement is fixed, while only 20% is variable depending on activity levels. Beneficiation activities consume the other two-thirds, split between concentration (24% of total energy use), smelting (28%) and refining (13%). With the exception of refining, which relies mostly on direct coal usage, electricity dominates all stages of the mining value chains. At the concentration phase, variable power requirements account for 70% of the total, with fixed demand standing at 30%. At the refining stage, power requirements are highly inflexible and demand is considered fixed in totality.

3.2. Climate change response measures: Underlying factors of vulnerability

As a result of the carbon intensity of the energy system and the limited ability of platinum mining firms to alter their energy profile in the short term, the impact of domestic climate change regulation, particularly carbon pricing, constitutes an important area of concern for the international competitiveness of South Africa's platinum value chain. The internalisation of the cost of environmental externalities (such as GHG emissions) may indeed impact the competitiveness of local industries (leading to reduced employment, revenues, etc.) compared to firms located in countries with less stringent (or no) carbon policies (Camco and TIPS, 2010; TIPS *et al.*, 2013).

Mining value chains, due to their energy intensity, would be the most impacted sectors from the implementation of carbon pricing domestically. Based on modelling from the National Treasury, the mining sector would suffer a deviation from baseline GDP in 2035 from -2.3% to -3.2%, respectively for a carbon tax of ZAR 100 and ZAR 200 per tonne of carbon dioxide-equivalent (tCO₂e) gradually implemented over a period of ten years and imposed upstream (in a scenario where revenues from a carbon tax are recycled through the value added tax)⁵ (National Treasury, 2013; Salie and Makrelov, 2013). Further modelling corroborates these findings, Alton *et al.* (2012) show a negative deviation from the baseline value over the 2010-2025 period of between 3.7% and 5.4% for the mining sector, respectively for a consumption-based tax and a production-based tax. Furthermore, according to Adelzadeh (2015), a carbon tax (as proposed by National Treasury in the 2015 Draft Bill) would result in lower investment, employment and output in the primary sector (which is dominated by mining activities in South Africa) compared to a business-as-usual scenario, with an absolute decline in investment. In annual terms, while the carbon would represent a negligible reduction of output growth, it is unclear whether this would be sufficient to impact the viability and development of the sector.

Secondly, South Africa's platinum value chains may face increased difficulties in accessing foreign markets, including financial flows. Overall, South Africa is the second most vulnerable country (after Chile) to climate change regulations on a trade-weighted basis. This results from the country's geographical distance from its key trading partners, a high ratio of trade to GDP (between 50 and 60%) and the driving role of exports in the country's GHG emissions (at 45% in 2008, which is significantly higher than the world average) (Monkelbaan, 2011; Peters and Hertwich, 2008). This is particularly in the case of the platinum value chain with the large majority (around 90%) of South Africa's platinum production being exported without any beneficiation and the global nature of the automobile industry, of which the production of catalytic converters forms part.

Measures already adopted, or measures that will be introduced, by (developed) countries to mitigate climate change could have concerning trade-related impacts on South Africa's platinum industry. On top of shifts in trade patterns towards products and services with lower carbon content, response measures

⁵ Other revenues recycling options suggest a varying impact on the mining sector. While recycling of revenues through the corporate income tax or the personal income tax would deepen the impact on the sector, the use of transfers or the redirection of investments would lessen the GDP reduction.

could be trade distortionary and discriminatory, introducing new forms of green protectionism (such as border carbon adjustment or non-tariff barriers for example) (Cosbey and Wooders, 2011; du Plooy and Jooste, 2011; Jooste *et al.*, 2009; TIPS *et al.*, 2013). In the long run, the carbon-intensive nature of the South African economy is also a concern in terms of access to local and international financial flows, which are increasingly directed towards sustainable practices (Montmasson-Clair, 2012). These risks are heightened by the status of emerging economy and upper-middle-income country of South Africa and the absence of domestic economy-wide carbon legislation. Indeed, exemptions at the international level (i.e. at the World Trade Organisation) are likely to be granted solely to low-income countries and, to some extent, to lower-middle-income countries, and to countries with meaningful carbon pricing in place domestically (Tamiotti *et al.*, 2009).

