



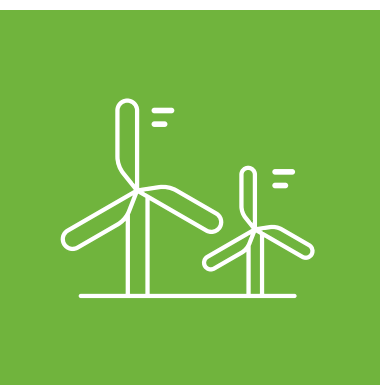
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Energy and Water Baseline and Best Practice Guidelines for the agro-processing industry:

Brewery sector | Fruit and vegetable sector | Poultry sector | Sugar cane sector



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Department:
Trade, Industry and Competition
REPUBLIC OF SOUTH AFRICA



NCPC
INDUSTRIAL EFFICIENCY IN SOUTH AFRICA



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About this document:

This document was compiled from a series of guidelines commissioned by the United Nations Industrial Development Organization (UNIDO) in South Africa as part of the South African Industry Adaptation (SAIA) Project. This project supports industries to transition to more climate-resilient operations, avoid negative impacts on the environment and people, and better prepare for future climate change impacts.

The guidelines were researched and developed by the National Cleaner Production Centre South Africa (NCPC-SA) for the brewery, fruit and vegetable, poultry, and sugar cane sectors. Additional documentation incorporated into this *Energy and Water Baseline and Best Practice Guidelines for the Agro-processing Industry* include a 'Decarbonised Roadmap for the Agroprocessing Sector' developed by the NCPC-SA; and a study by the Technology Innovation Agency (TIA) on a 'Strengthened Adaptation Capacity for a Green and Resilient Economy in South Africa'. The individual guidelines will be available www.ncpc.co.za, and the TIA-coordinated study at www.tia.org.za.

The United Nations' Sustainable Development Goals aim to provide a universal framework for addressing global challenges and achieving a sustainable future for all. Of particular relevance to these guidelines are Goals 9 and 12, which focus on industry, innovation and infrastructure; and responsible consumption and production, respectively.

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Acronyms/Abbreviations

AI	Artificial Intelligence
ATCF	After-Tax Cash Flow
bbl	Barrel
BEC	Baseline Energy Consumption
CIP	Cleaning-In-Place
EnMS	Energy Management Systems
GDP	Gross Domestic Product
HVAC	Heating, Ventilation and Air Conditioning
IIoT	Industrial Internet of Things
IRR	Internal Rate of Return
LCC	Lifecycle Costing
MARR	Minimum Acceptable Rate of Return
NCPC-SA	National Cleaner Production Centre South Africa
NPV	Net Present Value
PPP	Public-Private Partnership
PV	Present Value of Savings
R&D	Research and Development
RO	Reverse Osmosis
ROI	Return on Investment
SEC	Specific Energy Consumption
SEUs	Specific Energy Uses
SIR	Savings to Investment Ratio
SPB	Simple Payback Period
SRUs	Significant Resource Users
TIA	Technology Innovation Agency
UNIDO	United Nations Industrial Development Organization
VFDs	Variable Frequency Drives
VSD	Variable speed drive



1. This guideline in relation to UNIDO's Strategy for Africa, 2023–2025

UNIDO has a long history of working in and partnering with Africa. It provides crucial services and technical cooperation to the continent and envisions “an industrialised Africa driving inclusive and sustained economic growth, contributing to poverty reduction and aligning with the aspirations of the African Union’s Agenda 2063 and the global 2030 Agenda for Sustainable Development”¹.

Leveraging inclusive and sustainable industrial development, UNIDO works to strengthen the capacity and capability of African countries, empowering them to realise integrated, inclusive and sustainable manufacturing through carbon-neutral and climate-resilient industrial development.

UNIDO’s Strategy for Africa 2023–2025 consolidates its objectives and strategic focus in promoting inclusive and sustainable industrial development across the continent in partnership with national governments and like-minded institutions.

This guideline contributes to the growing body of knowledge targeting priority sectors and enabling these to lead the way in realising South Africa’s socio-economic and environmental sustainability goals. It aligns with the Strategy for Africa 2023–2025 in that, “Innovation and technological developments that arise from the process of industrialisation contribute to environmental protection and sustainable development by making production processes cleaner, supporting renewable energy production, and promoting green product development.”

One of UNIDO’s core competences concerns the provision of support in industrial standards compliance. This guideline gives effect to one of the functions described under this competence, i.e. guidelines, recommendations and best practices for solving industrialisation problems.

It is intended for the agroprocessing industry, in particular the brewery, fruit and vegetable, poultry, and sugar cane sectors. It is anticipated that these best practice guidelines tailored to the specific needs and constraints of both small and large agro-processing establishments will help industry stakeholders adopt sustainable practices and improve operational efficiency.

2. Adaptation vs mitigation

For decades, climate change mitigation has been at the forefront, concentrating on ways to avoid and reduce greenhouse gas emissions to prevent more extreme temperatures.

Now, however, climate change adaptation is necessary and brings into sharp focus deliberate behaviour change and transforming the way systems work to afford our people, economies and the environment better protection against climate change impacts that are unavoidable.

South Africa’s National Climate Change Response Policy is a framework for coordinating national adaptation and mitigation efforts. Its main objective is to address the inevitable impacts of climate change and the means to make a fair contribution to global efforts to stabilise, and ultimately reduce, greenhouse gas emissions.

Climate change adaptation is defined as the “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”.

¹ UNIDO Strategy for Africa, 2023–2025



2.1 INCREASED FOCUS ON ADAPTATION

The global population, currently at 7.3 billion, is projected to reach 8.5 billion by 2030, 9.7 billion by 2050, and 11.2 billion by 2100 (United Nations, 2015). Africa, experiencing the highest rate of population growth, is expected to contribute over half of the world's population increase between 2015 and 2050 (United Nations, 2015). This rapid growth places significant sustainability pressures on food manufacturing systems, which are the largest manufacturing sector in many countries and major consumers of energy and producers of emissions (Atuonwu et al., 2018). As the population expands, the pressure to decarbonise these systems is expected to intensify.²

It is estimated that without adaptation, climate change will drive approximately 132 million people into extreme poverty in the next decade. Climate change is expected to have the largest impact on rainfall, temperature, and water availability in South Africa. The western regions of South Africa are projected to have 30% reduced water availability by 2050.³

Over the last five decades, annual temperatures have increased by approximately 1.5 times in South Africa and 0.65 °C globally (Van der Bank et al. 2017). Yields are likely to decrease substantially for cereal crops sensitive to heat and drought, e.g. wheat, maize, rice, but less so for crops with higher heat tolerance, such as millet (Nelson et al. 2009; Leclerc et al. 2014). Overall, agricultural productivity and incomes have declined for smallholder farmers, pastoralists and dairy farmers, and are likely to decline further (FAO 2009; Gregory et al. 2009; Thulani and Phiri 2013; Junaidu et al. 2017).

2.2 ENHANCING ADAPTATION CAPACITY AT THE FOOD-WATER-ENERGY NEXUS

Understanding and addressing the intricate relationships between food, water, and energy is pivotal to achieving a resilient and sustainable economy. The nexus between these sectors is intricate, necessitating a comprehensive approach to mitigate vulnerabilities and exploit synergies.

A UNIDO-commissioned study by TIA looked into a 'Strengthened Adaptation Capacity for a Green and Resilient Economy in South Africa', specifically how a strategic amalgamation of hardware and ICT solutions enabled by the Industrial Internet of Things (IIoT) could enhance adaptation.

The study's findings will inform much-needed collaborations among industry, academia, government, and local communities, amplifying their respective expertise and resources to address the intricate relationships within the food, water, and energy sectors. The harmonisation of insights illuminated the potential of a hybrid model of value creation, one that intertwines hardware and ICT solutions through the IIoT.

This convergence holds the promise to revolutionise adaptation strategies within the agro-processing value chain, amplifying its sustainability and resilience in previously underserved areas. By harnessing the potential of the food-water-energy nexus and prioritising adaptation, South African industry can chart a course toward a more sustainable, climate-resilient economy while fostering opportunities for a greener workforce.

The agro-processing sector plays a significant role in the country's economy and food security. It involves transforming raw agricultural products into value-added goods, ranging from processed foods and beverages to other relevant sub-sectors including dairy, fruits processing (peels and pulp, apples, grapes, oranges, olives), breweries and wineries, sugarcane, pecan. South Africa's diverse climate and fertile land provide a conducive environment for agricultural production, resulting in a wide array of crops and raw materials suitable for agro-processing; however, in recent years, the sub-sector has faced notable challenges in specific areas relating to energy shortage and water scarcity.

² NCPC-SA (2024), A Sustainable Decarbonisation Roadmap for South African Priority Agro-processing Sub-sectors

³ TIA (2024), A Strengthened Adaptation Capacity for a Green and Resilient Economy in South Africa



3. South African Government view and support to industry

The government acknowledges that industry resilience is a vital component of national sustainability and economic growth agendas. To this end, South Africa has demonstrated commitment by developing policies, regulations, and incentives that encourage industries to adopt climate-resilient practices. Government initiatives promote energy efficiency, sustainable resource management, and emissions reduction within industrial sectors.

South Africa is confronted with a unique set of challenges due to its diverse ecosystems and reliance on sectors like agriculture and water resources. Rising temperatures, erratic rainfall patterns, and increased frequency of extreme weather events have necessitated robust adaptation measures. The government's response to these challenges reflects a commitment to safeguarding the nation's environment, economy, and communities.

