

# South Africa and the Global Hydrogen Economy

## The Strategic Role of Platinum Group Metals

The Mapungubwe Institute for Strategic Reflection (MISTRA), which was publicly launched as a think tank in March 2011, was founded by a group of South Africans with experience in research, academia, policy making and governance who saw the need to create a platform for engagement around strategic issues facing South Africa. It combines research and academic development, strategic reflections, and intellectual discourse. It applies itself to issues such as economics, sociology, governance, history, arts and culture, and the logics of natural sciences.

*South Africa and the Global Hydrogen Economy: The Strategic Role of Platinum Group Metals* is the publication of a MISTRA research project on the use of strategic minerals in the global putative hydrogen economy.

The book highlights the global significance of platinum group metals (PGM) and explores the strategic opportunities that arise out of South Africa's endowment of these strategic resources.

From their extraction to their applications in fuel cells, what options are available for the country, the region and the world to better leverage this endowment towards supporting growth and development objectives? In view of their expanding range of applications, do PGM need the hydrogen economy? Conversely, does the hydrogen economy need PGM?

Addressed to all key industry stakeholders, including those in the public and private sectors, the options explored in this book are based on a thorough analysis of the global dynamics that should inform policy and business models related to PGM.

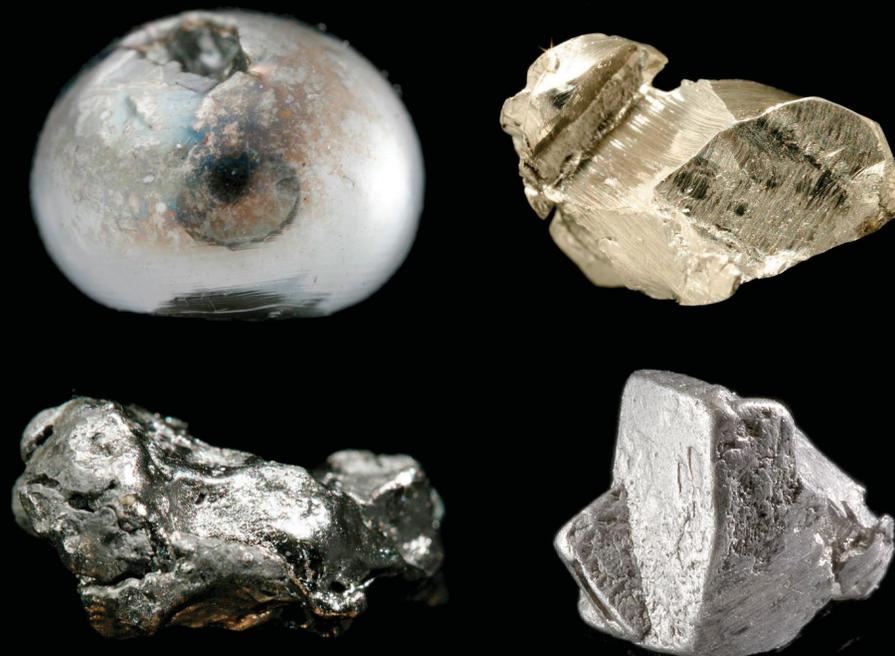


ISBN 978-1-920655-68-6

9 781920 655686



# South Africa and the Global Hydrogen Economy



# South Africa and the Global Hydrogen Economy

The Strategic Role of Platinum Group Metals

# CONTENTS

<b>Foreword</b>	<b>10</b>
<b>Authors</b>	<b>12</b>
<b>Acknowledgements</b>	<b>13</b>
<b>Abbreviations</b>	<b>15</b>
<b>List of Figures and Tables</b>	<b>18</b>
<b>Chapter 1: PGM and Other Strategic Minerals in the Hydrogen Economy: South Africa's Boon?</b>	<b>25</b>
1 Introduction	25
2 World Reserves of Platinum Group Metals	27
3 Contemporary Uses of Platinum Group Metals	27
4 Trends in PGM Demand and Applications	28
5 Prospects for Future PGM Applications	31
6 The PGM Supply Chain	35
7 New Energy Paradigm	39
8 Strategic Role of PGM and Other Strategic Minerals in the Hydrogen Economy	41
9 Other Strategic Minerals	44
10 Conclusion	45
Bibliography	46
<b>Chapter 2: The Global Hydrogen Economy and Fuel Cell Technology</b>	<b>51</b>
1 Introduction	51
2 Global Hydrogen Fuel Cells	60
3 Technological and Economic Challenges	64
4 Prototype and Demonstration Projects	66
5 Hydrogen Infrastructure	67
6 Commercial Applications of Platinum-based Hydrogen and Fuel Cell Technologies	68
7 Hydrogen and Fuel Cell Technologies: South Africa	71
8 Conclusion	73
Bibliography	74

<b>Chapter 3: Emergence of New Industries: Industry and Knowledge Factors</b>	<b>83</b>