As a result, South Africa's vulnerability, which is not diminished by scale or production volumes, appears relatively high compared to most other countries (TIPS *et al.*, 2013). Like with domestic legislation, mining value chains are moreover the sector which would be the most impacted should this risk materialise. Coal, non-ferrous metals (which include platinum) and other manufacturing sectors would be severely affected by the shift in trade pattern needed for developed countries to reduce their GHG emissions by 25% reduction by 2020 (based on 1990 levels) (du Plooy and Jooste, 2011). Similarly, the introduction of a border carbon adjustment of USD 20 per tCO₂e by the European Union and the United States of America would have a stringent impact on the South African economy. Non-ferrous metals (including platinum), iron and steel, mining and quarrying (coal), paper, pulp and print, chemical and petrochemical and textiles would be primarily impacted (Cosbey and Wooders, 2011).

The vulnerability of the South Africa's platinum value chains to climate change response measures arising from its carbon-intensity is therefore a real concern. While the high level of vulnerability does not predict the likelihood of the risk to effectively materialise, it warrants the need to adequately take it into account, monitor it as well as actively engage in risk mitigation. This is explored in the following section.

4. Energy: The core of platinum mining companies' climate mitigation strategies

Section 3 highlighted the key role of energy systems in the carbon profile of platinum mining companies and the vulnerability associated with them. Section 4 highlights the numerous avenues available to local firms to mitigate such risk while improving their competitiveness.

4.1. Energy efficiency: The foundations

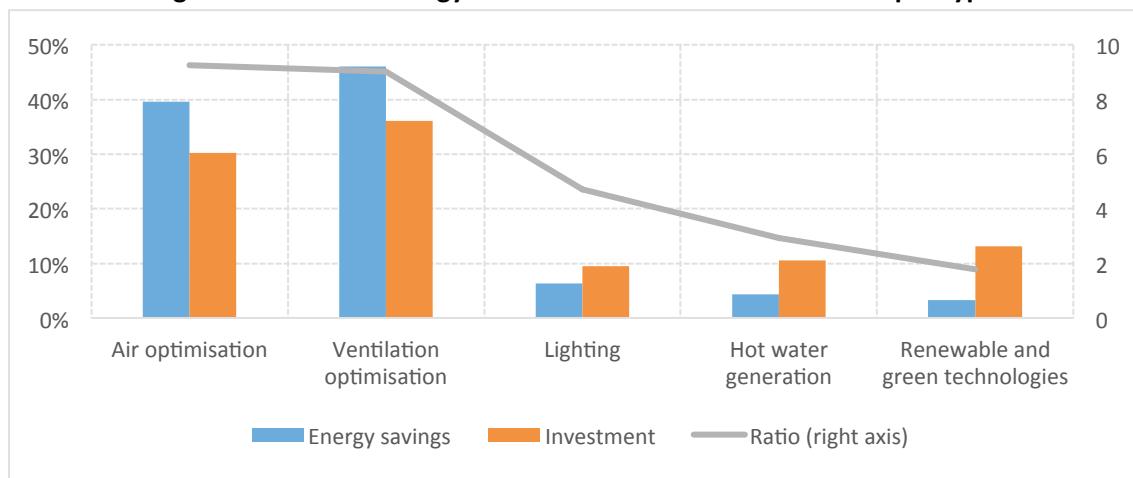
While the transition at the energy supply level clearly constitutes the main element necessary for improving the contribution of the platinum value chain to a low-carbon economy (due to the domination of Scope 2 emissions in the profile of local companies), performance improvement at the firm level, notably in terms of energy efficiency, are particularly important. In the short term (by 2020),

the mitigation potential is greater at the industrial level than at the energy supply stage, due to infrastructure lock-ins and the long lead time needed to change energy systems. Moreover, unlike at the energy supply level, most of the mitigation potential at the industrial level benefits from negative marginal abatement costs (see DEA, (2014a, 2014b) for detailed marginal abatement cost curves).