Technology emerges as a potent catalyst for strengthening industry resilience. The integration of innovative solutions, such as smart manufacturing processes, predictive analytics, and renewable energy adoption, can enhance operational efficiency while mitigating climate-related risks. Government plays a very important role in ensuring easy access and adoption of such technologies for the benefit of industry.

Renewable Energy Independent Power Producer Procurement Programme (REIPPPP)

REIPPPP indirectly contributes to climate adaptation by reducing reliance on fossil fuels and promoting sustainable energy sources.

National Climate Change Adaptation Strategy

The strategy focuses on enhancing resilience in sectors such as agriculture, water resources, health, and disaster risk reduction.

Water and Agriculture Adaptation Plans

These plans focus on enhancing water efficiency, promoting sustainable farming practices, and investing in infrastructure to combat drought and water scarcity.

Government initiatives to bolster climate change adaptation

Community Engagement and Capacity Building

Involving communities and empowering local stakeholders to understand and respond to climate change effectively.

Climate Finance and Investment

Government collaboration with international entities aims to secure funding for large-scale adaptation initiatives, ensuring sustainable development while reducing vulnerabilities.

Building Resilience in Vulnerable Communities

Projects include measures to improve water access, agricultural practices, and disaster preparedness.





4. Healthy ecosystem: Adaptable, innovative, collaborative

This journey through South Africa's pursuit of a green and resilient economy is emblematic of a global shift towards sustainable practices. It is a journey that is best served by embracing adaptability, innovation, and collaboration.

Industry participation in the opportunities and platforms provided by government and its agencies contributes to this healthy ecosystem.

4.1 ACCELERATOR PLATFORM FOR CO-CREATION AND TRANSLATION

Forward-looking initiatives from which industry can benefit include the establishment of an accelerator platform for co-creation and translation. This platform will serve as a collaborative ecosystem, uniting startups, SMEs, and industry leaders with the common goal of co-creating and commercialising transformative technology solutions to strengthen adaptation capacity and fostering a green and resilient agro-processing economy.

This platform will also facilitate the crucial stage of commercialisation where collaborators can gain insights into market dynamics, regulatory compliance, and customer preferences, enabling them to position their solutions for successful market entry. This comprehensive support structure empowers startups and SMEs to navigate the complex landscape of commercialisation with greater confidence.

Industry players engaging in the accelerator platform can identify promising innovations that align with their business needs. This can lead to mutually beneficial partnerships, where established businesses provide resources, market access, and mentorship to startups and SMEs in exchange for access to innovative solutions that enhance their competitiveness and sustainability.

It represents a space where startups, SMEs, and industry giants unite their strengths to create solutions that not only address challenges but also drive economic growth, job creation, and environmental stewardship. Through collaborative innovation, technology adoption, and a commitment to inclusivity, South Africa's agro-processing industry is poised to lead the charge in climate adaptation, sustainable practices, and economic prosperity. Technology-enabled solutions can empower industries to not only survive but thrive in the face of climate challenges, embodying a vision of a greener, more resilient future for all.

5. Energy and water baseline and best practice guidelines

5.1 INTRODUCTION

The UNIDO-commissioned study by the NCPC-SA, which integrated data from its assessment reports, critical evaluation of existing literature, and stakeholder engagements, revealed significant inefficiencies in the current use of energy and water in the targeted sectors. Establishing baseline metrics highlights considerable gaps between existing practices and industry best practices. These findings emphasise the urgent need for energy and water-saving measures to enhance resource efficiency.

Key recommendations to improve energy and water management within the brewery, fruit and vegetable, poultry, and sugar cane sectors of the agro-processing industry include:

- Implementing energy management systems (EnMS) to monitor, control, and optimise energy use.
- Upgrading to high-efficiency equipment and integrating renewable energy sources, such as solar and biomass.
- Adopting water recycling and reuse practices to minimise freshwater consumption.
- Implementing advanced water treatment systems to ensure sustainable water use.

The recommendations that follow serve as a practical guide for immediate action, supporting broader goals of sustainable development and environmental stewardship and should be viewed as the initial step towards further study and development down this path towards sustainability.



5.2 SITUATIONAL SNAPSHOT

South Africa is a leading exporter in the brewery, fruit and vegetable, poultry, and sugar cane agro-processing sectors. These industries rely on the country's limited and diminishing water and energy resources.

As part of the manufacturing sector, agro-processing is resource-intensive, particularly concerning energy and water consumption. However, the impacts of climate change, which increase the likelihood of future rainfall variability, and the country's energy crisis, necessitate the adoption of sustainable energy and water usage practices in these sectors (Mukheibir, 2007).

The agro-processing sector in South Africa contributes significantly to economic growth and job creation.



5.2.1 Water scarcity

South Africa is classified as water-stressed. The country faces recurring water shortages due to population growth, increased industrial activity, inefficient water management practices, and inadequate infrastructure. Severe droughts, particularly those in recent years, have intensified the strain on water resources, affecting various sectors of the economy, including agriculture and agro-processing. The prolonged droughts from 2015 to 2018 resulted in reduced water availability for irrigation, impacting crop yields and livestock production. The resulting effects of water shortages in the agro-processing sub-sectors include reduced feed production, increased costs to mitigate risks and ensure operational continuity, constraints on farming operations, lower production volumes, and disrupted supply chains (Baudoin et al., 2017). The implications of climate change in South Africa have not been fully integrated into the country's current water policy and decision-making frameworks, further exacerbating the issue (Mukheibir, 2007).



5.2.2 Energy crisis

Energy is critical to South Africa's supply chain, both as a final product for end-users and as an input for the agro-processing sectors. The largest energy-consuming sectors in the country are industry, residential, and transportation. The demand for energy far exceeds the available supply, leading to persistent shortages and difficulties in maintaining reliable operations. These shortages are due to several factors, including aging infrastructure, inadequate investment in new energy generation capacity, and dependence on coal-fired power plants, which are susceptible to disruptions and inefficiencies (Ayuk, 2023). The country's energy crisis is marked by frequent load shedding and power outages.

Persistent loadshedding has had severe repercussions on industrial sectors reliant on a constant energy supply. The agro-processing sub-sectors have been adversely affected by these energy shortages, with power interruptions disrupting production schedules, leading to increased downtime, reduced productivity, and higher operational costs. Given the lack of sufficient capital investment and infrastructure needed to resolve this energy crisis, there is a need to adopt sustainable and renewable energy usage patterns.



	15%	GDP contribution by the energy sector, with coal the main energy source.
	80.4%	Of total energy demand is from industry, residential, and transportation.
	63%	Of total energy use is from industrial energy use (Ziramba, 2009).
	205	Days of rolling blackouts in 2022 (Ayuk, 2023).

CO₂ Emissions per kWh of grid power generation

Country	CO ₂ Emissions per kWh (gCO ₂ /kWh)
South Africa	820–900
Germany	350–400
Norway	<20
USA	350–400
China	600–700
France	50–60

Source: A Sustainable Decarbonisation Roadmap for South African Priority Agro-processing Sub-sectors, NCPC-SA

5.2.3 Environmental impact

Driven by the energy crisis, South Africa faces the challenge of producing more coal to meet its energy demand while simultaneously trying to reduce greenhouse gas emissions (Menyah and Wolde-Rufael, 2010). These emissions significantly contribute to atmospheric pollutants, aggravating global warming and climate change. This situation necessitates a shift from the country's heavy reliance on coal towards exploring renewable energy options, such as nuclear and solar energy.

	87%	Carbon dioxide emissions – energy generation from coal.
	96%	Sulphur dioxide – energy generation from coal.
	94%	Nitrous oxide – energy generation from coal (Menyah and Wolde-Rufael, 2010).