1 Introduction	83
2 Theoretical Analysis	85
3 Data and Method	104
4 Findings	105
5 Conclusion	113
6 Model/Analytical Limitations	116
7 Policy Implications for South Africa	116
Bibliography	120
<b>Chapter 4: Innovation and Hydrogen Fuel Cell Manufacturing</b>	<b>125</b>
1 New Shift in Global Manufacturing	125
2 Collaborative Innovation in Manufacturing	127
3 Proton Exchange Membrane Fuel Cell Manufacturing	131
4 Factors Driving Proton Exchange Membrane Fuel Cell Manufacturing	136
5 Strategies of Firms in South Africa	146
6 Research Networks as a Localisation Strategy	149
7 Policy Implications	150
Bibliography	153
<b>Chapter 5: Exploring Pathways to a Hydrogen Fuel Cell Transition in the South African Road Transport Sector</b>	<b>157</b>
1 Introduction	157
2 What is Hydrogen in Physical and Energy Terms?	159
3 Challenges to a Hydrogen Economy	162
4 National Research Programmes in South Africa and Elsewhere	165
5 The Performance of Fuel Cell-powered Vehicles	167
6 The Future Costs of Fuel Cell Vehicles	171
7 Results and Discussion	176
8 Findings and Conclusions	194
Bibliography	197

<b>Chapter 6: Geopolitical Implications of a Global Hydrogen Economy for Southern Africa</b>	<b>199</b>
1 Introduction	199
2 Geopolitical Socio-technical Landscape of PGM	205
3 Geopolitical Factors in the Socio-technical Regime of PGM	217
4 The Dominant Practices and the PGM Sector	228
5 Some Considerations in a Geostrategic Approach	233
Bibliography	238
<b>Chapter 7: Beyond Mining: Sustainability and Sustainable Development – Theoretical Foundation</b>	<b>245</b>
1 Introduction	245
2 Beneficiation	251
3 Sustainability and Sustainable Development	268
4 Regulatory Structures Impacting Mining	275
5 Situational Analysis Pointing the Way Forward to Rethinking Sustainability on the Mines	278
6 Sustainable Development as Managed Transitions	279
Bibliography	281
<b>Chapter 8: Beyond Mining: Sustainability and Sustainable Development – Sustainability Orientated Model</b>	<b>291</b>
Section A	291
1 Introduction	291
2 Methodology and Theoretical Foundation	297
Section B	303
3 Toward an Industry in Secondary Beneficiation of Mining Waste Residue	303
4 Recommendations: Realisation of an Industry in Secondary Beneficiation	318
Bibliography	321

<b>Chapter 9: Policy Implications</b>	<b>325</b>
Bibliography	336
<b>Appendices</b>	<b>341</b>
Chapter 3	341
Appendix A	341
Appendix B	343
Chapter 5	366
Appendix A	366
Appendix B	383
Appendix C	386
Appendix D	388
Chapter 6	390
Appendix A1	390
<b>Index</b>	<b>393</b>

# FOREWORD

South Africa's endowment of mineral resources is legend. Valued at some US\$2.5 trillion (about R250 trillion), these reserves constitute a national asset from which the nation can collectively draw immeasurable benefit. While mining, refining and export are in themselves important, the significance of these endowments lies in building a mature industrial cluster that combines extraction, manufacturing of machinery and value-added products, and development of engineering services – all of which can be used domestically and for export.

