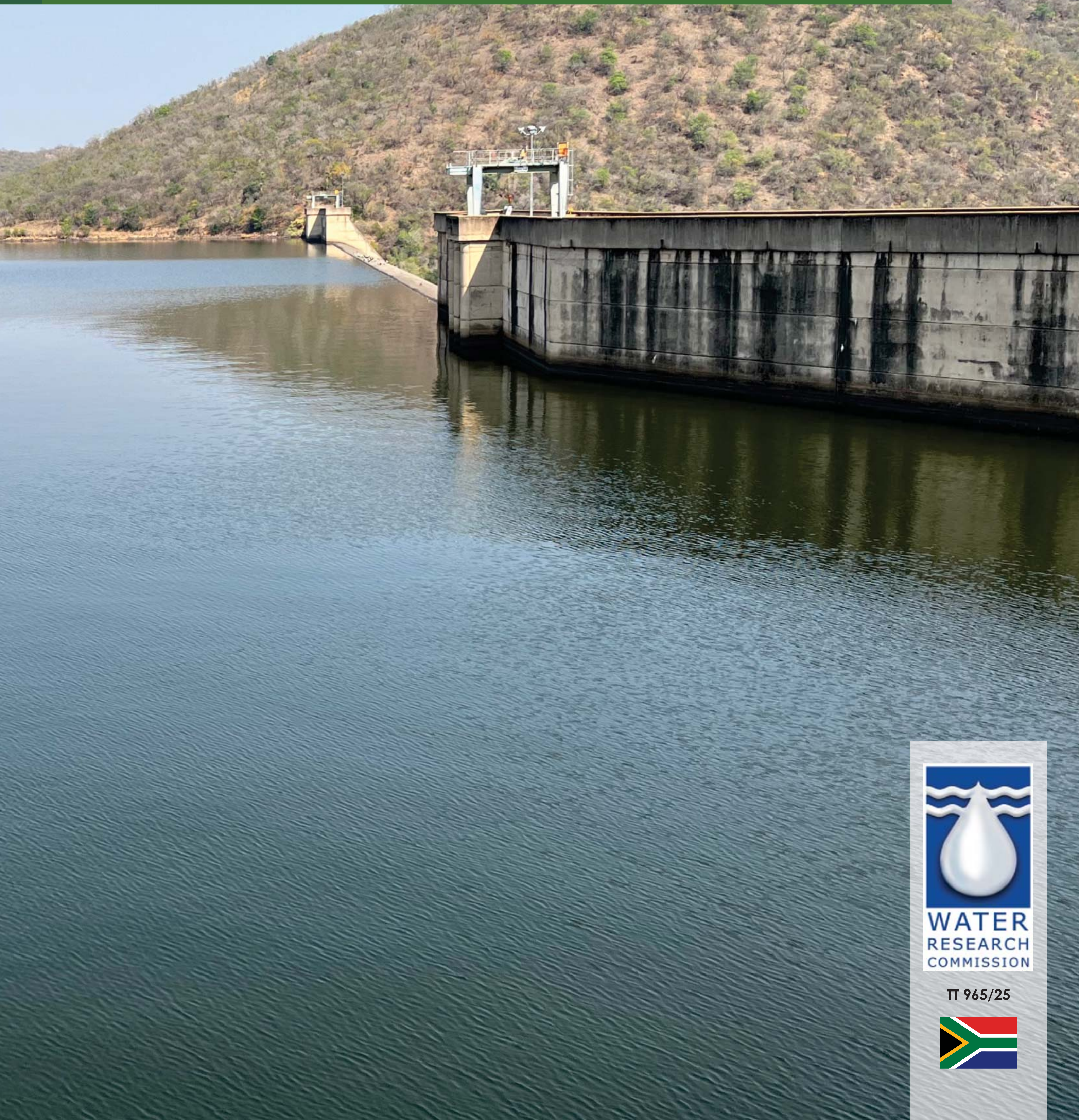
EXPLORING A NEW WATER ECONOMY FOR SUSTAINABLE DEVELOPMENT IN SOUTH AFRICA'S COAL MINING ZONES

Dineo Makate; Bernice Macquela; Valmak Mathebula; and Nompilo Mazibuko



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Exploring a New Water Economy for Sustainable Development in South Africa's Coal Mining Zones

Report to the

Water Research Commission

Prepared by

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EXECUTIVE SUMMARY

Mpumalanga has been central to South Africa's coal-based development for more than a century, supporting electricity generation, industrial activity, and employment at regional and national scales. This development pathway has relied heavily on water for coal mining and power generation, shaping long-term water allocation patterns, but also resulting in unintended declining water quality and environmental degradation in several river systems. As coal mines and power stations are progressively decommissioned, the province faces the challenge of managing the economic transition while addressing the legacy impacts of coal on water resources.

South Africa's commitment to a Just Energy Transition (JET) requires that the move away from coal reduces emissions while also addressing regional inequality, employment losses, and environmental degradation. In Mpumalanga, where coal mining and coal-fired power generation are deeply embedded in the regional economy, the transition must be managed in a way that creates alternative livelihoods and restores natural systems. Water plays a central role in this process, as changes in the energy system will directly affect water demand, water allocation, and water quality across the province.

The decommissioning of coal-based infrastructure will release substantial volumes of water that were historically allocated to the energy and mining sectors. Without a clear strategy, this water could remain underutilised or contribute to ongoing environmental risks associated with unmanaged discharges. In parallel, Mine-Influenced Water (MIW) and municipal effluent will continue to be generated, reinforcing the need for an integrated and forward-looking approach to water management during and after the transition.

This study examines whether water associated with coal mining and power generation can be recovered, treated, and reused to support a new water economy in Mpumalanga. The assessment focuses on three primary sources of water, namely, raw water previously used by Eskom power stations and coal mines, MIW generated from active and legacy mining operations, and treated municipal effluent from Wastewater Treatment Works (WWTW). The study evaluates the volumes, quality characteristics, and treatment requirements of these water sources to determine their potential for productive reuse.

The analysis indicates that more than 340 million m^3/a of water will become available by 2030 across Mpumalanga as coal mines and power stations are decommissioned. This includes relatively high-quality raw water released from Eskom operations, substantial volumes of MIW that can be treated for reuse, and approximately 93 million m^3/a of treated municipal effluent currently discharged into water resources. Together, these flows represent a significant resource that can be redirected to support development rather than contributing to pollution.

Technical assessment indicates that suitable treatment options exist to convert contaminated water into a usable supply at defined and manageable cost levels. Limestone and lime neutralisation represent the lowest cost treatment options, with average treatment costs of approximately R5.68 per m^3 for irrigation and other non-potable uses. Biological sulphate removal increases treatment costs to approximately R7.40 per m^3 while achieving improved sulphate reduction and broader industrial reuse potential. Reverse Osmosis (RO), required for applications demanding high purity water such as electrolysis, has an average treatment cost of approximately R18.61 per m^3.

Economic modelling demonstrates that irrigation offers the most immediate and inclusive benefits for Mpumalanga. Reusing treated MIW for irrigation could generate more than R3 billion in direct Value Added (VAD) and approximately R26 billion in total economic output each year. This pathway could also create about 16 000 jobs across agriculture, agro-processing, and associated value chains, providing important opportunities for communities affected by mine and power station closures.

Green Hydrogen (GH) production presents a longer-term opportunity for industrial diversification and participation in emerging low carbon markets. Mpumalanga's existing grid infrastructure, industrial base, and technical workforce provide a strong foundation for future hydrogen development. This role aligns with South Africa's Green Hydrogen Commercialisation Strategy, which recognises the importance of inland industrial regions in supporting domestic hydrogen demand, skills development, and early project deployment alongside coastal export hubs. The analysis indicates that, while water quality requirements are stringent, water availability and treatment costs are not the primary determinants of hydrogen viability when compared with Renewable Energy (RE) costs, electrolyser performance, and infrastructure readiness. Although RO is substantially more expensive, water treatment costs remain small relative to total GH production costs, which are dominated by renewable electricity prices and electrolyser capital and operating costs.

The findings show that water reuse can act as a practical enabler of JET by linking environmental restoration with economic renewal. Redirecting water released from coal-based activities toward productive uses supports employment creation, reduces long-term environmental risk, and strengthens water security, ensuring that affected regions benefit directly from the transition.

Priority should therefore be given to reusing released water for irrigation in the short- to medium-term, while creating the enabling conditions for future industrial uses such as GH. Achieving these outcomes will require coordinated planning across water, energy, and land-use systems, streamlined regulatory processes, and targeted investment in treatment and reuse infrastructure to ensure that water released from the coal sector becomes a driver of sustainable development, economic resilience, and environmental improvement.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

Al	Aluminium
AMD	Acid Mine Drainage
BCR	Benefit-Cost Ratio
COD	Chemical Oxygen Demand
DMPR	Department of Mineral and Petroleum Resources
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
GDP	Gross Domestic Product
GH	Green Hydrogen
GVA	Gross Value Added
GW	Gigawatt
H_2	Hydrogen
H_2O	Water
IRP	Integrated Resource Plan
IVRS	Integrated Vaal River System
JET	Just Energy Transition
MIW	Mine-Influenced Water
Mn	Manganese
PEM	Proton Exchange Membrane
RE	Renewable Energy
RO	Reverse Osmosis
VAD	Value Added
WARMS	Water use Authorisation and Registration Management System
WHO	World Health Organisation
WMA	Water Management Area
WRDC	Water Resource Development Charge
WRMC	Water Resource Management Charge
WWTW	Wastewater Treatment Work

CHAPTER 1: BACKGROUND AND INTRODUCTION

1.1 Coal-based Development, Water Use and Environmental Legacy

Coal has underpinned South Africa's economic development for more than a century, forming the backbone of electricity generation, industrialisation, and employment creation. Since the early twentieth century, the expansion of coal mining and coal-fired power generation has shaped national infrastructure investment, industrial location, settlement patterns, and energy policy. Early industrial development in South Africa was closely linked to the availability of cheap coal-based electricity, which enabled the growth of mining, mineral processing, manufacturing, and urbanisation. Coal-based energy systems have historically supported industrial growth while simultaneously generating long-term environmental externalities and structural economic dependence (Staffell et al., 2019; International Energy Agency [IEA], 2019).