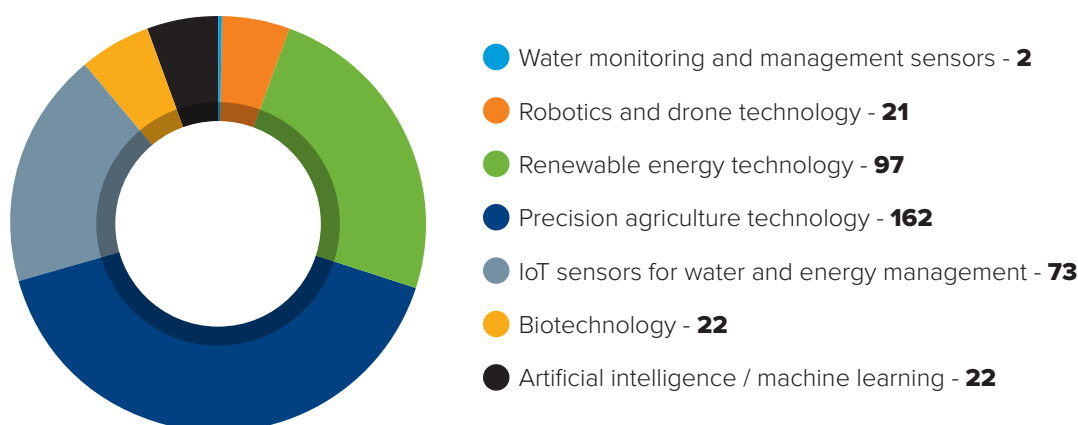


5.3 PERSPECTIVES FROM INDUSTRY AND ACADEMIA

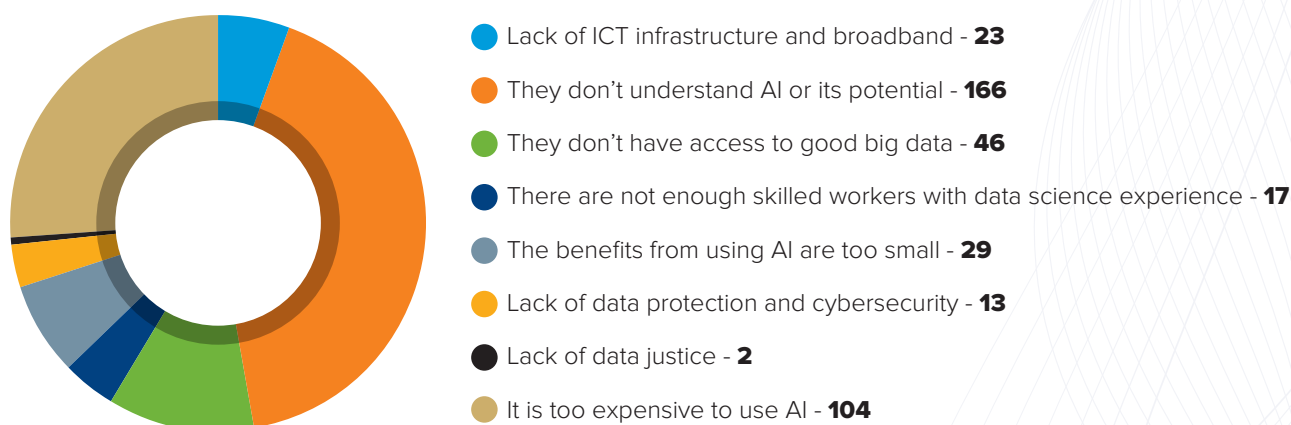
5.3.1 Quick facts: Industry professionals

As part of the TIA study, industry stakeholders provided valuable observations that underscored the sector's dynamics, challenges and the potential for transformation. The 207 responses from heads of departments (108), chief executive officers (24), chief technology officers (37), managers (13), and directors (25) offered insights into how collaboration, technology adoption, and adaptation strategies are perceived and practiced within the agro-processing value chain. Industry professionals provided practical insights, real-world experiences, and industry-specific challenges and opportunities regarding climate adaptation and technology adoption.

Technological solutions implemented by industry

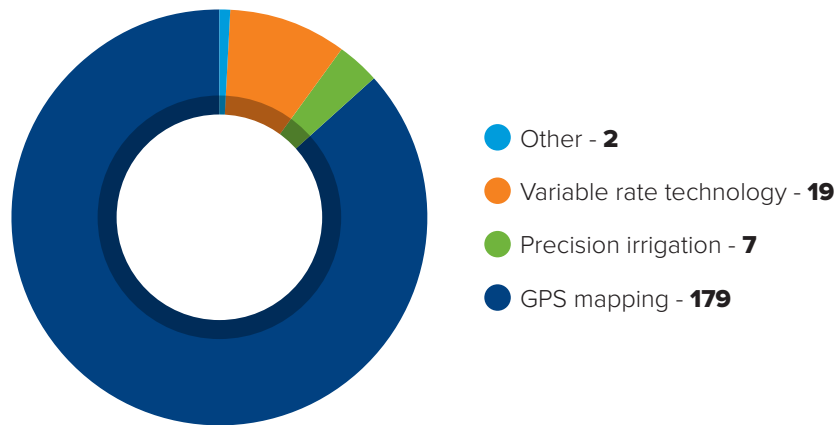


Reasons why organisations are not implementing AI solutions

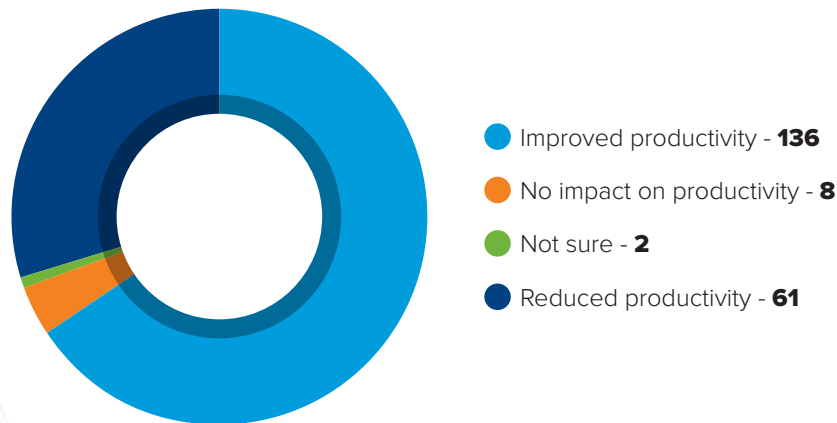




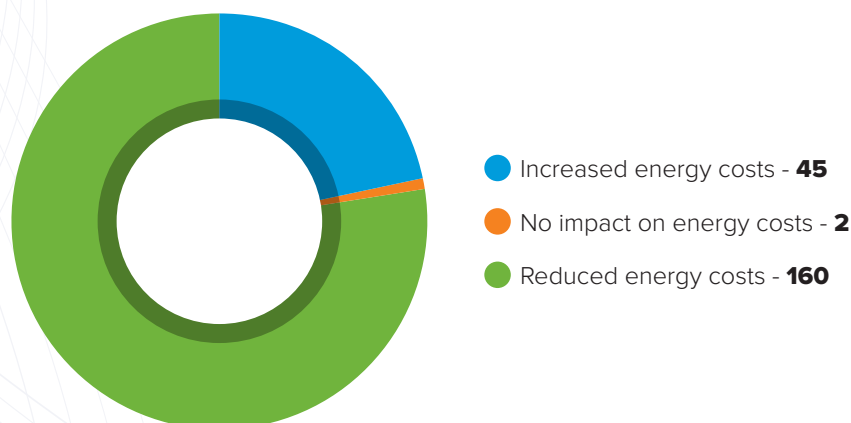
Types of precision agriculture technologies implemented



What industry is saying about the impact of ICT technology in agro production

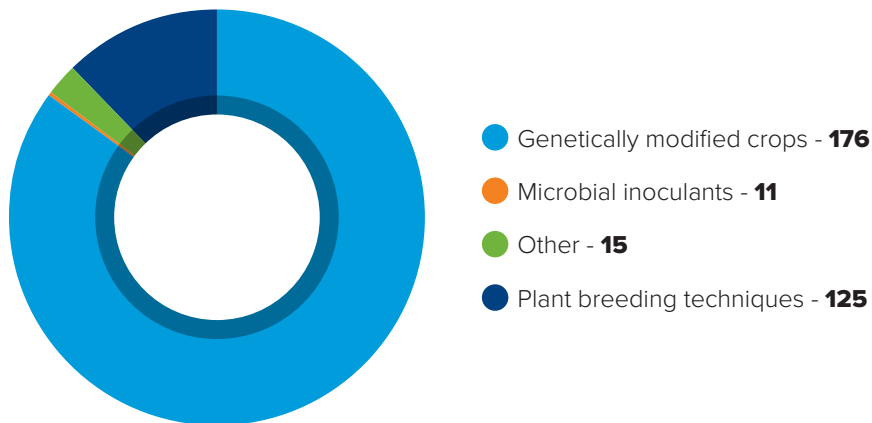


Impact of renewable energy solutions deployed by the agro-processing industry

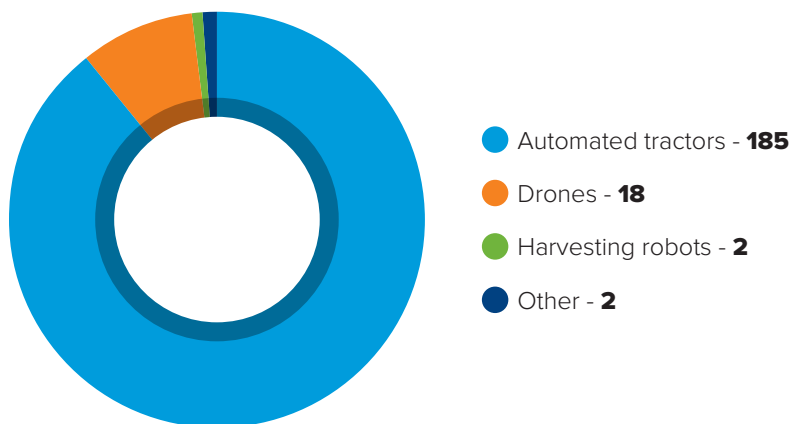




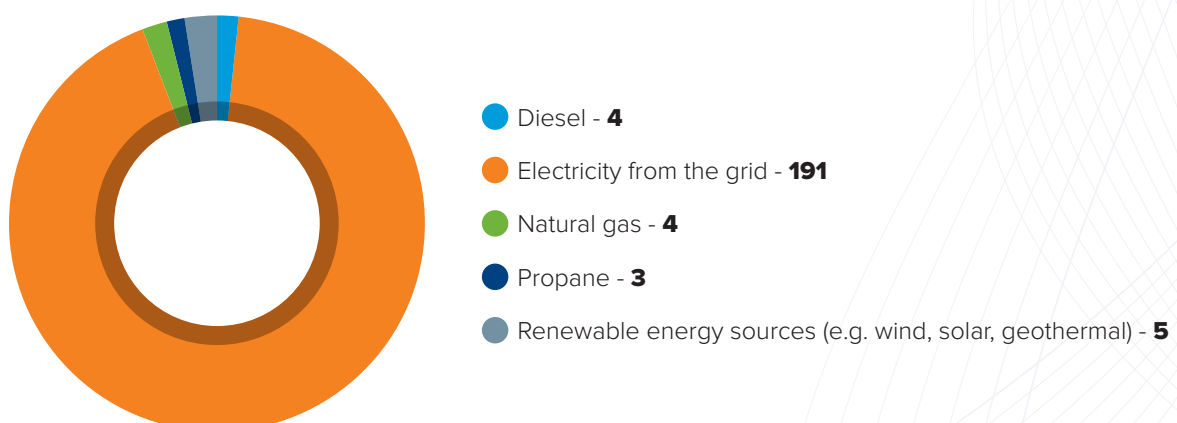
Industry respondents who have implemented some type of biotechnology solutions