The first port of call in order to manage and ultimately reduce GHG emissions revolves around a better understanding of emissions sources. Indeed, one of the main challenges facing large mining and manufacturing companies is accurate cost accounting of the daily/weekly and monthly stock of energy used in the business, their use/consumption, and how this relates to GHG emissions. In the last decade, platinum mining companies have taken steps to measure, monitor and report their GHG emissions. As part of the company's energy and carbon management programme (ECO₂MAN), Anglo American Platinum installed, in 2010, 598 metering points at a cost of ZAR 40 million. This system, which allows for live tracking of electricity use across the company's operations, is critical to energy efficiency management. Further development of the system in order to account for energy consumption beyond electricity (i.e. other fuels such as diesel) is planned (Anglo American Platinum, 2015a, 2014). The firm also spent more than ZAR 3 million on energy studies, identifying saving opportunities worth ZAR 700 million (Anglo American Platinum, 2014). Northam Platinum has implemented a similar system at its Booyensdal mine (Northam, 2013). Likewise, Impala Platinum conducts annual GHG emissions assessment in order to better understand its exposure as well as the areas of improvements (Impala Platinum, 2014, 2013).

Along with monitoring and tracking, companies have made some efforts to improve their energy performance. Companies have focused their efforts on low-hanging fruits, i.e. low-cost and non-disruptive interventions, largely at the mining level. Decision-making for energy efficiency investments, which is determined by the ease of implementation, complexity and cost, largely explain this trend. Improving energy efficiency is considered much harder (from a technical and financial perspective) at the smelting and refining stages than at the level of ancillary and mining operations (Impala Platinum, 2013) and, as shown in Figure 9, based on Lonmin's data, air optimisation and ventilation optimisation at the mining level offer the highest cost-benefit ratios and have logically been prioritised. Correspondingly, energy savings achieved by Anglo American Platinum as of 2012 were largely dominated by interventions linked to compressors (i.e. air optimisation) (64%). Smelting improvements (17%), underground lighting (6%), ventilations and fans (4%), refrigeration (2%) and heat pumps (2%) completed the benefits (Anglo American Platinum, 2013).

Figure 9: Lonmin's energy-related initiatives from 2007-2012 per type



Source: Author's composition, based on data from Lonmin

Companies have focused on gains through process optimisation. Optimisation accounts for the bulk of energy efficiency gains and can bring noteworthy savings. The optimisation of air networks is particularly pursued by companies, such as Anglo American Platinum (Rustenburg, Bafokeng Rasimone, Amandelbult and Modikwa mines) and Lonmin, through improved compressors (matching the generation of compressed air with demand and installing control systems minimising demand when air leaks are detected). With co-funding from Eskom, Lonmin has rolled out optimised air networks at Karee, Rowland and Eastern Platinum operations through better control settings, reducing the electricity load by 7.18 MW. The company also embarked on a compressed air initiative through an optimisation of the compressor control system and networks (Anglo American Platinum, 2015a; Lonmin, 2015). Impala Platinum has likewise optimised the use of compressed air systems at its Rustenburg operations, achieving savings of 7.8 GWh per annum (Impala Platinum, 2015, 2014). Ventilation systems are further improved through better fan settings (Anglo American Platinum, Northam Platinum and Aquarius Platinum).

Beyond air optimisation, Anglo American Platinum yielded substantial progress in energy efficiency at their smelters through the improved drying of concentrate and better furnace control (Anglo American Platinum, 2013). Similarly, Northam Platinum obtained noteworthy gains at the operational level through the better management of the ore pass capacity in order to minimise the use of conveyors while maximising output. Aquarius Platinum registered savings by improving dense media separation, stockpiling and processing separately the ore stream from the waste. The enhancement of shaft water pumping (Lonmin, Northam Platinum) is also used by some companies (Lonmin, 2015; Northam, 2013).