Mpumalanga Province occupies a central position within South Africa's coal economy. The province produces more than 80% of the country's coal and hosts most of Eskom's coal-fired power stations, including some of the largest coal-based plants on the African continent. The spatial concentration of coal mines and power stations has created a regional development trajectory in which economic activity, infrastructure provision, and employment are closely linked to the coal and energy sectors. Over several decades, this coupling has shaped land-use patterns, investment decisions, and the allocation of natural resources, particularly water, often with limited consideration of long-term environmental sustainability.

The concentration of coal-related activities in Mpumalanga has delivered significant economic benefits, including employment creation, fiscal revenue, and infrastructure development. At the same time, this development pathway has resulted in a high degree of economic concentration and resource dependency. As South Africa transitions away from coal, the province is expected to experience substantial economic, social, and environmental change associated with the restructuring of the national energy system.

These changes are closely linked to the way natural resources have been allocated and managed to support the coal economy, particularly water. The structure of the provincial economy and the design of supporting infrastructure have resulted in strong interdependencies between energy production and water use. Water has therefore played a central and enabling role in the development of the coal economy in Mpumalanga.

Coal mining and coal-fired power generation are inherently water-intensive, requiring water at multiple stages of the value chain. Water is used for drilling and blasting, coal washing and beneficiation, dust suppression, slurry transport, boiler feed water, flue gas desulphurisation, and cooling. In the province, large volumes of water have historically been abstracted from surface water and groundwater sources to support coal mining and power generation. Where local resources were insufficient, extensive inter-basin transfer schemes were developed to augment supply. These transfers have played a critical role in sustaining power generation but have also altered natural flow regimes and increased dependence on imported water.

The prioritisation of water allocation to the energy and mining sectors reflects historical development priorities that placed national energy security and industrial growth above competing water uses, including ecological reserve requirements. Over time, this allocation pattern has contributed to cumulative environmental impacts.

Mine-Influenced Water (MIW), industrial effluent, and inadequately treated municipal wastewater have contributed to cumulative degradation of key river systems, including the Olifants, Inkomati, Usuthu and Vaal Rivers. Elevated sulphate concentrations, increased salinity, acidification, and metal contamination have been documented over several decades, affecting agricultural productivity, aquatic biodiversity, and the cost of potable water treatment (Department of Water and Sanitation [DWS], 2023).

MIW represents one of the most persistent environmental legacies associated with coal mining in Mpumalanga. MIW can be treated to meet a range of quality requirements depending on intended use. South Africa has a long history of mine water treatment development supported by operational practice and applied research. Lime and limestone neutralisation processes reduce acidity and metal concentrations at relatively low cost, while Biological Sulphate Removal (BSR) reduces sulphate concentrations and enables resource recovery in some cases. Reverse Osmosis (RO) produces high-quality water suitable for industrial and potable use, although at a higher capital and operational cost (Maree et al., 2013; Schoeman and Steyn, 2001; Coaltech 2020; Van Rooyen, 2016; Karakatsanis and Cogho, 2010).

Large-scale applications of mine water treatment in South Africa provide operational experience relevant to future water reuse. The Emalahleni Water Reclamation Plant supplies treated MIW for municipal and industrial use. This facility reduces pollution loads while contributing to local water supply and economic activity when implemented within appropriate institutional and governance arrangements (Water Research Commission [WRC], 2004). These experiences support an approach that considers MIW as a recoverable water resource rather than solely an environmental liability.

1.2 The Just Energy Transition and Changing Water Dynamics

South Africa’s commitment to a Just Energy Transition (JET) reflects a national policy objective to reduce greenhouse gas emissions while addressing social equity, regional inequality, and environmental restoration. For coal-dependent regions, the transition extends beyond changes in energy supply to include broader economic and resource system adjustment.

In Mpumalanga, coal mining and coal-fired power generation are deeply embedded in regional livelihoods, governance systems, and spatial development patterns. The Integrated Resource Plan (IRP) projects the retirement of approximately 10 GW of coal-fired generation capacity by 2030, with further reductions thereafter, leaving only Medupi and Kusile operational by around 2040 (Department of Mineral Resources and Energy [DMRE], 2023). These changes are expected to be accompanied by the closure or downscaling of coal mines that have historically supplied Eskom’s power stations.

The scale and pace of these changes imply significant structural adjustment for Mpumalanga’s economy. The decline of coal-based activities will affect employment, municipal revenue, and supporting industries. At the same time, it will alter water demand patterns by reducing abstraction associated with power generation and mining. Water previously allocated to these uses will become available for reallocation, with implications for water pricing, cost recovery, and the financial sustainability of infrastructure designed around large industrial users.

Climate change adds a further layer of complexity to these dynamics. Water stressed regions undergoing energy transitions face compounded risks if adaptation considerations are not integrated into transition planning (IPCC, 2022). In Mpumalanga, climate variability is likely to interact with legacy pollution and changing water demand patterns, reinforcing the need for adaptive and resilient water management strategies.

These changes highlight the interdependence between water and energy systems. Green hydrogen (GH) production has emerged as a strategic component of many national decarbonisation strategies, but its feasibility is closely linked to water availability and water quality due to its reliance on electrolysis and cooling systems (International Renewable Energy Agency [IRENA], 2020; IEA, 2021). At the same time, irrigated agriculture remains one of the most water productive sectors in terms of employment creation and value addition, particularly in rural economies. The reuse of treated MIW and municipal effluent for irrigation has been identified internationally as a viable strategy in water scarce regions, provided that appropriate quality standards and monitoring frameworks are applied (Matebese et al., 2024).

This report examines the emergence of a new water economy as Mpumalanga transitions away from coal. A new water economy refers to the recovery, treatment, reallocation, and productive use of water resources that become available as a result of mine and power station closures. This includes raw water previously allocated to energy generation, treated MIW, and reused municipal effluent.

Rather than viewing these water sources solely through the lens of risk, compliance, or environmental liability, the concept of a new water economy emphasises their potential role in supporting economic diversification, environmental restoration, and social inclusion in a reduced coal consumption context.

This report presents the analyses of water as a central factor in assessing opportunities and risks related to the JET. It examines water availability, quality, treatment, and economic use, emphasising that effective water management is crucial for a sustainable energy transition. The study aims to determine how water resources can enable a post-coal water economy in Mpumalanga within South Africa’s JET framework.

The specific objectives of the study are to:

- Establish a baseline of water availability, use and quality across Mpumalanga’s major catchments with particular emphasis on coal-related water use.
- Assess the implications of coal mine and power station decommissioning for future water balances and identify volumes of water that may become available for reallocation.
- Evaluate the potential for reusing MIW and treated municipal effluent, including an assessment of appropriate treatment technologies.
- Quantify water requirements for selected post-coal economic pathways, namely, irrigation and GH production; and
- Assess the economic implications of a new water economy, including Value Added (VAD) employment creation and broader regional development impacts.

CHAPTER 2: WATER USE IN MPUMALANGA

2.1 Overview

In this chapter, the current water use across Mpumalanga's catchments is described. By describing the study area and its water use patterns, this chapter provides the framework for analysing water balances, identifying potential sources for reallocation, and evaluating future opportunities for a new water economy.

2.2 Study Area

Mpumalanga lies in the northeastern part of South Africa and represents a significant strategic contribution towards the national economy, hosting high industrial activities and vast tracts of agricultural and natural landscapes. The province's prosperity has historically been based on coal mining and energy production, but it is also an area of fertile farmland, forestry, and tourism, particularly in the Lowveld and escarpment regions. These multiple land uses place competing demands on the province's limited water resources and underscore the importance of understanding its hydrological systems in detail.

Mpumalanga's economy, environment, and water resources are deeply intertwined. Mpumalanga falls within three major Water Management Areas (WMAs), namely, the Inkomati-Usuthu, Upper Olifants, and the Upper Vaal. Each of these catchments has distinct hydrological characteristics, economic functions, and management challenges. Together they form the basis of the province's water economy and are central to the analysis undertaken in this study.

In terms of water use, irrigated agriculture accounts for approximately 57% of total water demand in Mpumalanga, making it the dominant water-using sector. Forestry contributes about 18% of total use, largely through consumptive evapotranspiration associated with commercial plantations. Power generation accounts for approximately 8% of total water use, reflecting ongoing requirements at coal-fired power stations. Domestic and municipal use represents around 8%, while manufacturing accounts for approximately 7% of total demand. Mining contributes the smallest share at about 2% of overall water use. Industrial and commercial water use is concentrated in major urban and industrial centres, particularly Secunda, Middelburg, and Emalahleni, where intensive industrial activities are located.