Specific type of robotic solution implemented

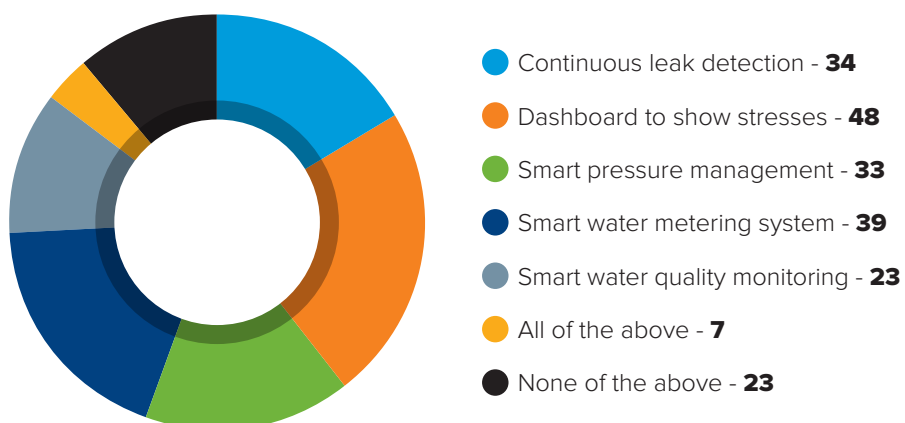


Respondents and energy sources they rely on





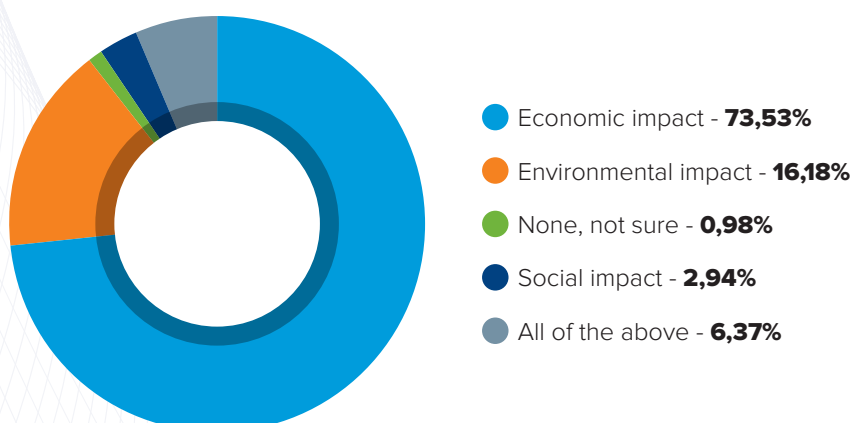
Specific water management solutions implemented



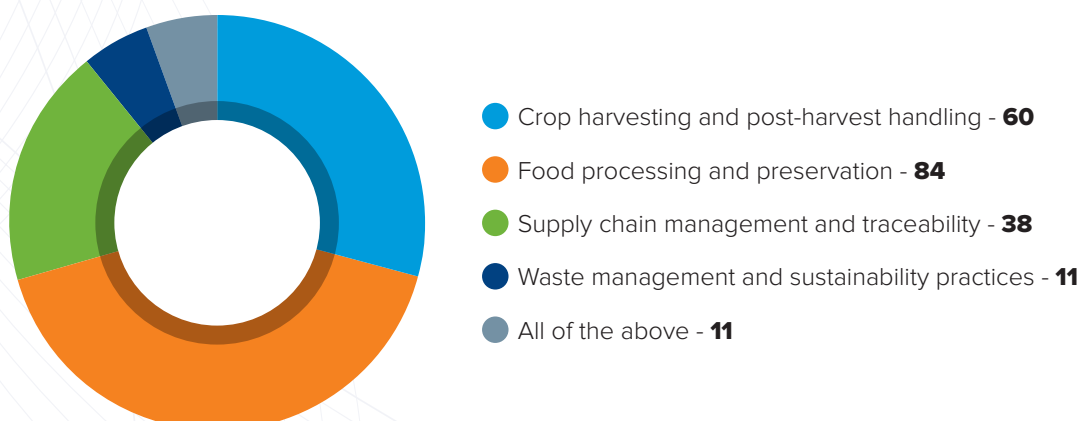
5.3.2 Quick facts: Academic perspectives

Responses from academic researchers totalled 204 (58% researchers, 29% professors, 6% lecturers, 3% postdoctoral researchers, 2% PhD students, 2% other) and provided a baseline for research, Innovation, and technology adoption strategies.

Identified area that impacts the agro-processing value chain the most

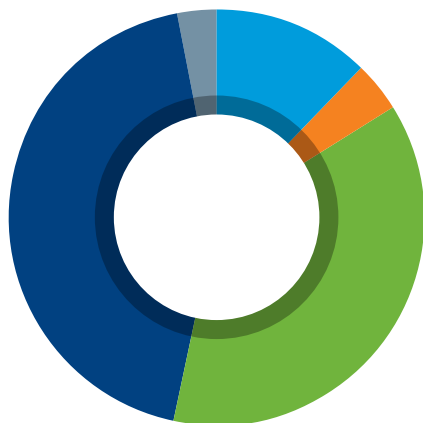


Specific areas within the agro value chain that require technological advancements



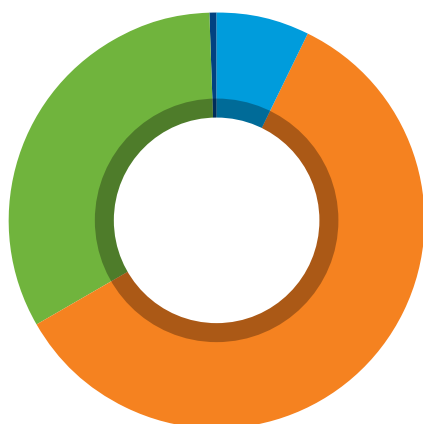


Technology gaps



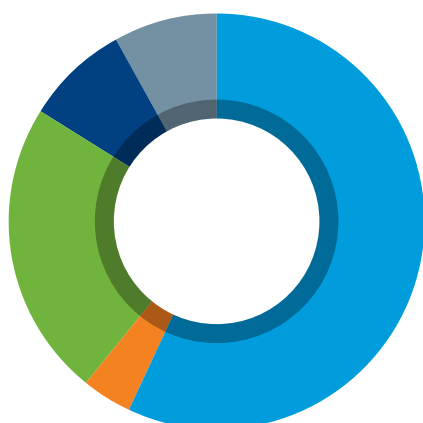
- Limited adoption of IoT devices - **25**
- Lack of renewable energy solutions for processing operations - **28**
- Lack of automated processing and packaging systems - **276**
- Insufficient use of data analytics for decision-making - **289**
- Inadequate food safety and quality control systems - **26**

Mode of engagement with industry stakeholders to close technology gaps



- Technology demonstration and pilot projects - **15**
- Knowledge-sharing initiatives and workshops - **121**
- Joint research and development projects - **67**
- Collaborative funding applications - **1**

Emerging technology with the greatest potential to address the value chain's technology gaps



- AI and machine learning - **57%**
- Blockchain and distributed ledger technology - **4%**
- IoT and sensors - **23%**
- Robotics and automation - **8%**
- All of the above - **8%**



5.4 GUIDELINE DEVELOPMENT

The NCPC-SA combined analysing existing reports and evaluating them to ensure a comprehensive approach. By relying on the information provided in the reports and rigorously evaluating their content, the study aimed to establish accurate baselines, develop effective best practices, and outline a strategic decarbonisation roadmap for South Africa's agro-processing sectors. This approach ensured that the findings are well-founded and actionable, guiding industry stakeholders towards more sustainable and efficient resource use.

Shortcomings identified from analysing existing reports included inconsistencies and inaccuracies in determining baselines and benchmarks. Significant resource users (SRUs) were identified; however, many reports featured incomplete or outdated baseline measurements. Local assessments across sub-sectors also revealed similar issues, with reports frequently lacking complete or current data. Reports from 2013 to 2015 indicated that the baselines used for site comparisons were insufficient, highlighting the need for streamlined energy auditing processes to enhance data reliability and usability. This led to the development of foundational best practices aimed at creating a more reliable local dataset.

To address the issues identified in the reports, several best practices were developed. A concern is that post-installation validation is not commonly practiced, despite the cost of interventions. Much of the evidence is based on expert estimates, which can be unreliable.

Two recommended best practices include:

- An implementation algorithm based on measure, analyse, intervene, and validate. This practice aligns with ISO 50001 for certification but offers benefits even for those not seeking certification.
- Automated metering for ease of use and scalability. Regular analysis, reflection, and measurement improve the likelihood of plant improvements. Repeatable and shareable prior and post datasets provide valuable insights.

6. Decarbonisation of South Africa's industry

6.1 DRIVERS AND IMPLICATIONS

The UNIDO-commissioned *Sustainable Decarbonisation Roadmap for South African Priority Agro-processing Sub-sectors*, developed by the NCPC-SA, lists several key drivers and implications of decarbonisation for the country, looking at the need for decarbonisation and the implications for trade and industry.