The use of equipment with improved power factor, such as fiberglass fan blades (Impala Platinum, 2014) and hydro-powered equipment like water rock drills instead of air drills (Anglo American Platinum, 2013; Northam, 2013), is another illustration of low-hanging fruits captured by companies. Through the installation of power factor correction equipment at the Rustenburg and Mimosa activities, a 4% reduction in energy consumption was achieved by Lonmin. Steel fan blades have been replaced with

fibreglass reinforced plastic blades at Mimosa, consuming 35% less power. Additionally, 45kW aerodynamically-optimised (and energy efficient) fans have been installed, saving 0.9 MW (Lonmin, 2015).

Over and above operational improvements, platinum mining companies have installed energy efficient equipment in their non-core operations, such as offices, mining houses, change rooms and hostels. Lonmin, for example, rolled out heat pump at change houses to replace conventional geysers, generating a load cut of 1.35 MW (Lonmin, 2015). Heat pumps were also installed in 2011 at the mining change houses of Anglo American Platinum's Rustenburg and Amandelbult mines, using ambient heat to warm showering water instead of conventional resistive elements in the boilers (Anglo American Platinum, 2014). Lighting retrofit with energy-efficient fluorescent and light-emitting diode lighting was also conducted at Lonmin's Platinum Division offices in Marikana, North West for a load reduction of 0.33 MW. Lonmin also implemented energy efficient lighting underground to replace Compact Fluorescent Lamps for a 0.08 MW reduction in load (Lonmin, 2015). Impala Platinum has likewise converted all underground lighting to energy-efficient technologies at the Rustenburg operations for an anticipated reduction of 15 GWh per annum (Impala Platinum, 2015).

Beyond low-cost, low-hanging fruits, some companies are pursuing larger, more disruptive technological changes in order to improve their competitiveness. Junior producers in the platinum sector have pioneered innovative production processes with substantial energy savings (Ryan, 2014). Pallinghurst has made pronounced improvement to the company's performance through a patented smelting technology, the Kell process. The new process removes the necessity to smelt and mill the PGM concentrate to remove the chrome content. This facilitates the processing stage and leads to a reduction in power consumption. The new process only requires 14% of the electricity used by conventional techniques. Pallinghurst has demonstrated an 80% decrease in energy costs linked to smelting (Creamer, 2014; Liddell *et al.*, 2010). Another example is Braemore Platinum, a wholly-owned subsidiary of Jubilee Platinum, which is implementing for the first time the ConRoast process. The innovative process allows the use of cleaner, direct current arc furnaces (by extracting the sulphur content before smelting). It also permits any proportion of chromite, which results in a more efficient and cost-effective production process (De Bruyn, 2010; Jubilee Platinum, 2015).

New shaft designs are also being explored by some companies to improve performance and resource use. According to Impala Platinum, a focus on mine shaft design features has proven to provide more opportunities for energy saving than trying to change smelters and refineries. For example, in order to add to energy savings, Pallinghurst has designed a shallow and largely mechanised, open-pit platinum mine. While it will eventually go underground, the mine will operate 1 500 metres above industry average for the first 30-40 years. In a different illustration, Northam Platinum, at its Zondereinde mine, is using backfills to reduce the heat ingress from worked-out areas and lower the underground temperature, resulting in a 65% decrease in the size of the area to be cooled. Going forward, the new virtual and reality mine design centre at the University of Pretoria inaugurated in August 2015 is expected to further improve performance (Creamer, 2015).

4.2. Alternative sources of energy: The new frontier

Despite the national control of energy supply in South Africa, some companies are pursuing the use of alternative cleaner energy sources in order to address the problem at a firm level. Due to the difficult economic climate and the absence of adequate regulatory framework for companies to invest in such projects, these initiatives are however still at their infancy (Montmasson-Clair and Ryan, 2014).