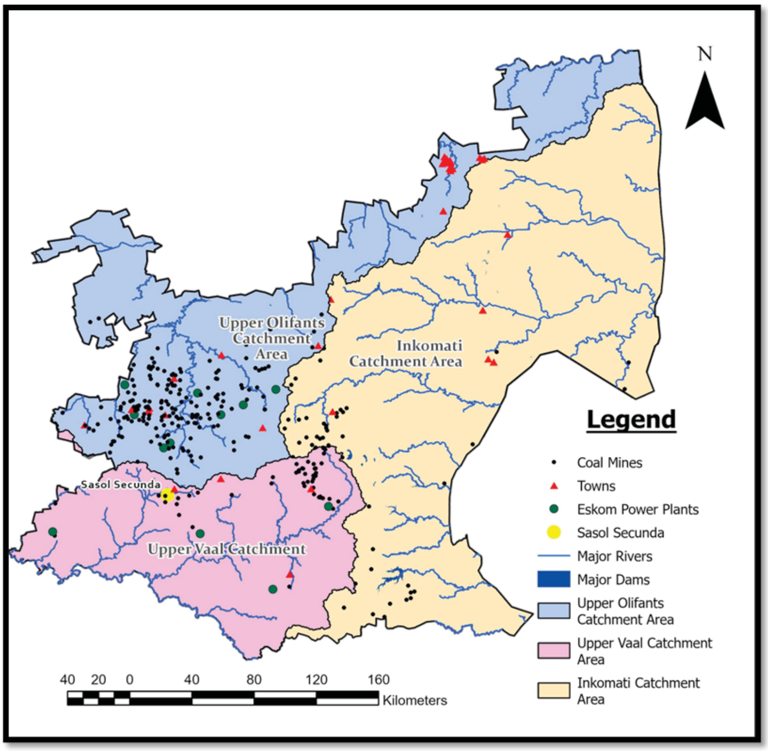

Figure 2-1: Study Area and its Land-use Activities

2.2.1 Inkomati-Usuthu Water Management Area

The catchment supports a mix of irrigated agriculture, commercial forestry, mining, and tourism. Its upper reaches receive relatively high rainfall and are covered by extensive plantations of pine and eucalyptus, which play an important role in the regional economy but also reduce streamflow due to high evapotranspiration rates. Downstream, irrigation farming of sugarcane, fruit, and vegetables depends heavily on a reliable water supply from dams and rivers. The catchment is subject to international water-sharing agreements that require South Africa to maintain specific flow volumes into Mozambique, creating an additional layer of management complexity. Water quality issues arise mainly from agricultural runoff, urban wastewater, and small mining operations.

2.2.2 Upper Vaal Water Management Area

The catchment overlaps with the industrial corridor linking Secunda, Standerton, and parts of the Free State. It is a highly developed catchment that provides water to both industrial and municipal users. The Grootdraai Dam on the Vaal River is a critical storage and transfer facility that supplies water to the petrochemical industry and power generation stations. Inter-basin transfers from the Usuthu and Komati Rivers augment supply to meet industrial demand. The catchment is also home to Sasol’s synthetic fuel plant at Secunda, which is one of the largest single industrial water users in the country. Urban settlements in the area depend on the same water system, creating competition between domestic and industrial needs. Water quality challenges include high salinity, nutrient enrichment from wastewater discharges, and contamination from industrial effluents.

2.2.3 Upper Olifants Water Management Area

This catchment contains the largest concentration of mines and power stations in the country. Major tributaries such as the Klein Olifants, Wilge, and Steenkoolspruit drain into the Olifants River, which eventually feeds into the Loskop Dam and further downstream into the Limpopo River system. The area has been heavily altered by mining, with extensive opencast pits, tailings dams, and ash disposal sites. Water quality has been severely affected by Acid Mine Drainage (AMD) and industrial effluent discharges. Elevated levels of sulphates, iron, and other metals have been recorded in many streams, posing risks to agriculture and aquatic ecosystems. Despite these challenges, the catchment remains an economic powerhouse, hosting major Eskom power stations such as the Kendal, Duvha, and Kriel power stations, as well as large-scale mining operations operated by Exxaro, Seriti, and Glencore.

2.3 Water Use by Sector

Water use in Mpumalanga is dominated by power generation, manufacturing, and agriculture, with municipal and domestic accounting for the remaining demand. The distribution of water use across sectors reflects historical development patterns linked to mining, energy production, and irrigated agriculture. The sectoral distribution of water demand is summarised below.

Power Generation: Eskom's fleet of coal-fired power stations in Mpumalanga uses an estimated 214 million m^3/a (Eskom, 2024). The water is primarily used for cooling systems, boiler feed, and flue gas desulphurisation. The Komati power station has already been decommissioned, and its closure has released an estimated 15 million m^3/a of water. Additional decommissioning of Hendrina, Camden, and Grootvlei power stations is expected to further avail approximately 50 million m^3/a of water by 2030.

Manufacturing: The manufacturing sector uses approximately 179 million m^3/a of water, with the Upper Vaal region accounting for the majority of this demand at approximately 111 million m^3/a. Sasol is one of the largest industrial water users in the province. This water is sourced primarily from the Integrated Vaal River System (IVRS). Direct water demand at the Secunda operations is expected to increase in the medium term (Sasol Limited, 2023).

Agriculture: Agriculture is the largest water using sector in Mpumalanga, accounting for the majority of total water withdrawals across the province. Total agricultural water use is estimated at approximately 1 434 million m^3/a, of which about 1 069 million m^3/a occurs within the Inkomati-Usuthu Catchment. Irrigated agriculture in this area is dominated by sugarcane, citrus, and other subtropical crops that depend on regulated river abstractions and dam releases. Agricultural water use is particularly concentrated around towns such as Malelane, Komatipoort, Nkomazi, Barberton, and the Lower Crocodile River area, where large-scale commercial irrigation schemes are well established.

Forestry: Forestry water use totals approximately 450 million m^3/a across the province, of which about 428 million m^3/a occurs within the Inkomati-Usuthu Catchment. This water use occurs mainly through evapotranspiration rather than direct abstraction and reduces runoff and groundwater recharge in areas with high plantation density. Major commercial forestry operations in the catchment include plantations associated with companies such as Sappi, which represent a significant component of the provincial forestry sector.

Municipal and Domestic: Urban and rural municipalities in Mpumalanga collectively use approximately 202 million m^3/a of water for domestic and municipal purposes. Non-revenue water is estimated at about 40%, largely due to ageing infrastructure, leakages, and operational inefficiencies, as reported in the Green Drop assessment (DWS, 2021). These losses reduce effective water availability and place additional pressure on existing supply systems. Return flows from (WWTW) amount to approximately 94 million m^3/a, representing a potential source for reuse following appropriate treatment.

2.4 Summary

Water use in Mpumalanga is dominated by irrigated agriculture, forestry, and coal-based energy production, reflecting the province's historical development pattern. Irrigated agriculture is the largest water using sector, concentrated mainly in the Inkomati-Usuthu area. Mining represents the smallest volumetric demand, although its impact on water quality is significant.

Water demand in several parts of the province exceeds locally available surface water resources and is therefore supported by regulated storage and inter-basin transfers, particularly in the Upper Vaal and Upper Olifants areas. These transfers are essential for sustaining industrial activity and power generation, as local supplies alone are insufficient to meet demand. This reliance on managed transfers highlights the importance of understanding how water allocation and demand will change as coal mines and power stations are decommissioned, and how released water could support a new water economy based on reallocation, reuse, and improved efficiency.

CHAPTER 3: SOURCES OF WATER FOR A NEW WATER ECONOMY

3.1 Introduction

Assessing the potential for a new water economy in Mpumalanga requires an understanding of the sources of water that are expected to become available as coal mines and selected power stations are decommissioned. The province presents a strategic opportunity to reallocate substantial volumes of water that have historically been reserved for coal-based energy production and mining activities. As Eskom decommissions power stations under the JET, raw water previously used for power generation will be released and can be redirected to alternative productive uses, if allocation and system constraints are appropriately managed.

In parallel, MIW will continue to be generated from both active and closed coal mining operations as groundwater systems recover following mine closure. Although traditionally regarded as an environmental liability due to its quality characteristics, MIW represents a reliable and continuous source that can be converted into a usable resource through appropriate treatment. In addition, treated effluent from municipal WWTWs provides a further source of water that can support non-potable applications while reducing pressure on freshwater resources. This chapter, therefore, focuses on identifying and characterising three key water sources, namely, raw water released through power stations and mine decommissioning, MIW, and municipal wastewater effluent, by examining their volumes, spatial distribution, and quality characteristics to inform subsequent assessment of water balances and suitability for productive uses such as irrigation and GH production.

3.2 Raw Water from Power Stations and Coal-mining Operations

A significant opportunity for reallocating water in Mpumalanga comes from the decommissioning of Eskom power stations. These facilities have historically consumed large volumes of water, supplied through various inter-basin transfer schemes. As the power stations decommission as part of the JET, the raw water that was previously allocated for their operations may become available for alternative uses such as GH production.

Table 3-1 provides a breakdown of Eskom's projected water demand up to 2035. By 2030, the decommissioning of Komati, Hendrina, and Camden will result in about 43.5 million m^3/a becoming available, of which 34.5 million m^3 is from the Komati system and 9 million m^3 from the Vaal system. By 245, the cumulative water release from all stations is expected to reach between 200 and 245 million m^3/a. Notably, Arnot is expected to reduce its water usage by 92.7%, while Kriel and Hendrina will have water use decreases of 89.6% and 90.5%, respectively. Similarly, Camden power station's demand is projected to decrease by over 97%, indicating a significant reduction in operations. Other substantial reductions are expected at Matla and Duvha power stations, both of which will reduce their water demands by more than 60%. These changes are consistent with the planned phasing out of these power stations.

Table 3-1: Projected Water Demand for Eskom Power Plants for the Year 2035 (Eskom, 2024)

Power Station	Projected Gross Water Demands from Eskom Power Stations (million m^3/a)	
	2024	2035
Hendrina	13.337	1.264
Arnot	25.307	1.838
Duvha	26.113	9.974
Komati	2.619	2.619
Kriel	29.569	3.067
Matla	37.585	14.541
Kendal	8.667	13.267
Camden	16.087	0.445
Majuba	20.037	14.669
Tutuka	26.718	24.498
Kusile	8.125	11.046
Total	214.16	97.23

Coal-mining operations in Mpumalanga have historically relied on substantial volumes of raw water to support a range of operational activities. These include dust suppression, coal washing and beneficiation, equipment cooling, slurry transport, and general site operations. Raw water for mining has been abstracted from surface water resources, groundwater, and regional supply systems, often supported by inter-basin transfers in areas where local resources were insufficient.