Why the need to decarbonise?		
Aspects		
 Environmental responsibility	 Economic benefits	 Public health
• South Africa is one of the world's largest emitters of greenhouse gases due to its reliance on coal for energy. Decarbonising is essential to mitigate and adapt to the impacts of climate change, such as extreme weather events, rising sea levels, and biodiversity loss. • Aligning with global sustainability initiatives, such as the Paris Agreement, requires South Africa to reduce its carbon footprint and promote cleaner energy sources.	• Transitioning to renewable energy sources can enhance energy security by reducing dependence on imported fossil fuels and mitigating the risk of fuel price volatility. • The renewable energy sector can create numerous jobs in manufacturing, installation, and maintenance, boosting the economy and providing new employment opportunities.	• Reducing emissions from fossil fuels can significantly improve air quality, leading to better health outcomes for the population, including reduced respiratory and cardiovascular diseases.



Implications for trade and industry				
Aspects				
 Competitiveness & market access	 Regulatory compliance	 Cost implications	 Supply chain impacts	 Investment & financing
- Many international markets, especially in the European Union, are implementing stringent carbon regulations and tariffs. South African industries that decarbonise will have better access to these markets and avoid potential carbon border taxes. - Companies that adopt sustainable practices can enhance their brand value and reputation, attracting environmentally conscious consumers and investors.	- The South African Government is likely to implement stricter environmental regulations and policies to meet international commitments. Industries must adapt to these regulations to avoid penalties and ensure compliance. - Increasing pressure from stakeholders, including investors and consumers, requires companies to demonstrate their commitment to sustainability and reduce their carbon emissions.	- Transitioning to low-carbon technologies may require significant upfront investment. However, these costs can be offset by long-term savings in energy costs and improved operational efficiency. - Decarbonisation can drive innovation and lead to the development of more efficient processes and technologies, reducing operational costs and increasing productivity.	- Industries will need to ensure that their supply chains are sustainable and low-carbon. This may involve sourcing raw materials from sustainable sources and working with suppliers who adhere to environmental standards. - A decarbonised economy is more resilient to climate change impacts, ensuring the continuity of supply chains and reducing the risk of disruptions.	- Investors are increasingly favouring companies with strong environmental, social, and governance performance. Industries that prioritise decarbonisation are more likely to attract investment and secure financing at favourable terms. - The government may offer incentives, such as tax breaks or subsidies, for companies investing in renewable energy and energy-efficient technologies, reducing the financial burden of decarbonisation efforts.

6.2 PENALTIES

- Regulatory penalties:** Including substantial fines and legal sanctions for companies that do not comply with environmental regulations such as the National Environmental Management Act. Severe cases of non-compliance, especially where environmental damage is extensive and corrective measures are not promptly implemented, can even lead to the closure of operations (SA News).
- Financial penalties:** South Africa's carbon tax, designed to incentivise the reduction of greenhouse gas emissions, results in higher tax liabilities for companies that do not lower their emissions, thereby directly affecting their financial performance (SA News). Additionally, reliance on fossil fuels and outdated technologies can increase operating costs due to fluctuating fossil fuel prices and rising carbon taxes, which ultimately impacts profitability.
- Market penalties:** Including the risk of losing access to international markets, particularly in the European Union, which increasingly demand low-carbon products. Non-compliance with these environmental standards can result in exclusion from these markets (KZN Industrial News). Furthermore, companies that fail to prioritise decarbonisation may suffer reputational damage, losing consumer trust and investment opportunities (KZN Industrial News).



- **Competitive disadvantages:** Companies that do not invest in sustainable and energy-efficient technologies will fall behind competitors, resulting in a loss of market advantage and difficulties in attracting customers and partners.
- **Operational inefficiencies:** Ensuing from not adopting modern technologies, can also reduce overall productivity and profitability (SA News).
- **Environmental and social penalties:** Including contributions to environmental degradation such as air and water pollution, which can prompt stricter regulations and community opposition. High emissions that lead to poor air quality can adversely affect public health, increase healthcare costs, and result in social backlash from local communities (Business Link).
- **Insurance and financing penalties:** Companies that do not address environmental risks may face higher insurance premiums due to increased risk exposure, as insurers now consider environmental factors in their risk assessments.

7. Insights and best practices relevant to all four sectors

The following information has been aggregated from all four sector studies. It concerns foundational best practices relevant to the brewery, fruit and vegetable, poultry, and sugar cane agro-processing sectors.

7.1 FOUNDATIONAL BEST PRACTICES

This guide draws from the principles outlined in the ISO 50001 standard, which have been objectively cited as best practice in energy management.

7.1.1 Best practice: Implementing energy management systems

Executive commitment and leadership

Ensure top management is committed to energy management, providing the necessary support and ensuring the allocation of resources, as emphasised by the ISO 50001 EnMS standard. Top leadership should actively participate in energy management meetings and communicate the importance of energy efficiency to all employees.

Establish clear goals and objectives

Set specific, measurable, achievable, relevant, and time-bound (SMART) goals for energy management, aligning with the ISO 50001 EnMS requirements. Goals will provide a clear direction and benchmarks for measuring progress. Set a goal to reduce energy consumption by 15% over the next three years.

Energy policy development

Develop a formal energy policy that outlines the organisation's commitment to energy efficiency and sustainability, as per ISO 50001 guidelines. The policy will create a foundation for all energy management activities and ensure consistency in approach. The policy should include objectives, scope, responsibilities, and a commitment to continuous improvement.



Conduct energy audits and assessments

Perform comprehensive energy audits to identify energy use patterns, inefficiencies, and opportunities for improvement, in accordance with ISO 50001 standards. Audit and assessment information will provide a detailed understanding of energy consumption and areas for potential savings. Consider hiring external consultants to conduct detailed energy assessments and provide recommendations.

Develop an energy management team

Form a cross-functional team responsible for implementing and maintaining the EnMS, as recommended by ISO 50001. This ensures diverse perspectives and expertise in energy management initiatives. Include representatives from operations, maintenance, finance, and human resources on the energy management team.

Implement energy monitoring and targeting

Install meters and monitoring systems to track energy consumption in real-time, meeting ISO 50001 EnMS monitoring requirements. This will provide accurate data for analysing energy use and identifying inefficiencies. Use energy management software to monitor electricity, gas, and water usage across different departments.

Employee engagement and training

Educate and train employees on energy-efficiency practices and the importance of energy management, following ISO 50001 guidelines for competence and awareness. This fosters a culture of energy awareness and encourages proactive energy-saving behaviours. Conduct regular training sessions and workshops on energy conservation techniques [and the energy policy and other company-relevant energy assessments].

Regular reporting and communication

Provide regular updates on energy performance and progress toward goals to all stakeholders, ensuring transparency as outlined in ISO 50001. Regular communication maintains transparency and keeps everyone informed and motivated. Share monthly energy performance reports with all employees and stakeholders.

Continuous improvement and feedback loop

Regularly review and update the EnMS to incorporate new technologies, processes, and feedback, as emphasised by ISO 50001. This ensures the EnMS remains effective and adapts to changing conditions and opportunities. Review the EnMS annually and incorporate lessons learnt and new best practices.

Incentives and recognition

Implement incentive programmes to reward employees and departments for achieving energy-saving targets, supporting the continuous improvement cycle of ISO 50001. This motivates employees to participate actively in energy management initiatives. Offer bonuses, awards, or public recognition for departments that achieve significant energy reductions [and share best practices internally to encourage other departments].



Implementation steps

By adhering to these best practices, in alignment with ISO 50001 standards, organisations can effectively implement an EnMS that drives significant energy savings, reduces costs, and supports sustainability goals.



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7.1.2 Best practice: Audit guideline

This sequential process involves:

- Identifying and understanding what to look for and why.
- Assessing the relevance of the identified elements.
- Reporting findings in a scalable and systematic manner.

1. Begin the assessment:

1.1 Gather data from the establishment (12–24 months)

Consider:

- Time: Report on the year and months (e.g. Jan '22–Dec '22).
- Resources:
 - » Electricity and fossil fuels: (e.g. LPG gas, diesel, paraffin, petrol). Convert all energy resources to a common unit (kWh).
 - » Water sources: municipal, borehole, wellpoint
- Production data:
 - » Total production output (tons, kg, units, etc.)
- Facility area :
 - » Total facility area
 - » Area designated for irrigation/lawns.

1.2 Log information:

- Description: Type of processing facility
- Region: Geographic location.
- PV and batteries: Presence of photovoltaic systems and battery storage.
- Water systems: Presence of water storage, efficiency, and or treatment systems.

2. Develop a site-specific baseline:

2.1 Regression analysis

- Use electricity consumption and production output to determine the trendline formula.
- Compare the trendline to a guide formula.
- Ensure the baseload is within 50% of total electricity consumption.
- Analyse scatter plots to identify performance areas and outliers.

2.2 Develop benchmarks

- Create benchmarks using ratios and compare them to guide benchmarks.
- Establish upper and lower limits.

3. Energy balance:

3.1 Determine the energy breakdown

- Calculate the percentage of total energy from electricity and fossil fuels.
- Focus on the primary energy source (e.g. electricity if it constitutes 75% of total energy).

3.2 Develop benchmarks

- Create benchmarks using ratios and compare them to guide benchmarks.
- Establish upper and lower limits.



4. Water balance:

4.1 Apply the same methodology as for energy balance

- Apply the methodology to municipal and borehole water.