Anglo American Platinum is exploring the possibility to build a 60-MW biomass thermal power plant and a 30-MW solar photovoltaic power plant. The firm is also assessing the possibility of using micro-hydropower, installing a waterwheel generator in the overflow pipe to generate power through fluid gravitation (Anglo American Platinum, 2015a). Lonmin is assessing the possibility of developing a renewable resource facility (probably solar-based) through a power purchase agreement with an independent power producer (Lonmin, 2015).

Anglo American Platinum also launched a fuel cell demonstration plan in Limpopo which generates 200 kilowatt of electricity from coal-bed methane (Anglo American Platinum, 2015a). Similarly, Lonmin completed a feasibility study to determine whether the company's precious metal refinery in Brakpan, Gauteng, could be fully/partially migrated off the national grid by using a natural gas-fired fuel cell solution. Such a project would be the first of its kind in South Africa and would provide valuable insight into Southern Africa's potential to increase its own power-producing capacity using its vast untapped natural gas fields (Lonmin, 2015).

In terms of cogeneration, with the support from the Industrial Development Corporation and the Department of Trade and Industry, Anglo American Platinum is commissioning a 3.75-MW waste-heat recovery power generation plant to power the Anglo Platinum Converting Process at the Waterval Smelter complex in Rustenburg, North West. The project, developed by an independent power producer, entails extracting waste heat from the high-pressure water system used to cool the converter off-gas in the Anglo Platinum Converting Process (previously rejected through fin-fan coolers). Thanks to an innovative, closed system, an Organic Rankine Cycle power plant will recover 20 MW of thermal energy and convert it to 3.75 MW of electrical power.

Beyond electricity, Anglo American Platinum is investigating the use of biodiesel to replace as much as 5% of its diesel usage, using used cooking oil or the farming of *moringa oleifera* plants (Anglo American Platinum, 2015a, 2014). Impala Platinum is assessing the feasibility of using biomass (from bamboo) rather than coal as an energy source at its Rustenburg smelter (Impala Platinum, 2015, 2014).

Rather than a constraint, energy consumption therefore appears as an opportunity for platinum mining companies to reduce their environmental footprint and improve their competitiveness and performance. While the core of the problem (and solutions) lies at the national level, companies have a key role to play in improving energy use at the operational stage. Besides supply-side considerations, the transition to sustainable energy systems necessary for the materialisation of a low-carbon economy

could have positive spillovers for mining value chains from a demand-side angle, as discussed in the subsequent section.

5. Platinum: A low-carbon energy solution

In addition to supply-side dynamics discussed in Sections 3 and 4, the global shift to low-carbon economies is driving the emergence of new technologies. Section 5 discusses the prospect of one such example, fuel cells, becoming a major source of demand for platinum and the opportunity for South Africa to be a leading player in the field.

5.1. Fuel cells: A growing global opportunity

In the long run, new demand dynamics arising from the global transition to a low-carbon economy are a source of opportunities for platinum products. While the net impacts of a low-carbon development path on platinum mining and linked manufacturing companies remain largely unknown, market trends are likely to generate numerous opportunities (Camco and TIPS, 2010; Montmasson-Clair, 2015b; UNEP and DEA, 2013; WEF and Accenture, 2014).

While the focus has been on supply-side dynamics, substantial low-carbon opportunities exist for platinum value chain on the demand side. Over and beyond the current utilisation of platinum in catalytic converters, which contributes to reducing the negative environmental impacts of motor vehicles (International Platinum Group Metals Association, 2013),⁶ platinum has multiple energy-related usages which can make a meaningful contribution to the transition towards a low-carbon economy.