Total raw water use associated with coal mining in Mpumalanga is estimated at approximately 43 million m^3/a, making mining a relatively small volumetric user compared to agriculture, forestry, and power generation. Despite this lower volume, mining-related water use is spatially concentrated in areas such as the Upper Olifants, where coal mining activity has been most intensive. In these areas, mining water use has been closely integrated with power station supply systems and regional water infrastructure.

3.3 Mine-Influenced Water

The province’s history of coal mining has resulted in extensive underground workings, waste rock dumps, and open pits that collect and release water into surrounding systems. This water is often contaminated with sulphates, metals, and other dissolved solids, but it represents one of the largest recoverable resources in the province.

As mines close, these stored waters can either pose a pollution risk through uncontrolled decant or be reclaimed through treatment for industrial or agricultural use. Treatment processes such as neutralisation and RO have already been demonstrated successfully in facilities such as the eMalahleni Water Reclamation Plant, which produces potable quality water from MIW.

MIW is a significant component of the water resources landscape in Mpumalanga, especially in areas with active or legacy coal mining. While only about 4% of this water is discharged directly into rivers, many mines use adjacent rivers as key sinks for excess water. This creates complex interactions with river systems and raises concerns around cumulative water quality impact.

According to the Water Use Authorisation and Registration Management System (WARMS, 2023), coal mining operations in the province produce approximately 224 million m^3 per annum of MIW. This water is managed through a combination of point source discharge and infiltration into the water resource.

Among the catchments, the Upper Olifants records the highest volume of MIW, followed by the Inkomati-Usuthu and Upper Vaal. These figures underscore the scale of MIW and the importance of long-term water quality management in these areas, particularly in light of mine closures under the JET.

Table 3-2: Mine-Influenced Water in Mpumalanga by Catchment (WARMS, 2023)

Discharge Method	Upper Olifants (m^3/a)	Upper Vaal (m^3/a)	Inkomati-Usuthu (m^3/a)
Sink (into rivers)	163,539,005	11,535,979	35,140,261
Point Source Discharge	13,293,045	174,900	373,900
Total	176,832,050	11,710,879	35,514,161

3.4 Municipal Effluent

The 2022 Department of Water and Sanitation (DWS) Green Drop Report indicates that Mpumalanga Province operates 76 municipal WWTWs, collectively discharging about 93 million m^3/a of treated municipal wastewater into the water resource. This municipal effluent represents a significant but underutilised component of the province's overall water resources. The performance of these WWTWs varies widely, with only a few meeting full compliance according to the 2022 Green Drop Audit Report (Green Drop Report, 2022).

Despite these challenges, treated municipal effluent presents a substantial opportunity for reuse within Mpumalanga's new water economy. With appropriate upgrades, effluent from WWTWs could supply water for industrial processes, irrigation and non-potable municipal applications.

3.5 Summary

Mpumalanga has access to three water sources that can support a new water economy as coal mines and power stations are decommissioned, namely, raw water currently allocated from power generation and mining operations, MIW, and treated municipal effluent. Together, these sources form a substantial and reliable resource base that can be repurposed for productive use as coal-based activities decline. This confirms that water availability itself is unlikely to be a limiting factor for post-coal development, provided that these sources are actively managed as assets rather than treated as residual by-products of closure.

The key challenge is therefore not the presence of water, but how effectively it is treated, allocated, and integrated into development planning. Converting raw water, MIW, and municipal effluent into economic and environmental value will require a coordinated approach that links mine closure planning, water management, and targeted investment. When aligned, water reuse can support irrigation, reduce pollution risks, and enable longer-term industrial development, positioning water as a practical enabler of JET.

CHAPTER 4: NEW WATER ECONOMY PATHWAYS

4.1 Introduction

This chapter examines the water requirements and potential water resource implications of two priority pathways within a new water economy, namely, GH production and irrigation. As Mpumalanga transitions away from coal, these activities are increasingly considered for their potential to support economic diversification, employment creation, and long-term regional development. Understanding their water demands and quality requirements is essential to ensure that emerging uses are compatible with available water resources and existing water management constraints.

The chapter focuses on defining both the quantity and quality of water required for these uses, with particular attention to how technology choices influence water demand. For GH production, this includes distinguishing between feedstock and cooling water requirements and assessing the implications of different cooling system configurations. For irrigation, the chapter outlines the water quality standards needed to protect agricultural productivity, soil health, and environmental integrity. Together, the analysis provides a foundation for evaluating the sustainability of these uses and their role in supporting a new water economy in Mpumalanga.

4.2 Green Hydrogen Production: Water Quantity Requirements

Water is consumed as feedstock for electrolysis and cooling feed water during GH production. Figure 4-1 shows a schematic diagram for a GH production process, which indicates rivers, lakes, groundwater seawater and treated municipal wastewater as various possible sources of water for GH production.

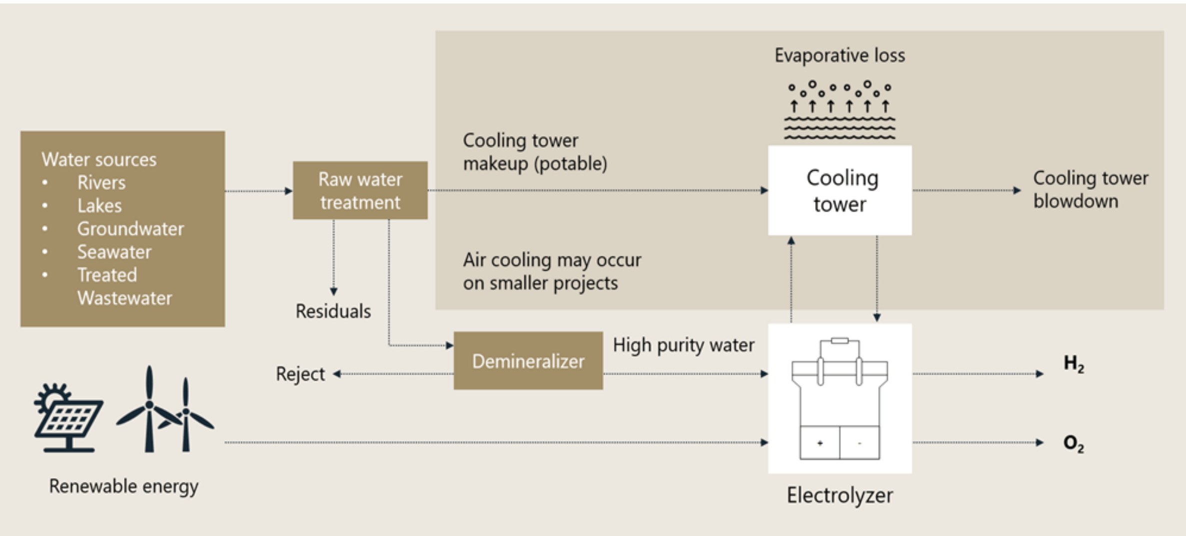

Figure 4-1: Schematic Diagram of GH Production (GHD, 2022).

The water requirement for GH is stoichiometrically 9 L of water per kg of hydrogen produced. Cooling water has the potential to be the largest contributor to water usage in the GH production value chain. These additional loads can lead to as much as 60 to 95 L of water required per kg of GH produced, assuming full evaporative cooling. A typical breakdown for GH production process water utilisation is shown in Figure 4-2.

Water requirements are generally higher in the production of GH than blue hydrogen, due to both feedstock water consumption and cooling water consumption and losses.

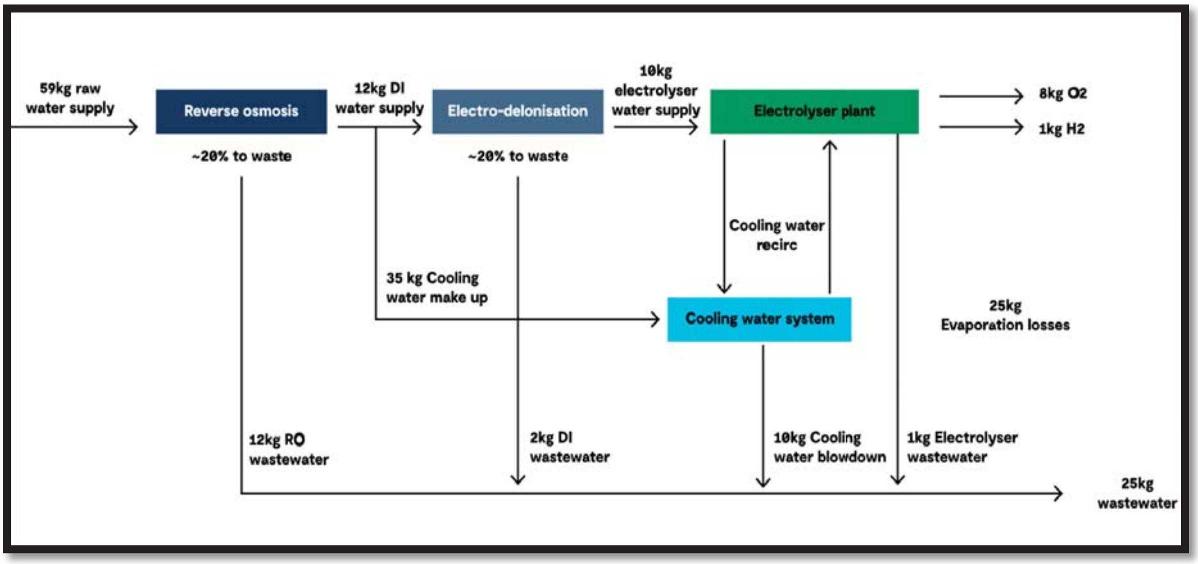

Figure 4-2: Breakdown for GH Production Water Demand, ~60 L H_2O per kg H_2 (GHD, 2022)

The type of cooling system used for GH production and carrier conversion has a significant effect on the amount of water usage in a system, as shown in Table 4-1. For this reason, water requirements for different cooling systems were investigated, including once-through, closed recirculating (non-evaporative), and open recirculating (evaporative) systems.