5. Determine the significant resource users (SRUs):

5.1 Energy SRUs (if no sub-meters)

- Manually calculate SRUs.
- Inventory all equipment:
 - » Power rating
 - » Load factor (utilisation percentage)
 - » Hours of operation per day
 - » Days of operation per year
- Calculate the product of the four inputs and divide by total electricity consumption to find the percentage consumption.
- Apply the Pareto principle to identify the top 80% electricity consuming contributors

The Pareto Principle, or 80/20 Rule, is a theory commonly used in business. It holds that 20% of the items in a company or system account for 80% of the effect.

5.2 Water SRUs

- Follow the same process as for energy SRUs.

6. Recommendations and implementation:

6.1 Select recommendations from the table

- Develop specifics (e.g. brand type, power rating).
- Calculate expected savings and compare to the table.

7. Implementation:

- Implement the interventions once the table is complete.

8. Validation:

- To be considered best practice, post-intervention data must be collected over 12 months to demonstrate performance improvement.
- The measurement and verification process should be followed to validate the intervention as best practice.

7.1.3 Best practice: Baseline formulation for energy and water efficiency

Identifying a sample size

The baseline energy consumption (BEC) and specific energy consumption (SEC) for an industry sector are often represented as average or absolute values. This approach can be unfair to industries with varying production capacities and technologies. Instead of using a constant or average value, the relationship between BEC/SEC and corresponding factors should be developed to obtain rational values based on actual production conditions and technologies.

To evaluate energy efficiency with the relevant sub-sector, we need to segment establishments into two categories: advanced and standard. This classification reflects ranges based on the extent of a plant's implementation of sustainability measures (e.g. energy-saving technologies, renewable energy use). It facilitates a more accurate analysis of energy consumption patterns across different types of establishments within the range and makes it easier to study and compare energy consumption patterns within and between these groups. This approach allows validation of best practices outside the range or within a similar set.



This segmentation can be based on specific criteria:

- Energy consumption: Less than 100 kWh per unit.
- Production facility size: Smaller than 20 000 square meters.

From this segmentation, we can identify a sample size. In analysing energy consumption across these establishments, trendlines can be used to highlight various levels of efficiency (this is further illustrated in the image that follows):

- **Light-blue trendline:** Covers all X facilities, providing a comprehensive view.
- **Dark-blue trendline:** Examines Y and other facilities combined to explore shared energy patterns.
- **Turquoise trendline:** Focuses on the specific attributes of Z turquoise facilities, offering detailed insights into their energy performance.

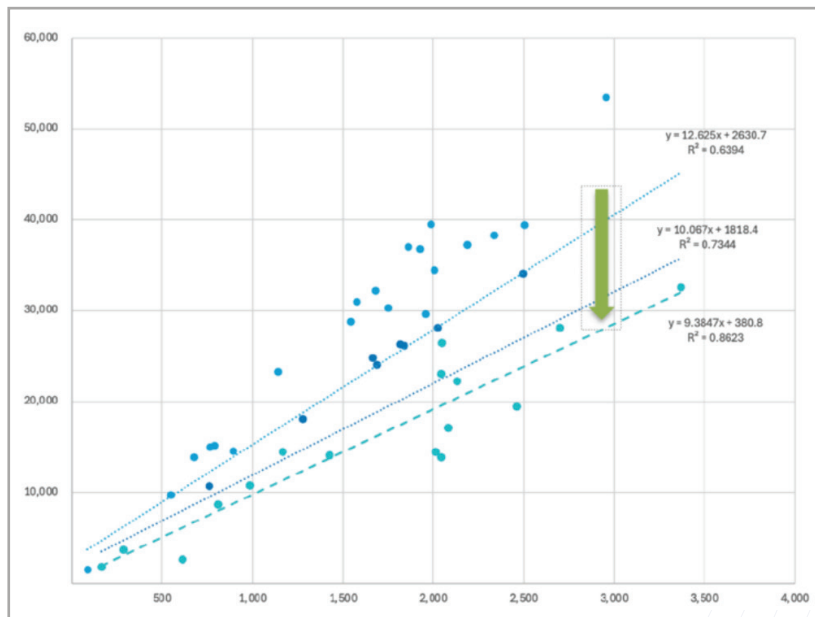
A linear regression analysis can then be conducted to establish a trendline or baseline for energy consumption among these facilities. The baseline formulas derived from a graph, with their corresponding R^2 values indicate a relatively strong relationship and significant variability in the dataset.

Significance of production output

Production output is a significantly relevant variable in determining energy consumption. The established formula can be utilised to predict future energy consumption for facilities with smaller production areas and to monitor current performance.

Performance evaluation

- Above the baseline: Establishments that fall above the trendline are not operating efficiently. An in-depth analysis of the specific energy uses (SEUs) is recommended to identify areas for improvement.
- Below the baseline: Establishments below the trendline should continue to focus on SEUs for ongoing improvements and decarbonisation efforts.



Baseline best practice example

Scope of analysis

It's important to note that this analysis primarily concerns electricity consumption and does not include the use of fossil fuels.

Indicator of performance difference

The arrow in the graph highlights the performance offset between standard and advanced plant performance. This visual aid helps illustrate the gap and potential areas for energy optimisation.



Best practice and baseload

For the advanced group's population, the average energy consumption can be determined from the graph in kWh per annum. This benchmark serves as a guideline for what advanced establishments should aim to achieve as a minimum baseline consumption.

This analysis provides a clear framework for assessing and improving energy efficiency based on production output and energy consumption metrics. Establishments can use the trendline as a benchmark to evaluate their performance and implement targeted interventions for enhanced energy management and sustainability.

By adhering to this framework, organisations can systematically identify, evaluate, and implement energy-efficiency improvements, ultimately contributing to better energy management practices and sustainability goals.

7.1.4 Best practice: Metering and monitoring

Metering and monitoring are crucial for tracking plant-wide consumption of energy and water. This includes:

- Electricity and fuels: Comprehensive tracking of all electrical and fuel usage specific to processing and storage facilities.
- Municipal and borehole water: Monitoring both municipal water supply and borehole water usage, especially for irrigation and cleaning processes.

Sub-meters are essential for tracking SRUs within the sector, allowing for detailed analysis of consumption patterns. Once data are gathered, analysed, and reported, they can be used to establish a baseline based on empirical data. This baseline is vital for predicting future consumption and measuring performance improvements.

Approach to metering

Adopting an ISO 50001 approach for metering is recommended. While full certification is not necessary, the following elements should be metered:



Main meters

- Electricity mains: Monitor overall electrical consumption in processing plants, cold storage, and distribution centers.
- Water mains: Track overall water usage from municipal and borehole sources, focusing on irrigation and washing of produce.



Significant energy users

- Meter key energy-consuming equipment such as refrigeration units, processing machinery, and lighting systems.



Significant water users

- Meter significant water-consuming areas such as irrigation systems, washing stations, and cooling systems.

According to recommendations from the NCPC-SA's guide – <https://www.ifc.org/content/dam/ifc/doc/mgrt/metering-monitoring-guideline.pdf> – the best practices for metering and monitoring include:

- Digital meters
 - » Dataset collection: Data should be automatically collected to ensure accuracy and efficiency.
 - » Reporting Options: Allow output at set time intervals, including:
 - 30-minute intervals
 - 60-minute intervals



- Daily
- Weekly
- Monthly
- Annually.
- Automated reporting and alerts: Set up to promptly address any irregularities or issues.

To ensure accurate installation and setup, it is advisable to have a sales engineer visit your premises and provide a quotation based on your specific needs.

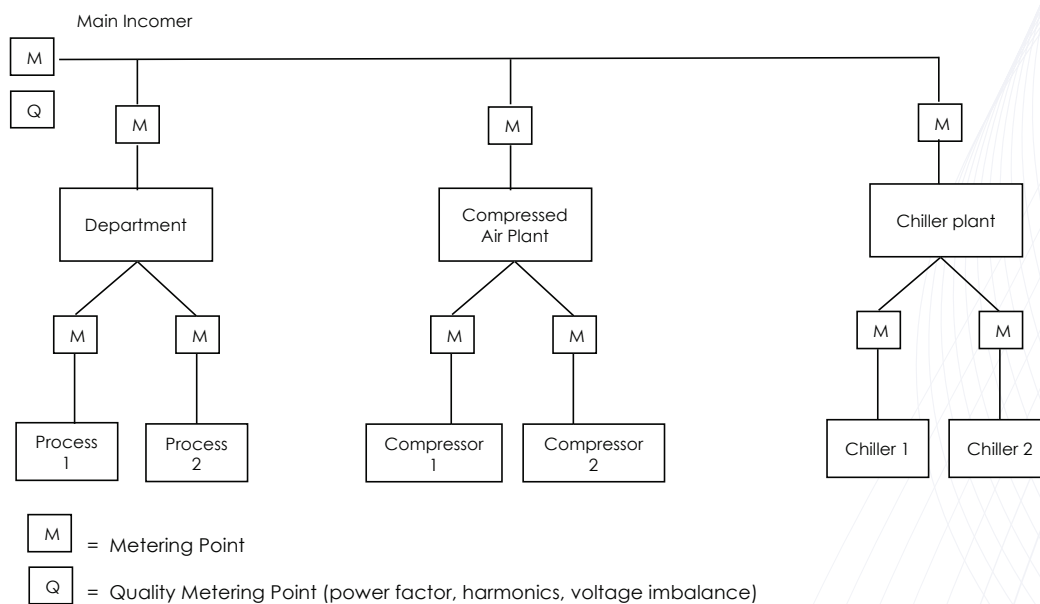
By implementing a comprehensive metering and monitoring system, organisations can:

- Track and analyse consumption: Monitor plant-wide energy and water consumption, particularly in areas like irrigation, refrigeration, and processing.
- Establish empirical baselines: Predict future consumption and identify trends specific to seasonal variations and production cycles.
- Measure performance improvements: Ensure that efficiency measures are effective and track progress accurately.
- Focus on SRUs: Identify and target SRUs for efficiency measures, improving overall sustainability.