The most prominent and promising technological uses are in fuel cells. Fuel cells have the ability to generate and store power by combining a fuel (usually hydrogen) and oxygen from the air to produce electricity, heat and water (Johnson Matthey, *n.d.*). Fuel cells can provide clean, efficient, versatile and scalable power both in stationary (such as residential systems), mobile (such as power trains for vehicles) or portable applications. The application of fuel cell technologies range from domestic to industrial usages, providing clean and reliable power that can be used in many ways. Applications include rural electrification, back-up power for telecommunications, combined heat and power applications for residential, commercial and industrial buildings, portable power and battery charging. Although in small proportions, most fuel cell systems use platinum as a catalyst. Fuel cells are not a new innovation. The very first fuel cell using platinum electrodes was devised in 1842. Much improvement of the technology has been realised in the last two decades and operational usage are slowly being implemented. The demand for fuel cells is expected to pick up from 2020, rapidly becoming

⁶ The introduction of catalytic converters for automobiles is already a major driver for the production of platinum. Catalytic converters absorb almost 40% of the global demand for platinum. The industry accounted for exports of ZAR 16 billion in 2012 (Chamber of Mines, 2012). As car sales keep increasing worldwide and environmental regulations for automobile emissions are progressively strengthened, the production of catalytic converters is likely to remain an important driver of platinum demand in the future.

the main driver for platinum in the future (Jourdan, 2015). According to the International Energy Agency (IEA, 2012b), fuel cell electric vehicles are forecasted to capture about a quarter of the light duty vehicle market by 2050. This could equate to a 250% increase in the demand for platinum over the period (Jourdan, 2015).

Although a longer-term opportunity, the use of proton exchange membrane fuel cells in fuel-cell electric vehicles is an exciting market segment of PGM-based products. Multiple car manufacturers are developing fuel-cell electric cars. Toyota commercialised its first model in 2015 while Hyundai, Honda and Kia are also aimed to enter the market shortly. Nissan, Ford and Daimler, which entered into a tripartite alliance, are expected to follow by 2017. BMW and Toyota are further collaborating to produce by 2020 a fuel-cell system, architecture and components for a sports car, light-weight technologies and a ‘post-lithium’ air battery. As such, the market is expected to grow exponentially (at a 22% compounded annual growth rate) in the decades to come, to a USD 1.8-billion market by 2030. Germany, Japan and California in the United States of America have started the initial roll-out of hydrogen refuelling infrastructure. This initial stage is critical to establish and grow a potential market for fuel-cell market vehicles. The long driving range (about 500 kilometres) and the short refuelling time (approximatively five minutes) of fuel-cell electric vehicles are considered as key advantages which will drive the growth of the market in the future (Anglo American Platinum, 2014).

Platinum mining companies, primarily Anglo American Platinum and Impala Platinum, are heavily investing in R&D in this field, in association with leading international companies. Anglo American created the PGM Development Fund in 2009, with an initial investment of USD 10 million for research, technology development, demonstration and scale-up and commercialisation. The company further committed over USD 100 million in 2014, with USD 20 million to be invested annually over five years. The fund provides start-up and growth capital to entities working on using or enabling the use of PGM-based technologies.

While the fund is meant to support all potential usages of platinum (energy, hydrogen and fuel cell value chain, medical devices, electronics, water treatment, aerospace, recycling and resource efficiency), the current investment portfolio is heavily focused on energy issues (Anglo American Platinum, 2015a, 2014, 2013). Fuel cells and electrolyzers are set to play a key role in energy storage and power grid stability as the role of renewable energy increases going forward. This is particularly the case in off-grid residential applications where the cost of electrification through an expansion of the national grid may be cost or technically prohibitive. In this respect, the PGM Fund supports technology and energy companies, such as Altergy (a designer and manufacturer of fuel cell power systems), Ballard (a producer of clean energy fuel cell products), Primus Power (a low-cost grid-scale energy storage solution provider) and Hydrogenious Technologies (a developer of safe storage of hydrogen) (Anglo American Platinum, 2015a, 2014, 2013). Furthermore, Anglo American Platinum and the Department of Mineral Resources launched in August 2014 the world-first fuel-cell rural electrification project in the Moqhaka municipality in the Free State. As part of the project, 34 households are initially powered using a methanol fuel cell prototype product. Upon successful completion of the trial phase, plans are to proceed to a pilot test, rolling out the technology to between 200 and 300 units in villages across rural South Africa. The end-

goal is to establish an entire fuel cell value chain in South Africa, creating employment and additional demand for platinum of up to 7 500 ounces over the next 15 years (Kotze, 2014).