Platinum group metals (PGM), of which the country possesses over three-quarters of known global reserves, are one sub-sector with such possibilities, given their utility which includes jewellery, electronic goods, catalytic converters and hydrogen fuel cells. It is on the latter that this research initiative, *South Africa and the Global Hydrogen Economy: The Strategic Role of Platinum Group Metals* has chosen to focus. The platinum catalyst is a core component of proton exchange membrane fuel cells which are emerging as a dominant hydrogen fuel cell type, capable of powering automobiles and acting as stationary devices to provide electricity.

Herein lies the confluence of factors that have inspired the Mapungubwe Institute (MISTRA) to interrogate this issue: the extensive reserves of a unique class of minerals, the utility of such natural endowments in a nascent energy value chain, and the fact that possibilities exist for such energy to be generated with as little destruction to the environment as possible. In its long-term vision, government has set its sights on South Africa supplying about 25% of global platinum-based fuel cells by the turn of this decade. This may be a tad ambitious: but it does focus the mind on the variety of interventions required to plan appropriately for the tide and ride the crest of a wave.

This report examines the challenges that attach to this ambition. To what extent are PGM relevant to the emergent hydrogen economy and is this economy truly on the rise? What is the state of global research on hydrogen fuel cell technology? What are the lessons that can be learnt from experience on the emergence of a 'disruptive technology'? Is the country's knowledge base, and are its capabilities suited to, and being mobilised for, the changes that are required?

At core is the issue of a knowledge-based network, already manifest in the Hydrogen South Africa (HySA) initiative in which the Department of Science and Technology has invested some resources. If – or indeed, when – the hydrogen economy takes off in earnest, the demand for PGM and fuel cells will be significantly impacted. Yet this will escalate along with capabilities to recycle PGM, which are largely non-perishable. Related to all these probabilities is the potent mix of geo-political issues relating to global security of supply, PGM trading arrangements that minimise disruptive price volatility, and social stability within the mining communities and South Africa at large. Similarly, the extent to which key role-players in the PGM-mining sector – mining corporations, government, workers and communities – are able to forge a compact informed by mutual strategic interest, will be a crucial part of the equation.

The ability to ride the crest of a wave also depends on the courage to take the plunge. This implies, among others, starting today to invest in highly skilled human capital across technologies and segments of the hydrogen fuel cell value chain. It also requires the courage to expand massively, the creation of fuel cell demand within South Africa itself.

A few countries across the globe, including the USA, Germany, Canada, Japan, China and South Korea are undertaking extensive research on hydrogen fuel cell technologies. Needless to say, among these, and between them and South Africa, can be expected some level of subliminal or even open competition. But, as the researchers note in this report, no single country can excel in this field without partnering with others. Each country will have to determine its own balance between pursuit of relative self-sufficiency, and mutually-beneficial global networking across the public and private spheres.

Besides literature reviews and interviews with experts in this field, the researchers have also attempted a novel approach, to apply the optimisation model of the South African energy system to fuel cell-based road transport. The fledgling nature of the hydrogen economy means that many questions are as yet unanswered. MISTRA's modest aim is to contribute to the continuing exploration of, and discourse on, this subject. The researchers, peer reviewers and other partners in this project deserve our profound gratitude. And so do the funders who have made it possible for us to undertake this work.

**Joel Netshitenzhe**  
Executive Director