Water usage is highest for once-through cooling systems with no water losses. However, for evaporative cooling systems, there are water losses and required makeup. For an evaporative cooling system, makeup water per kg of GH can range from 3 L in the coolest or high humidity area to 60 litres in the hottest or low humidity area. This highlights the need to consider water-efficient cooling system design in water-scarce and high-evaporation regions like South Africa.

Table 4-1: Water Usage in the Cooling Systems

Water requirement per cooling system	High end (L)	Low end (L)
Cooling H_2O Consumption per kg H_2 (evaporative water cooling)	43	23
Cooling H_2O Required per kg H_2 (once-through cooling)	1813	913
Cooling H_2O Consumption per kg H_2 (air cooling)	0	0

4.3 Green Hydrogen Production: Water Quality Requirements

GH requires highly purified water as a feedstock; however, it is necessary to distinguish between two types of water and their quality requirements, namely, (i) ultrapure water, used as feedstock for the electrolyser, and (ii) cooling water.

4.3.1.1 Water Quality Requirements: Feedstock

Water used for GH production must be of high purity to prevent damage to electrolyser components and to maintain the efficiency of the electrolysis process. The two types of commercially available electrolysers include the Proton Exchange Membrane (PEM) electrolysers and alkaline electrolysers.

Although they operate differently, both require feed water that is virtually free of impurities to ensure stable operation and the prevention of long-term performance degradation.

Several categories of contaminants must be carefully controlled. Dissolved ions in the water can interfere with electrochemical reactions and corrode sensitive internal components. Particulates may accumulate on membranes or internal flow paths, causing clogging, abrasion, or inconsistent flow. Organic compounds can form unwanted deposits on electrode surfaces or create insulating layers on membranes, affecting current flow and energy efficiency. Additionally, organics support microbial growth, which may result in the formation of biofilms. Bacterial contamination, in turn, can obstruct water passages and impair system function.

To avoid these challenges, water must be treated to meet stringent quality criteria, as shown in Table 4-2.

Table 4-2: PEM and Alkaline Electrolyser Feed Water Quality (according to the American Society for Testing and Materials International)

Parameter	Unit	Limit
Electrical conductivity	μS/cm at 25°C	1.0
Electrical resistivity	MΩ·cm at 25°C (minimum)	1.0
Total Organic Carbon, max	μg/L	50
Sodium, max.	μg/L	5
Chlorides, max.	μg/L	5
Total Silica, max.	μg/L	3

4.3.1.2 Water Quality Requirements: Cooling Water

As there is variation in the types of cooling water systems used, there are variations in recommended water quality. There are two types of cooling systems used:

- Once-Through Cooling
- Evaporative Cooling

Once-through cooling water systems use large volumes of water as they immediately discharge the water after it has been used for cooling. As such, there is little evaporation, so the water quality requirements are less strict. Often, raw water sources such as surface water and seawater are used, with limited treatment required before use. Unlike the high-purity water required for electrolysis, only limited treatment is required to screen large objects that may damage equipment (Australian Hydrogen Council, 2022).

Evaporative cooling systems require less raw water than once-through cooling, although there is more concern regarding the cooling water quality. As cooling water is circulating, some proportion of the water is lost through evaporation or blowdown (discharging of water from the cooling system). As makeup water is added to replace water lost, the concentration of dissolved solids increases. This is detrimental to cooling performance as these solids can cause corrosion and fouling. As such, evaporative cooling systems have strict requirements for water quality, as the concentration of dissolved solids in the feed water quickly increases due to cycles of concentration.

4.4 Potential Impact of Green Hydrogen Production on Water Resources

Depending on the electrolyser and cooling system utilised for GH production, environmental considerations relating to water use vary. Some of the environmental considerations include water source selection, water treatment methods selection, waste management and environmental discharge.

GH production requires the use of ultra-pure water, which comes with the requirement to treat the water prior to its use. The use of RO to treat water for use to produce GH results in the production and discharge of potentially large quantities of brine that require careful management.

Various types of waste streams are therefore produced from water treatment using various treatment technologies and these need to be managed for disposal. These include:

- Sludge and dewatered solids
- Chemical waste stream
- Brine stream from the reverse osmosis process, and membrane elements or resins from various process

The need to understand the design of an RO Plant and the sensitivity of the discharge area prior to the commencement of the environmental authorisation process (i.e., Environmental Impact Assessment and Water Use Authorisation) is important.

Defining the quantity and quality of brine discharges, along with mitigation measures/strategies for dealing with this effluent are important and requires upfront investment in the conceptual design of the RO plant and the effluent treatment system. Table 4-3 shows some environmental considerations for waste generated.

Table 4-3: Sources of Waste and Environmental Considerations

Process Treatment	Type of Waste	Environmental Consideration
Chemical flocculation and clarification	Floating scum/algae from any flotation process equipment and sludge stream from clarifier	Further sludge drying helps to reduce sludge volume, minimise nuisances and maximise the recovered value of sludge. As water treatment sludge is mostly inorganic matter and subject to local regulations, sludge cake material may be appropriate for reuse, for example, as a replacement for raw materials in road base, backfill or concrete mix. However, consideration of residual contamination will be required.
Reverse Osmosis	Brine stream	• Find an opportunity to co-discharge with nearby wastewater treatment plant facility if possible • The brine concentration, when compared to background concentrations, the velocity of its release, the temperature and colour of the brine discharge • The existing ecosystem, including the presence of significant or sensitive ecosystems • The depth, distance from shore and prevailing currents in the "mixing zone" • The presence of socially or culturally significant landscapes (e.g., commercial fishing grounds)

4.5 Irrigation: Water Quality Requirements

The use of irrigation as a new water economy in Mpumalanga will require water that complies with irrigation quality standards. This plays a vital role in safeguarding agricultural productivity, soil health, and environmental integrity. Regardless of the water source, any water intended for irrigation must comply with specific quality criteria to ensure it is fit for use on crops and does not result in long-term harm to soil or surrounding ecosystems.

Irrigation water quality is assessed by analysing key parameters including pH, Electrical Conductivity (EC), suspended solids, and Chemical Oxygen Demand (COD). These factors influence water-soil-plant interactions and are critical in determining the suitability of water for agricultural use. In addition to these general indicators, particular attention must be paid to trace element concentrations, many of which can accumulate in soils and plants over time and potentially reach toxic levels.

The South African Irrigation Water Quality Guidelines (1996) establish maximum acceptable limits for trace elements for both short-term use (20 years) and long-term use (100 years). These thresholds serve as a benchmark for evaluating whether water is appropriate for irrigation under varying durations of exposure.

Table 4-4: Maximum Acceptable Trace Element Content in Irrigation Water (DWAF, 1996)

Water Quality Parameters	Long-Term Limit (100 years) (mg/L)	Short-Term Limit (20 years) (mg/L)
Aluminium	5.0	20.0
Arsenic	0.1	2.0
Beryllium	0.1	0.5
Boron	0.5	Varies by crop (0.5–15.0)
Cadmium	0.01	0.05
Chromium (VI)	0.1	1.0
Cobalt	0.05	5.0
Copper	0.05	5.0
Fluoride	2.0	15.0
Iron	5.0	20.0
Lead	0.2	2.0
Lithium	2.5	–
Manganese	0.2	10.0
Mercury	0.002	–
Molybdenum	0.01	0.05
Nickel	0.2	2.0
Selenium	0.02	0.05
Sulphate	200.0	1000.0
Uranium	0.01	0.1
Vanadium	0.1	1.0
Total Dissolved Solids	450.0	2000.0
Zinc	1.0	5.0

There have been updates to the 1996 guidelines, most notably through work undertaken by the WRC (2017). The more recent guidelines are implemented through a decision support system rather than fixed threshold values. This system is intended to assist users in assessing the fitness of a water source for irrigation use, setting the appropriate water quality requirements for irrigation users, and accessing supporting information. While the report remains grounded in the 1996 guidelines, it extends them by incorporating site-specific factors such as crop type, soil characteristics, climate conditions and irrigation management practices. These factors are considered in combination to determine irrigation water quality suitability and associated risk, rather than relying solely on generic parameter thresholds.

4.6 Summary

GH development in Mpumalanga must also be understood within the context of South Africa's National Green Hydrogen Commercialisation Strategy, which identifies the country's potential to participate in emerging global hydrogen markets through RE resources, existing industrial capacity, and export infrastructure. While the national strategy highlights coastal hubs and export-oriented value chains, it also recognises the importance of inland industrial regions in supporting domestic hydrogen demand, skills development, and technology deployment. In this context, the analysis presented in this report complements national policy by examining how water availability and water reuse in Mpumalanga can enable hydrogen production while supporting regional development objectives and the JET.

The assessment demonstrates that both GH production and irrigation can be supported within a new water economy, but they place very different demands on water resources. GH requires relatively small quantities of water as feedstock, yet total water demand can increase substantially depending on cooling system selection and operating conditions. This means that GH development must be designed with careful attention to water efficiency and water quality requirements to avoid unnecessary pressure on limited water resources.

Irrigation offers immediate and well-understood benefits for food production, employment, and regional stability once standards are met. GH, while not water-intensive in absolute terms, introduces additional environmental management requirements related to treatment residues and brine disposal. Effective planning must therefore prioritise appropriate technology choices, treatment standards, and environmental safeguards to ensure that water reuse supports long-term development.

CHAPTER 5: ECONOMIC ASSESSMENT OF THE NEW WATER ECONOMY

5.1 Overview

This section examines whether creating a new water economy in Mpumalanga will be economically viable by 2030, as water is expected to become available when power stations are decommissioned. The economic assessment is undertaken by first looking at the treatment technologies available for treating water, as well as their associated costs. This serves as a basis for the costs associated with the different possible uses of the water. Once costs and uses are understood, the impact of each economic pathway is assessed. The economic impact entails looking at possible Gross Domestic Product (GDP) impacts of each water use and the possible jobs resulting from these pathways.