Hydrogen fuel cell systems are also considered “cost-effective replacements for conventional batteries or diesel engines in underground mining vehicles” (Anglo American Platinum, 2015b, p. 31). For example, Anglo American Platinum is developing fuel-cell-powered mining equipment, such as alternative power system for underground locomotives, in partnership with Ballard Power Systems and original equipment manufacturers Trident South Africa and Battery Electric (Anglo American Platinum, 2015a, 2013). This relies on the use of highly efficient, low-carbon, quiet fuel cells instead of lead-acid batteries and diesel generators. This is an illustration of how fuel cells can combine the mobility, power and safety features of diesel units with the environmental cleanliness of battery vehicles. In addition, lower recurring costs, reduced ventilation costs (compared with those for diesel vehicles) and higher productivity play in favour of fuel-cell mine vehicles, which are expected to be rapidly cost competitive. The first fuel-cell locomotive prototype was launched at Anglo American Platinum’s Khomanani mine in Rustenburg, North West in April 2012. Similarly, Impala Platinum has invested ZAR 6 million in the development of fuel cell technology for forklifts (Wild, 2012).

The South African government aims to seize opportunities associated with such developments by supplying 25% of the global demand for hydrogen fuel cell catalysts by 2020. In order to achieve this objective, the South African government, through the Department of Science and Technology, has invested since 2008 in infrastructure through a 15-year knowledge-based network programme known as Hydrogen South Africa (Makhuvula *et al.*, 2013; Pillay, 2013; Pollet *et al.*, 2014). The South African Government is also working towards the establishment of a Platinum Special Economic Zones in the North West Province of the country, with the aim of boosting investments in the platinum value chains in South Africa (SAnews.gov.za, 2016).

The Carbon Trust estimates that thousands of jobs could be created through the development of a local fuel cell industry over the next 30 years provided long-term investment and the successful commercialisation of the technology (Creamer, 2011). In the long run, the development of a fuel cell industry in South Africa could have substantial positive spillovers from an economic (fiscal revenues, infrastructure, backward and sidestream linkages), social (employment, skills, knowledge) and environmental (lower GHG emissions) perspective, and constitute the best opportunity for platinum mining value chains to contribute positively to the transition to sustainable energy systems.

5.2. Fuel cells in South Africa: Many challenges ahead

The development of fuel cell technologies is nevertheless not without challenges. Despite more than 20 years of intensive research, scientific and practical problems linked to handling and transporting highly explosive hydrogen have hampered development of the market and the commercialisation process (Ryan, 2014).

The size of this opportunity associated with fuel cells will depend on a range of unpredictable variables such as: oil prices, the development of the wider hydrogen economy, the reduction of production costs (through the development of technology and mass production), further technical and technological improvements to widen possible usages, future developments around diesel engines, hybrid cars and other energy technologies and the availability of platinum (Kaiser Associates, 2007). In sum, in the transport sector, “four miracles [...] need to be realised for hydrogen and fuel cells to make commercial sense, [namely...]: price parity of fuel cell cars with the internal combustion engine option; price parity of hydrogen fuel with gasoline; hydrogen storage; and the hydrogen distribution infrastructure” (Makhuvela *et al.*, 2013).

In addition, South Africa is not the only economy investing significant effort in the development of a local fuel cell industry. A number of other countries, such as the United States of America, Canada, Japan, South Korea, China, France, Denmark, Germany and Sweden, are actively supporting the development of local industries through a variety of government programmes (Curtin and Gangi, 2014; Fuel Cell Today, 2013; IDC, 2013). Japan leads the manufacturing of fuel cell systems, while South Korea is the leading country of adoption for large stationary fuel cell systems. Worldwide employment statistics in the fuel cell industry reflect the domination of Asian countries, with close to 39% of the jobs. The United States of America and Europe follow with 28% and 23% of total employment (Fuel Cells 2000, 2011). Concomitantly, leading firms in the fuel cell industry originate from these countries, namely Bloom Energy Servers, Altergy, FuelCell Energy and Nomadic Fuel Cells from the United States of America and Panasonic Ene Farm, Toshiba Dynario, Toyota, and Nissan from Japan (Fuel Cell Today, 2011).