This approach not only helps in achieving compliance with ISO 50001 standards but also contributes to significant cost savings and sustainability goals, ensuring the sector remains competitive and environmentally responsible.

The NCPC-SA's Metering and Monitoring Guideline illustrates the following:

- Electricity cost escalation: Comparison of cost escalation of electrical energy over the last eight years.
- Water and electricity cost escalation: Indication of both water and electricity cost escalation over the past 24 years.
- Electrical energy metering.
- Metering schematic: Electrical and water metering schematics for visual representation of metering points (duplicated below).



Energy monitoring schematic

7.1.5 Best practice: Accounting and economics

Importance of financial evaluation

When launching a project, it's crucial to ensure that recommendations are not only feasible but also profitable over time, thus making them viable. Currently, the focus tends to be predominantly on the feasibility aspect, using metrics that do not fully capture the financial viability of a project. This can lead to an incomplete assessment of a project's potential profitability and economic implications.



Comprehensive financial metrics framework

Relying solely on the simple payback (SPB) period is inadequate as it does not consider the broader economic impacts, potentially leading to projects that either underperform or exceed budget expectations. The lack of a standardised financial evaluation approach further complicates decision-making, leaving companies without clear insights into the long-term benefits and risks of their investments. Emphasising a more holistic set of financial metrics will provide a clearer picture of both immediate and extended economic outcomes, ensuring better-informed investment decisions.

Implementing a comprehensive financial metrics framework allows for informed decision-making and ensures that projects are both economically viable and strategically aligned with organisational goals. By adhering to these best practices, companies can achieve greater financial clarity and optimise their investment strategies, ultimately driving long-term success and sustainability.

Project financial metrics

The financial data streamlines the decision-making process for the company, enabling it to assess the profitability potential of each suggested intervention. The following financial metrics should be applied:

- SPB: The time required to recoup the initial investment based on net annual savings.
- Return on investment (ROI): The percentage of net gain earned from the total investment cost.
- Present value of savings (PV)
- Net present value (NPV): The difference between the present value of cash inflows (benefits) and the present value of cash outflows (costs).
- Savings to investment ratio (SIR): The ratio of the present value of savings to the present value of costs, indicating the economic feasibility of an investment.
- Lifecycle costing (LCC)
- Internal rate of return (IRR): The discount rate at which the net present value of an investment becomes zero, determining the profitability of the project.
- After-tax cash flow (ATCF): The annual savings minus the taxable portion of the savings (after accounting for annual depreciation).
- Minimum acceptable rate of return (MARR): MARR is the lowest return on an investment that a manager or company is willing to accept before starting a project. It's often determined by the company's cost of capital plus a risk premium.
- Decision-tree analysis: The decision-tree model helps with evaluating different project scenarios and outcomes based on various financial metrics and risk assessments.

Project accounting and economics formulae

$$1. SPB = \frac{\text{Investment cost}}{\text{Net annual savings}}$$

$$2. ROI = \frac{\text{Net gain per year}}{\text{Total cost}}$$

$$3. NVP = PV_{\text{Benefits}} - PV_{\text{Cost}}$$

$$4. SIR = \frac{\text{PV of savings}}{\text{PV of cost}}$$

$$5. IRR: NPV = 0; \frac{\text{Cost}}{\text{Savings}} = \left(\frac{P}{A}, i, n \right)$$

$$6. ATCF = \text{Savings} - ((\text{savings} - \text{annual depreciation}) \times \text{tax rate})$$



Financial performance metrics (evaluation method)

Project classification:

- Strategic: $IRR > MARR \geq 0\%$
- $SIR > 1$
- $NPV = PV \text{ benefits} - PV \text{ costs} > 0$
- Hurdle rate: 15%
- $SPB: < 3 \text{ years}$
- Before and ATCFs.

Indicative cost-benefit analysis

Projects are itemised showing:

- Annual savings
- Equipment lifespan
- SPB
- Present value of the savings streams per project (PV savings)
- NPV
- IRR
- SIR
- ATCF.

For projects to be viable:

- SPB should be less than 3 years
- NPV should be > 0
- $SIR > 1$
- $IRR \geq 20\%$.

Present worth factors for calculating PV savings

The present worth factors are derived from the Oxford University Press global compound interest tables and are used to calculate the present value of savings for various time periods and interest rates.

Time period	Present worth factor (P/A, 15%)
15 years	5.847
10 years	5.019

7.1.6 Best practice: Best energy and water saving strategies from assessments

This review (Abdelaziz et al., 2011⁴) examines various energy-saving strategies encompassing management, technologies, and policies. The significance of energy management has grown markedly within industries, with senior management frequently involved in planning energy management projects. Effective energy-saving measures, such as the implementation of high-efficiency electric motors, reduction of boiler flue gas temperatures, and the use of variable speed drives to align with load requirements, have been identified as cost-effective methods to decrease energy consumption in key industrial equipment. These strategies are not only economically viable but also contribute to significant emission reductions. Furthermore, the implementation of effective public policies is essential to further decrease industrial energy consumption and emissions.



8. Individual sector insights and best practices

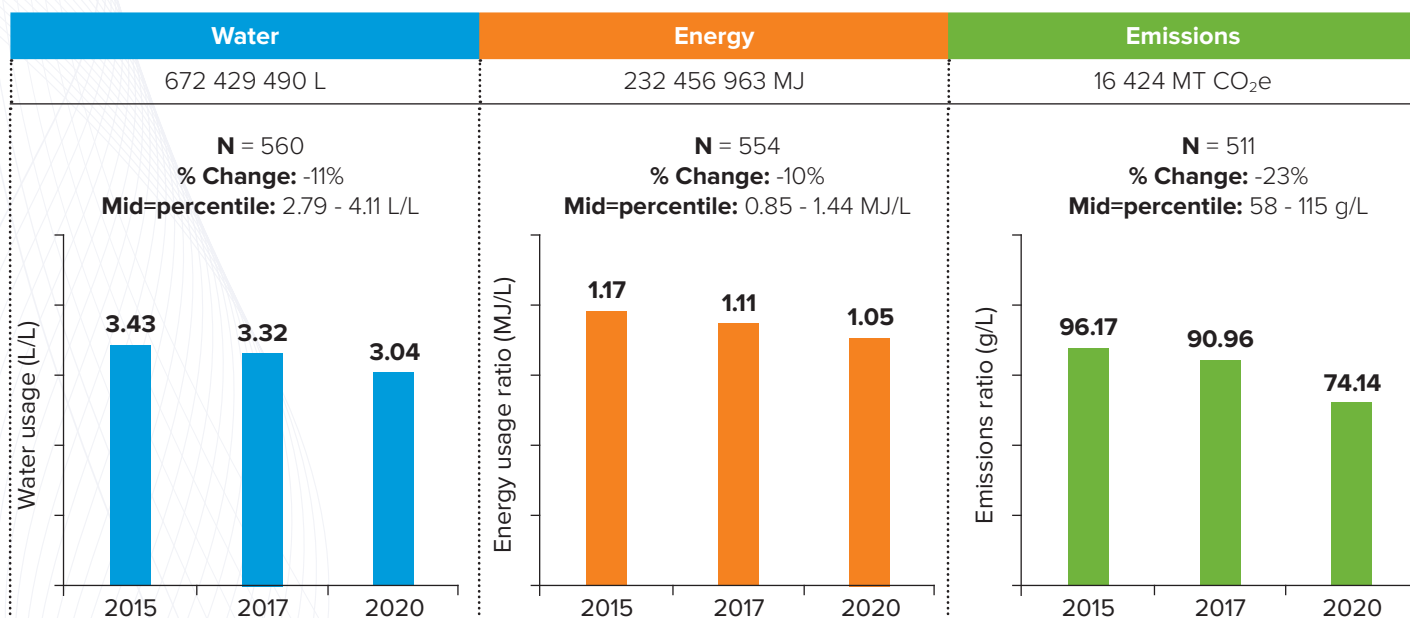
This section features individual sector insights, looking at global energy baselines and benchmarks, common energy and water-saving strategies, and significant energy and water users.

8.1 BREWERY SECTOR

8.1.1 Global energy baseline and benchmarks

The brewery industry is of economic importance because of its scale and size. It also benefits from economic and technological spillover from similar sub-sectors like wineries and distilleries, carbonated drinks, and bottled water.

The current international drive toward sustainability through resource efficiency shows a trend in improved resource efficiency over time through continuous improvement. For example, a large international study considering 452 breweries, found that 75% of plants were reporting average water usage, energy usage, and CO₂ emissions (BIER, 2021). This demonstrates the trend that the international community has instinctively implemented these as key performance indicators, further demonstrated by an annual reduction. This trend suggests measurement and instrumentation be integral in modernising breweries.



Continuous improvement figures for breweries (source: Bier, 2021)

Secondly, a trend shows that larger breweries tend to be more efficient. For example, a sustainability benchmark report in the USA shows that the specific resource ratios decrease exponentially with plant size (Breweries Association, n.d.) [Breweries Association, 2017]. This suggests that benchmark ratios should be fitted based on curve, not single number. This is supported by a subsequent local study on using 58 South African Breweries' sites (Kirstein and Brent, 2017). Finally, a recent microbrewery study shows similar poor performance (650 MJ/bbl) due to the small production quantities.