5.2 Treatment Technologies

Understanding the costs related to water treatment is the first step in determining whether a new water economy is feasible. This involves assessing the different treatment options available for each type of water, as well as the associated costs.

The treatment technologies evaluated in this study were selected based on full-scale demonstration studies conducted in South Africa. These include:

- Lime neutralisation pilot undertaken in the Witwatersrand and Mpumalanga coalfields, which demonstrated effective removal of acidity and metals from acid mine drainage.
- The limestone and lime Sequencing Batch Reactor system was developed and piloted in the Western Basin of Gauteng.
- The high recovery precipitating RO process implemented at the eMalahleni water reclamation plant in Witbank.
- The CSIR Biosure biological sulphate removal pilot plant evaluated under the CoalTech research programme.

All treatment technologies were found to be capable of treating MIW, while only RO was explored for treating raw water to potable standards. Based on their performance, scalability, and cost data, four technologies were selected for economic comparison (see Table 5-1):

- Neutralisation with lime only
- Neutralisation with limestone and lime
- RO
- Biological Sulphate Removal

Of the treatment technologies explored, the neutralisation with limestone and lime emerges as the cheapest one with a total cost of R5.68/m^3, followed by biological sulphate with a total cost of R7.40/m^3. RO is the most expensive option with a total cost of R18.61/m^3.

Table 5-1: Treatment Technologies and Costs

Treatment Method	CAPEX Cost (R/m³)	OPEX Cost (R/m³)	Total (R/m³)
Neutralisation with Lime Only	0.83	9.27	10.10
Neutralisation with Limestone + Lime	0.83	4.85	5.68
Reverse Osmosis	3.34	15.27	18.61
Biological Sulphate Removal	0.81	6.59	7.40

5.3 Green Hydrogen Production

5.3.1 Raw Water

The GH production using raw water is modelled on three cooling methods. As a result, the production costs shown in this section are the costs of treatment using the RO treatment as this is the one most relevant and effective for treating raw water to GH standards. The costs are presented per cooling method.

5.3.1.1 Air Cooling

In hydrogen production systems that use air cooling, no water is consumed for thermal regulation. This offers a distinct advantage in water-scarce regions such as Mpumalanga, as it substantially reduces total water demand. In this configuration, the only water requiring treatment is the high-purity process water for electrolysis. Although this water still needs to undergo RO, and possibly additional purification steps, the overall volume is significantly lower compared to systems that depend on evaporative or once-through cooling.

Table 5-2 outlines the key assumptions for calculating raw water demand and treatment cost under the air-cooling scenario, based on the production of 315,000,000 kg of GH annually (tonnes converted to kilograms).

Table 5-2: Assumptions for Air Cooling Scenario

Parameter	Value
Annual hydrogen production	315,000,000 kg
Water requirement per kg H_2 (air cooling)	0.0145 m^3
Total annual water requirement	4,567,500 m^3
Unit treatment cost (RO, incl. CAPEX + OPEX)	R18.61/m^3

Using a treatment cost of R18.61/m^3 to the reduced water volume gives the estimated annual cost of water treatment under this scenario (Table 5-3). These costs reflect the treatment of raw water using RO as well as the cost of producing ultra-pure water for GH production, but do not include electricity expenses.

Table 5-3: Estimated Annual Cost of Treating Raw Water (Air Cooling)

Parameter	Value
Total water volume	4,567,500 m^3
Unit treatment cost	R18.61/m^3
Total annual cost	R84,992,475
Treatment cost	R0.27/kg H_2

5.3.1.2 Once-Through Cooling

Once-through cooling systems withdraw large volumes of water to absorb process heat, passing it through a condenser or heat exchanger before discharging it back to the source. While the net water loss in such systems is relatively low, the gross intake volume is extremely high.

If raw water is used and requires full treatment through RO, the treatment cost is directly tied to the high-intake volume. This scenario assumes that the full intake volume must be treated to meet the quality standards required for electrolysis and cooling, which significantly increases overall water treatment costs (Table 5-4).

Table 5-4: Assumptions for Once-Through Cooling Scenario

Parameter	Value
Annual hydrogen production	315,000,000 kg
Water requirement per kg H_2 (once-through)	1.3775 m^3
Total annual water requirement	433,612,500 m^3
Unit treatment cost (RO, incl. CAPEX + OPEX)	R18.61/m^3

Using an average raw water requirement of 1.3775 m^3/kg H_2, the total annual intake under this scenario is approximately 433.6 million m^3 (Table 5-5). If all this water must be treated to RO standards, the resulting cost would be substantial.

Table 5-5: Estimated Annual Cost of Treating Raw Water (Once-Through Cooling)

Parameter	Value
Total water volume	433,612,500 m^3
Unit treatment cost	R18.61/m^3
Total annual cost	R8,067,540,812
Treatment cost	R25.6/kg H_2

This projected annual treatment cost of over R8.06 billion makes once-through cooling with RO treated water economically unfeasible for GH production in Mpumalanga. It emphasises the importance of selecting a cooling system that balances water availability, treatment intensity, and operational costs. While once-through systems are sometimes used in areas with abundant surface water and low treatment requirements, the need for high-quality input water in this scenario makes the configuration financially impractical in inland regions.

5.3.1.3 Evaporative Cooling

Evaporative cooling is one of the most used methods for heat rejection in industrial hydrogen production systems. It operates by passing recirculated water over fill media where air is drawn through, causing a portion of the water to evaporate. This evaporation cools the remaining water, which is then recirculated. However, the process also results in the loss of water, not just through evaporation but also through blowdown (to manage water quality) and drift (minor water carried out with the air).

For hydrogen production, these combined losses result in a cooling water demand of 0.033 m^3/kg H_2. This represents the actual quantity of water that is consumed and must be replaced.

When combined with the updated 0.0145 m^3 per kg required for electrolysis, the total raw water requirement under this scenario becomes 0.0475 m^3/kg H_2 (Table 5-6).

Table 5-6: Assumptions for Evaporative Cooling Scenario

Parameter	Value
Annual hydrogen production	315,000,000 kg
Total water requirement	0.0475 m^3/kg H_2
Total annual water requirement	14,962,500 m^3
Unit treatment cost (RO, incl. CAPEX and OPEX)	R18.61/m^3
Total annual cost	R278,578,125
Treatment cost	R0.88/kg H_2

This scenario results in an estimated annual water treatment cost of R278.6 million, assuming all water required for both electrolysis and cooling is treated using RO.

Evaporative cooling offers a balance between moderate water use and effective heat removal, making it viable for many industrial hydrogen production settings. However, its dependence on a continuous supply of clean water may pose challenges in times of limited availability or competing demands.

5.3.1.4 Summary

The choice of cooling system has a significant impact on both total water use and the cost of treating that water for GH production. Air cooling requires the least amount of water and thus has the lowest treatment cost. Evaporative cooling offers a practical balance, using a moderate volume of water for both electrolysis and heat rejection. Once-through cooling, on the other hand, demands an extremely large intake volume, making it the most water- and cost-intensive option when paired with RO treatment.

The table below summarises the total raw water requirements and estimated treatment costs for each cooling method, based on an annual hydrogen production of 315,000,000 kg.

Table 5-7: Summary of Water Use and Treatment Costs by Cooling Type

Cooling Method	Water Required (m^3/year)	Treatment Cost (R/year)	Treatment Cost (R/kg H_2)
Air Cooling	4,567,500	84,992,475	0.27
Evaporative Cooling	14,962,500	278,578,125	0.88
Once Through Cooling	433,612,500	8,067,540,812	25,6

This comparison shows that evaporative cooling is likely the most feasible option in Mpumalanga when balancing technical suitability and cost, especially in areas where water is available but not abundant. Air cooling offers the lowest cost per kg of hydrogen and is highly attractive where environmental and technical conditions permit its use. In contrast, once-through cooling, if full RO treatment is required for all intake water, results in a prohibitively high cost and is not economically viable under the assumptions applied in this study.

5.3.2 Mine-Influenced Water

There are two treatment technologies that are considered for treating MIW to GH standards: BSR (BSR) and RO. As the RO method costs remain the same and are discussed in section 5.3.1. This section primarily focuses on the costs associated with the BSR method, while the summary section presents the costs for both the BSR and RO methods.

5.3.2.1 Air Cooling

In air-cooled systems, only the electrolysis water needs to be treated. While biological treatment is more commonly applied to high-volume, lower-purity applications, it can still be used to produce water suitable for use in less sensitive parts of the hydrogen production chain or in pre-treatment setups. When applied to low-volume, high-purity demands like air-cooled electrolysis, the cost remains relatively moderate.

Table 5-8: Cost of Treating MIW with BSR (Air Cooling)

Parameter	Value
Annual hydrogen production	315,000,000 kg
Water use	0.0145 $m^3/kg\ H_2$
Total water volume	4,567,500 m^3
Unit treatment cost	R7.40/m^3
Total annual treatment cost	R33,797,500
Treatment cost	R0.11/kg H_2

5.3.2.2 Once-Through Cooling

When used with once-through cooling systems, BSR would need to be scaled significantly to treat the large volumes of water required. The high intake volumes translate into a substantial total treatment cost, despite the per-unit affordability of this method.

Table 5-9: Cost of Treating MIW with BSR (Once-Through Cooling)

Parameter	Value
Annual hydrogen production	315,000,000 kg
Water use	1.3775 $m^3/kg\ H_2$
Total water volume	433,612,500 m^3
Unit treatment cost	R7.40 per m^3
Total annual treatment cost	R3,208,732,500
Treatment cost	R10,19/kg H_2

5.3.2.3 Evaporative Cooling

For evaporative cooling, BSR strikes a useful balance between volume and treatment cost. With a water requirement of 0.057 $m^3/kg\ H_2$, this scenario requires moderate treatment volumes and results in a total cost under R110 million per annum.