Compared to other countries, South Africa’s efforts to promote the development of fuel cell manufacturing therefore appear rather limited. Moreover, a 2014 review of South Africa’s Hydrogen South Africa programme highlighted key weaknesses. The need for more effective coordination between technical and commercialisation processes (i.e. the scientific and economic governance of the programme) and the lack of a clear and strategic commercialisation plan for R&D activities were particularly pointed out (Jourdan *et al.*, 2014).

In the end, while the fuel cell market remains at its infancy, the industry bears a significant potential in the long run. Substantial uptake of the technology globally is necessary for fuel cells to become a key driver of platinum mining and pro-active efforts are required for South Africa to seize associated opportunities. As concrete applications are starting to be rolled out, the next decade appears crucial in the development of the market in South Africa and globally.

6. Conclusion: Threat or opportunity?

The transition to a low-carbon world represents a fundamental transformation for platinum value chains. Despite weakening fundamentals, the South African economy, which plays a leading role in the

global supply of platinum, is at the core of this new dynamic, which centred on energy issues. Indeed, the energy-intensive nature of the platinum industry in South Africa, coupled with the country's carbon-intensive energy system is a prime factor of vulnerability for the industry. The ability of firms to reduce risk factors is moreover limited due to the national control over South Africa's electricity supply industry and the nature of platinum mining activities. Firm-level interventions, in terms of energy efficiency and alternative use of energy, nevertheless exist to mitigate the risks associated with climate change response measures and improve the competitiveness of the sector. Furthermore, the global low-carbon transition may open the door to new markets for platinum through the development of fuel cells.

Whether or not such a shift will be an opportunity or a threat to South Africa's platinum value chains is not definite at this stage. This will largely depend on the ability of the industry, in collaboration with the South African Government and other relevant stakeholders, to position local firms preferably in terms of supply, demand and competitiveness dynamics.

On the supply side, the transition implies a complete overhaul of energy systems from energy supply to energy use in order to reduce firms' GHG emissions. Indeed, most of the mitigation potential is situated at the energy supply level, notably in terms of electricity, and further considerations must be given to shifting to a low-carbon energy sector. In addition, significant mitigation opportunities, many with direct financial benefits, exist at the firm level, particularly in the short term. Further room must be created for mining companies and other large users to manage their energy intake. The opportunity for mining companies to change energy sources remain at this point constrained and more efforts, notably through targeted support for investment and R&D in energy management and the procurement of clean energy, must be directed towards opening the room for firms to shift energy patterns.

On the demand side, preliminary findings suggest that the shift to a low-carbon economy is likely to increase the overall requirements for platinum and other mineral-based products. Nevertheless, a thorough understanding of the real potential for fuel cells is still required. More efforts must be directed towards building the business case for fuel cells and acquire the necessary knowledge and capabilities to be a leading player in the field. The dominant design option that will succeed to the internal combustion engine has not yet emerged and the window of opportunity to influence the trajectory towards a platinum-based technology is still opened. More investments, notably in demonstration products and projects, are therefore required to reduce uncertainty, increase the understanding of fuel cells (i.e. their benefits and shortcomings), improve performance, expand technological possibilities, and sensitise markets and decision-makers.

Finally, in terms of competitiveness, the capacity of the South African platinum industry to be a major player in new low-carbon development (besides mineral extraction) hinges on the establishment of an internationally competitive, low-carbon value chain in South Africa. Many countries have been heavily investing in the development of fuel cells and competition appears fierce in the field. As illustrated by the catalytic converter experience, the domination of South Africa over platinum reserves does not guarantee a strong role in the fuel cell industry. Active efforts will be required to promote competitive (on economic, but also social and environmental fronts) manufacturing in South Africa.

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