Table 5-10: Cost of Treating MIW with BSR (Evaporative Cooling)

Parameter	Value
Annual hydrogen production	315,000,000 kg
Water use	0.0475 $m^3/\ kg\ H_2$
Total water volume	14,962,500 m^3
Unit treatment cost	R7.40/m^3
Total annual treatment cost	R110,722,500
Treatment cost	R0.35/ kg H_2

BSR offers a middle-ground option for treating MIW. While more cost-effective than RO and more robust than basic neutralisation methods, its suitability depends on site-specific factors such as the presence of toxic compounds that may inhibit biological activity. For scenarios with medium-water demand, such as evaporative cooling, it presents a practical and scalable solution.

5.3.2.4 Summary

The feasibility of treating MIW for GH production in Mpumalanga depends on two main factors: the volume of water required under each cooling configuration and the associated cost of treating that water to meet hydrogen production standards. The selection of a cooling system drives water demand, while the treatment method influences both capital and operational costs. Together, they determine the cost per kilogram of hydrogen and the practicality of using MIW at scale.

Air cooling is the most water-efficient configuration. It requires only high purity water for electrolysis, with no additional volume needed for thermal regulation. As a result, the total annual water requirement is just over 4.5 million m^3. In this scenario, BSR, though slightly more expensive, remains affordable at R0.11/kg. RO, while capable of producing ultra-pure water, comes in at a higher cost of R0.27/kg. Given its minimal water use and relatively low treatment cost, air cooling paired with biological treatment is highly feasible for hydrogen production in Mpumalanga, particularly where air cooling is technically viable.

Evaporative cooling results in moderate water use due to combined losses from evaporation, blowdown, and drift. The total annual water demand under this scenario is nearly 15 million m^3. BSR is moderately higher at R0.35/kg, while RO becomes significantly more expensive at R0.88 per kg. Although more water-intensive than air cooling, evaporative systems strike a balance between thermal performance and water use.

Once-through cooling is the most water-intensive option by far, requiring more than 433 million m^3 of water per annum. Even though much of this water is returned to the source, the scenario assumes that all of it must be treated to meet quality standards for use in electrolysis and cooling systems. Under this assumption, the cost of treatment becomes extremely high. BSR rises to R10.19/kg, and RO reaches a prohibitively expensive R25.6/kg. These figures show that once-through cooling is not financially viable in Mpumalanga unless water quality requirements are reduced or alternative low-cost sources of clean water are identified. The cost of treating such a large volume makes this configuration unsuitable for GH production using treated mine water.

Table 5-11: Summary of MIW Treatment Costs by Technology and Cooling Type

Treatment Method	Cooling Type	Water Volume (m^3/year)	Total Cost (R/year)	Cost (R/kg H_2)
Biological Sulphate Removal	Air Cooling	4,567,500	33,797,500	0.11
Biological Sulphate Removal	Evaporative Cooling	14,962,500	110,722,500	0.35
Biological Sulphate Removal	Once-Through Cooling	433,612,500	3,208,732,500	10.19
Reverse Osmosis	Air Cooling	4,567,500	84,992,475	0.27
Reverse Osmosis	Evaporative Cooling	14,962,500	278,578,125	0.88
Reverse Osmosis	Once-Through Cooling	433,612,500	8,067,540,812	25.60

These cost estimates show that MIW can realistically support both irrigation and GH production if the right treatment options are selected. For irrigation, neutralisation with limestone and lime remains the most affordable approach at around R1.27 billion per annum, making it a scalable and cost-effective way to expand agricultural activity in Mpumalanga.

For GH production, air and evaporative cooling systems paired with lower-cost treatment methods like BSR offer the most feasible combinations. Once-through cooling, while technically effective, becomes financially unworkable due to the massive treatment volumes required.

5.3.3 Economic Impact for Green Hydrogen

Besides agriculture, GH represents another key opportunity for strategic water use, particularly in regions undergoing industrial transition. While GH is still in the early stages of development in South Africa, its success is highly dependent on access to water for electrolysis and a supportive infrastructure.

To estimate the potential economic impact of water use for GH, a proxy derived from existing industrial water productivity benchmarks has been used.

The water productivity value in South Africa's energy sector is approximately R0.59 per m³ (DWS, 2025). This figure represents the Gross Value Added (GVA) generated per m³ of industrial water used across the national energy system. It reflects economic activity generated through the operation of thermal plants, cooling systems, and related industrial energy processes.

While this benchmark is not specific to GH, it provides a reasonable generic approach for assessing the potential economic return on water inputs into the energy sector more broadly. This GVA figure captures direct contributions to the economy, including salaries, profits, and taxes generated from energy production using industrial water.

Using the national productivity benchmark of R0.59/m³, the estimated GVA values that might result if MIW or raw water is directed toward GH production have been determined and given in Table 5-13.

Table 5-12: GVA Estimates for Water Use in GH Production

Water Source	Volume (million m³)	Water Productivity (R/m³)	Estimated GVA (R)
MIW	224	0.59	131,960,246
Raw Water	116,9	0.59	68,884,427

The results show that if all the MIW were allocated towards GH production, then the GVA to the national economy would be approximately R132 million, whereas using raw water for the same purpose would contribute an estimated R68 million to the national economy. These estimates are based on national-level averages for water use in the energy sector and provide a preliminary view of economic returns from water-intensive hydrogen production.

While both irrigation and GH present viable pathways for water reuse, irrigation emerges as the most immediately feasible and cost-effective option. The economic returns are substantial, treatment costs are lower, and the infrastructure needs are relatively modest. GH production remains promising but will depend on additional factors such as the availability of RE, hydrogen storage, and distribution infrastructure. In the short term, prioritising irrigation provides the highest Benefit Cost Ratio (BCR) and the fastest route to inclusive local development, while laying the groundwork for longer-term industrial opportunities linked to the GH economy.

5.3.4 Feasibility of Green Hydrogen

GH technology is fast progressing around the world, with a concurrent drop in production costs, which is an important consideration when assessing the feasibility of GH as a potential water-use option. Even greater cost reductions are expected over the coming years. These falling costs are linked to reductions in the price of renewable electricity generation for use in hydrogen production and increasing efficiency in both the production and operation of electrolysers. Most estimates project that GH will be cost-competitive with other, less clean forms of hydrogen by 2030 (IRENA 2020; IEA 2019). Furthermore, the prices associated with less clean forms of hydrogen may be expected to climb with rising gas prices and broader costs associated with CO_2 (Ajanovic et.al., 2022)

South Africa's transition away from grey hydrogen toward blue and, eventually, GH will naturally result in cost savings from lower reliance on traditional energy sources. While GH is currently more expensive than conventional hydrogen, these cost differentials are expected to narrow over time, and the associated savings should be channelled toward infrastructure development for the storage and distribution of GH. Currently, South Africa mainly produces hydrogen from natural gas supplied by Sasol. Aside from the recent turbulence in natural gas prices due to the war in Ukraine, prices are usually in the range of US$3 to 7 (R50 to 117) per million British thermal units and are the biggest cost component in grey hydrogen production, accounting for 45 to 75% of production costs (IEA, 2019).

One way to assess the affordability of GH is to compare it to the products it is seeking to substitute. This would currently be blue hydrogen and its input natural gas but may also include other energy carriers or storage solutions such as battery energy storage systems. This comparison provides useful context when interpreting GH production costs rather than viewing them in isolation.

Globally, the cost of GH currently sits at around US$9 to 10 (R150 to 170) per kg, which is approximately US$80 to 90 (R1,360 to 1,530) per million British thermal units. This is around ten times the price of natural gas. Even blue hydrogen currently comes in at around US$3 (R50) per kilogram, which equates to approximately US$26 per million British thermal units, or four to eight times the price of natural gas. Although these figures appear high relative to fossil fuels, they represent current prices prior to the anticipated cost reductions driven by scale and technological learning. These prices are expected to come down significantly in the coming decade, but considerable research and development as well as economies of scale will be required to bring these prices in line with those for natural gas.

International estimates put the price of GH at around US$1.40 to 1.80 (R23 to 30) by 2030 and as low as US$0.7 to 0.9 (R12 to 15) by 2050 (IEA 2021). However, local studies place the price closer to US$4 (R67) around 2030 (DSI 2022). The price development depends largely on the costs of electrolysers and the energy inputs. Despite higher local estimates, these prices remain within a range that supports feasibility when assessed against expected revenues and broader economic benefits. For South Africa to gain a competitive advantage, it is important to start moving fast to bring these costs down timeously and significantly.

In the local case, with current fuel prices at relatively high levels, it is estimated that for hydrogen to be competitive as a transport fuel, the price to the final consumer would need to be in the range of US$3.9 to US$4.8 (R65 to R80) per kilogram. To compete with gas, it would need to be closer to US$2.8 (R47). These benchmark prices provide an important reference point when evaluating whether production inputs such as water treatment materially affect overall feasibility.

When considering all factors involved in the production of GH, the estimated global price ranges between R150 and R170 per kg. When this price range is compared to the water treatment costs per kg, the relative contribution of water treatment to total production costs becomes clear. The following ranges were observed:

- BSR: R0.10 to R10.18/kg across all cooling types
- RO: R0.26 to R25.61/kg across all cooling types

In the broader context of the final GH price, these treatment costs, while they may appear high in isolation, represent only a small portion of the total cost. This indicates that water treatment costs do not pose a significant barrier to GH production in Mpumalanga, with treatment costs forming only a fraction of the potential revenue per kg of hydrogen produced. However, it is important to note that these figures reflect only the treatment costs. Total production costs may vary and should be considered when assessing full project viability.

5.4 Irrigation

5.4.1 Raw Water

Raw water for irrigation is primarily sourced from surface water and groundwater, with supplementary contributions from inter-basin transfer schemes. The raw water charges are composed primarily of two components: the Water Resource Management Charge (WRMC) and, where applicable, the Water Resource Development Charge (WRDC).

The WRMC is imposed on water users, including irrigation stakeholders, to support the sustainable management and regulation of water resources. It is a critical economic instrument used by water authorities to recover the costs associated with administering, monitoring and safeguarding water supplies. In the context of irrigation, the WRMC serves as both a revenue-generating mechanism and a policy tool that encourages efficient water use and enhances accountability among users.

For the 2023/2024 financial year, the approved WRMC for irrigation in the Olifants WMA was approximately 3.26 c/m^3 of water used, and this rate is subject to change annually.

The WRDC is a financial mechanism designed to recover the capital costs associated with the development, expansion, and rehabilitation of water infrastructure, including irrigation systems. It is levied on beneficiaries of water infrastructure, particularly farmers and irrigation users, to support sustainable financing and equitable cost-sharing for the construction and improvement of public or community-managed water schemes.

Specific WRDC rates for catchments in Mpumalanga are influenced by factors such as the cost of infrastructure projects and the financial requirements for ongoing maintenance. For the 2023/2024 financial year, the approved WRDC for irrigation in the Mpumalanga was ranging from 8-85 c/m^3.

5.4.2 Mine-Influenced water

Mpumalanga generates approximately 224 million m^3 of MIW per year, primarily from coal mining operations, according to WARMS 2023. Rather than treating this water solely for discharge or industrial reuse, there is an opportunity to repurpose it for agricultural irrigation. This supports the province's goal of expanding its agricultural economy as part of the broader JET.

To be suitable for irrigation, MIW must meet specific quality guidelines, especially regarding sulphate levels, metals, and salinity. Several treatment technologies can produce water of sufficient quality for agricultural use. The table below compares the unit treatment costs and total annual costs of treating the full available volume of AMD using each method.

Table 5-13: Cost of Treating MIW for Irrigation

Treatment Method	CAPEX Cost (R/m³)	OPEX Cost (R/m³)	Total Cost (R/m³)	Total Annual Cost (R)
Neutralisation with Lime Only	0.83	9.27	10.10	2,262,400,000
Neutralisation with Limestone and Lime	0.83	4.85	5.68	1,272,320,000
Reverse Osmosis	3.34	15.27	18.61	4,169,440,000
Biological Sulphate Removal	0.81	6.59	7.40	1,657,600,000

Using the most cost-effective option, neutralisation with limestone and lime, the total cost to treat the full volume of MIW for irrigation in Mpumalanga would be approximately R1.27 billion per annum. This approach offers a practical and scalable solution for expanding agricultural water access, particularly in support of the province's JET objectives.

More advanced treatment technologies, such as RO, can produce higher quality water but at a significantly greater cost of R4.17 billion per annum. While these methods may be appropriate where ultra-pure water is essential, such as for drinking water or hydrogen production, they are not cost-effective for irrigation and are therefore less suitable for widespread agricultural use.

5.4.3 Economic Impact for Irrigation

Water allocation not only supports basic supply and environmental flows but also plays a catalytic role in enabling economic activity. Whether sourced from raw supplies or treated MIW, water enables growth in sectors such as agriculture, manufacturing, and logistics. One of the most economically impactful uses of water is irrigation, which drives rural development, food production, and broader supply chain linkages. To quantify this impact, it is important to understand two key concepts: value added (VAD) and the multiplier effect.

VAD refers to the direct economic contribution of a sector to the economy. It represents the net output created, which includes wages to workers, profits to businesses, and taxes to the government. In the context of irrigation, VAD measures the increase in economic activity generated from using water to produce agricultural outputs. According to a Prime Africa (2024) economic analysis of irrigation in Mpumalanga, each m^3 of water used for irrigation generates R13.63 in direct VAD, which contributes directly to South Africa's GDP.

The multiplier effect captures the ripple effect of this value through the wider economy. It includes both indirect effects (such as demand for inputs like seeds, fertiliser, and transport) and induced effects (spending by workers and service providers supported by the irrigation value chain). In this study, a multiplier of 8.5 means that for every R1 of VAD through irrigation, an additional R8.50 is generated through linked economic activities. Therefore, the total impact of water use in irrigation includes both the initial GDP contribution and its broader stimulation of the economy.

The allocation of raw water (i.e., 116.9 million m^3/a) to irrigation yields nearly R1.593 million in direct GDP value through agricultural production. The resulting multiplier effect expands this to over R13 billion in total GDP impacts (which include direct and indirect contributions). This also results in a direct contribution of around 8,300 jobs within the irrigation sector. The extremely high benefit-cost ratio (BCR) of 284.2 reflects how water used productively in agriculture yields exponential economic returns (Table 5-15).

This high economic return in benefits is also due to the fact that not much treatment is required for raw water and majority of the costs lie with the WRMC and the WMDC.

Table 5-14: Economic Impact of Raw Water Use in Irrigation

Metric	Value
Volume Available	116.9 million m^3
VAD	R1,593,797,264
Multiplier Effect	R13,547,276,748
Estimated Jobs Created	8,300
BCR	284.2

When the full volume of available MIW is allocated to irrigation (i.e., 224 million m^3), it can generate over R3 billion in direct VAD to GDP. With the multiplier effect, this grows to nearly R26 billion in total economic output. This scale of investment has the potential to directly contribute 15,901 jobs within the irrigation sector (Table 5-16), providing a compelling argument for repurposing treated MIW to support productive land and rural economic systems.

Table 5-15: Economic Impact of MIW Use in Irrigation

Metric	Value
Volume Available	224 million m^3
VAD	R3,053,199,241
Multiplier Effect	R25,952,193,547
Estimated Jobs Created	15,901

While the economic returns from irrigation are significant, the costs of water treatment vary by technology. Among these technologies, limestone and lime neutralisation stand out with a BCR near 6, indicating strong economic returns per unit cost (Table 5-17). RO, despite its ability to produce high-purity water, has the lowest BCR, reflecting its higher treatment and energy costs. The choice of treatment method should therefore balance water quality needs with cost efficiency and intended use, especially when water is being channelled into high-value sectors like agriculture.

Table 5-16: BCRs for MIW Treatment Technologies

Treatment Technology	BCR Value
Neutralisation with Lime Only	3.31
Neutralisation with Limestone and Lime	5.89
Reverse Osmosis	1.80
Biological Sulphate Removal	4.52

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

The planned decommissioning of coal mines and power stations in Mpumalanga will result in the availability of more than 340 million m³/a of water, creating an opportunity to reallocate this resource to sectors that can drive sustainable development and regional diversification after mining. With effective management, this water can support agriculture, new industries, and environmental restoration, positioning Mpumalanga to develop a new water economy. The current study has therefore demonstrated that establishing a new water economy in Mpumalanga is both feasible and necessary to enable a just and inclusive transition away from a coal-based economy.

Successful implementation of a new water economy requires coordinated planning that aligns water management with energy, industrial, and land use priorities. In this regard, establishing designated water treatment and reuse zones in strategic catchments across the province can create the foundation for infrastructure investment and resource reallocation. These areas offer the best opportunity to link water reuse with agricultural and industrial growth. Integration of these zones into existing catchment reconciliation strategies will ensure transparency, strengthen governance, and promote efficient use of resources while restoring affected ecosystems.

The assessment of treatment technologies indicates that cost-effective options exist for converting contaminated water into a valuable resource. Neutralisation using limestone and lime remains the most affordable treatment method at approximately R5.68/m³, followed by BSR at R7.40/m³. While RO achieves high-purity output, its higher cost of R18.61/m³ confines its use to applications such as providing high-purity water for electrolysis. When combined with efficient cooling systems, particularly air or evaporative configurations, water treatment costs for GH production can range between R0.11 and R0.88/kg H_2, keeping overall production within feasible limits.

An important consideration in scaling up GH production is the management of brine generated during water purification processes. RO and similar treatment systems produce concentrated brine that contains dissolved salts, trace metals, and treatment chemicals. If not properly managed, this by-product could undermine the water quality improvements achieved through mine rehabilitation. Brine management should therefore be built into all GH project planning. Options include recovery of useful minerals such as gypsum and salts, controlled blending for backfilling or dust suppression in rehabilitated mines, or adoption of near zero liquid discharge systems to minimise waste.

The use of treated MIW for irrigation presents an opportunity for agricultural expansion in Mpumalanga. Allocating this water to irrigation could generate over R3 billion in direct VAD and R26 billion in total economic output each year, while creating approximately 16,000 jobs across agriculture, agri-processing, and related sectors. The productive reuse of MIW and raw water, therefore, stands out as one of the most immediate and impactful interventions within the province's JET framework.

While both irrigation and GH present viable pathways for water reuse in support of a new water economy in Mpumalanga, irrigation emerges as the most immediately feasible and cost-effective option. The economic returns are substantial, treatment costs are lower, and the infrastructure requirements are relatively modest.

GH production remains a promising long-term opportunity but will depend on factors beyond water availability, including the development of RE, adequate storage, transportation, and distribution infrastructure. Mpumalanga's existing grid capacity and technical workforce, however, provide a strong starting point. Hydrogen logistics, including pipelines, compression systems, and export terminals, must be developed in parallel with water treatment and supply networks. Coordinated investment between the public and private sectors is therefore critical, supported by blended finance under the JET Investment Plan to mobilise capital and reduce project risk.

Institutional cooperation and regulatory reform remain central to implementation. DWS should streamline licensing and allocation processes to enable new users, particularly smallholder farmers and green industry developers, to access the water. As the water transfer schemes will be impacted by the decommissioning of power plants, the Department of Mineral and Petroleum Resources (DMPR), Eskom and provincial authorities must consider this when dealing with water and energy availability. Integrating water and energy planning with the national climate and industrial policies will ensure coherence, accountability, and sustainability.

Mpumalanga's emerging new water economy represents a critical pillar of South Africa's transition toward a low carbon and climate resilient future. Through strategic investment, sound governance, and integrated planning, the province can transform its post-coal mining legacy into an everlasting engine for sustainable development, job creation, and environmental restoration.

CHAPTER 7: REFERENCES

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