⁴ E.A. Abdelaziz, R. Saidur, S. Mekhilef (2011), A review on energy saving strategies in industrial sector, Available at <https://www.sciencedirect.com/science/article/abs/pii/S136403211000290X?via%3Dihub>



Benchmark values for the brewery sector (source: Breweries Association, n.d.)

1000	Water (bbl/bbl)	Electricity (kWh/bbl)	CO ₂ (LBs/bbl)
1k	34	650	340
10k	10	250	95
100k	5.2	100	60
1000k	5	80	40

8.1.2 Global breweries benchmark

	0.43 kWh/ Litre beer	Energy consumption metric: This value is limited to large breweries. For smaller breweries, the value is determined through the production output. For example, micro-breweries are expected to have significantly lower efficiency.
	6.5 hL water/ hL beer	Water consumption metric: This value varies significantly across countries. The prior study concluded a 5 hL/hL (Breweries Association 2017). A best technological level suggests 4hL/hL (Oyebode & Adewumi, 2014). South Africa is of high standing in the international beer production and the leader in southern Africa. Some reports suggest breweries in South Africa are above the global average 5hL/hL, consuming less water than many other countries. (Van der Merwe & Friend, 2002).
	510-842 g/l	Carbon consumption metric: South Africa is expected to have high emissions due to the country's reliance on coal power plants. Local estimates for carbon emissions are not available.

South African breweries are currently well positioned by international standards, excelling in water and energy efficiency. However, to sustain competitiveness and ensure future growth, it is essential to pursue renewable energy sources. Reducing carbon emissions is crucial to remain competitive in the face of the impending carbon tax and evolving consumer trends. Given that South Africa's energy mix is largely dependent on coal, adopting renewable energy offers a feasible approach to achieving cleaner production in breweries.

8.1.3 Brewery sector SEUs and suggested interventions

Significant energy users are typically considered first for energy audits and improvements. This is, however, not always the case. For example, there are cases where the interventions are infeasible due to infrastructure or available technology – for example, using spent grain for boiler fuel requires special coating and cleaning [Tanzania]. If this technology is not locally feasible, the intervention becomes impractical. Another example is where the largest consuming process is not the largest benefit – for example, [Tanzania] performs an energy flow according to IEEE SA 7391995 and finds boilers have the highest potential saving, even though it is a lower-ranked SEU. These examples shift the suggested SEU-intervention tables to suggest low-tech alternatives.

Energy in breweries can be split into electrical and thermal energy. This split is estimated at 80% thermal and 20% electrical energy [energystar]. Therefore, much of the expected improvements are to be found in thermal systems. Also: different forms of packaging can significantly affect the energy efficiency of the entire process.



SEU	Suggested interventions
Refrigeration	• Optimise production and lead times » Minimise storage time by producing only what is needed and when it is needed. This ensures that products spend minimal time in storage, leading to lower energy consumption for refrigeration. • Regular maintenance and cleaning » Regularly clean condenser and evaporator coils to ensure efficient heat exchange. » Check and replace air filters, and ensure that fans and other moving parts are functioning properly. • Temperature control and optimisation » Optimise set points and ensure that refrigeration systems are not cooling more than necessary. » Implement proper zoning and temperature control strategies to avoid cooling unused areas. • Insulation » Insulate refrigerated spaces and piping to minimise heat gain. » Repair any damaged insulation promptly. • Equipment upgrade » Replace old refrigeration units with energy-efficient models. » Install high-efficiency compressors, condensers, and evaporators. • Variable speed drive (VSD) » Install VSDs on compressors, pumps, and fans to match the load requirements and reduce energy consumption. • LED lighting » Use LED lighting in refrigerated spaces, as they generate less heat compared to traditional lighting, reducing the refrigeration load.
Water treatment	• Efficient washing systems » Implement efficient bottle and keg washing systems that use less water. • Advanced filtration » E.g. Reverse osmosis (RO) removes impurities and ensures high-quality water for brewing processes. • Treat and reuse water from cleaning and rinsing operations for non-potable uses, such as cleaning floors or cooling, and capture and reuse condensate from steam and refrigeration systems.
Compressed air	• Ensure that compressors and air receivers are appropriately sized for the brewery's requirements and select energy-efficient compressors and associated equipment. • Conduct routine inspections to identify and fix leaks in the compressed air system. • Install VSDs on compressors to adjust the motor speed to match the air demand, reducing energy consumption during lower demand periods.
Boiler and steam distribution	• Use of spent grain for fuel. • Ensure boilers are properly sized to match the brewery's steam and hot water demands, and implement strategies to manage and distribute loads efficiently, avoiding frequent cycling. • Perform regular steam leak and maintenance



8.1.4 Brewery sector SWUs and suggested interventions

The quality and quantity of brewery wastewater fluctuate considerably, characterised by high organic content and easily biodegradable components (Sharda et al., 2013).

Treatment methods typically involve biological processes, with anaerobic treatments such as upflow anaerobic sludge blanket reactors demonstrating high chemical oxygen demand removal efficiency (Romana Salla & Hasan, 2017). Advanced technologies like membrane bioreactors and sequential batch reactors are recommended for improved performance (Sharda et al., 2013).

Implementing best management practices can significantly reduce water consumption, with modern plants achieving ratios of 3.7–4.7 litres of water per litre of beer produced (Babu Aremanda et al., 2022).

Employee involvement and water reuse strategies are crucial for improving water efficiency in breweries (Babu Aremanda et al., 2022).

It is suggested that slightly acidic water could be prioritised in both water sourcing and recycling. However, this should be approached with caution to avoid interference with existing processes. These and other advanced techniques should be evaluated on a case-by-case basis to ensure optimal performance and compatibility with the brewery's operations.

Breweries are significant water users, with several processes contributing to high water consumption and wastewater generation. Key water-intensive processes include raw material handling, wort preparation, fermentation, filtration, cleaning-in-place (CIP), and packaging (Sharda et al., 2013). Bottle cleaning and chase water are particularly impactful, accounting for up to 84% of total effluents (Babu Aremanda et al., 2022).

SWU	Suggested interventions
Brewhouse operations	• Optimise water-to-grain ratio. • Use efficient lautering systems. • Recover and reuse hot water from the boiling process. • Use water-efficient heat exchangers. • Recover cooling water.
Fermentation and conditioning	• Implement water-efficient cleaning practices. • Reuse cleaning water.
Packaging	• Use air rinsing where possible. • Optimise rinsing systems to reduce water use. • Use automated keg washers with water-saving features.
Cleaning and sanitation	• Use dry cleaning techniques where possible. • Install water-efficient cleaning systems. • Optimise CIP systems for water efficiency • Reuse final rinse water.
Cooling and refrigeration systems	• Use closed-loop cooling systems. • Optimise cooling tower operations.
Wastewater treatment	• Implement water recycling and reuse systems. • Improve wastewater treatment efficiency.
Utility water	• Use condensate recovery systems. • Optimise boiler blowdown procedures.



8.1.5 Common energy- and water-saving techniques

Focus area	Application	Intervention
Energy efficiency		
1. Develop and implement energy management policy	Establishing a comprehensive energy management policy helps breweries monitor, manage, and reduce energy consumption.	Develop policies that include regular energy audits, setting energy reduction targets, and engaging employees in energy-saving practices.
2. Electronic condensate drain trap or equivalent	Condensate traps remove water from compressed air systems without losing compressed air, improving system efficiency.	Install electronic condensate drain traps to replace manual or timed traps, which often result in air loss and inefficiency.
3. Fan maintenance, repair, and optimisation	Fans are used extensively in brewing processes for ventilation and cooling.	Implement a maintenance schedule for fans, ensuring they are clean and operating efficiently. Optimise fan speed and usage based on demand.
4. Install solar water heater	Heating water is a significant energy cost in breweries for processes such as cleaning and brewing.	Install solar water heaters to use renewable energy for heating water, reducing reliance on gas or electric heaters.
5. Install boiler stack economiser	Boiler stacks emit a significant amount of heat energy.	Add economisers to boiler stacks to capture and reuse waste heat, improving boiler efficiency and reducing fuel consumption.
6. Install ceiling insulation	Insulation helps maintain desired indoor temperatures, reducing heating and cooling costs.	Enhance thermal insulation in ceilings to prevent heat loss in winter and heat gain in summer.
7. Install geyser blankets and timers	Geysers or water heaters consume energy to maintain water temperature.	Use geyser blankets to insulate and retain heat. Install timers to operate geysers only when needed, reducing energy consumption.
8. Install light occupancy sensors	Lighting can be a major energy expense in large brewery facilities.	Install occupancy sensors to ensure lights are only on when areas are in use, reducing unnecessary lighting.
9. Install VSDs on motors	Motors are used in various brewery operations such as pumps, conveyors, and compressors.	Use VSDs to adjust motor speed to match operational needs, significantly reducing energy consumption.
10. LED lighting	Traditional lighting systems consume more energy and have shorter lifespans.	Replace incandescent and fluorescent lights with energy-efficient LED lights, which use less energy and last longer.
11. Optimise condensate recovery	Recovering condensate from steam systems can reduce water and energy usage.	Implement systems to capture and reuse condensate, improving overall efficiency.
12. Power factor correction	Poor power factor can lead to increased energy costs and reduced system efficiency.	Install power factor correction devices to improve electrical system efficiency and reduce energy losses.
13. Pump efficiency improvement	Pumps are essential in various brewery processes, including wort transfer and CIP systems.	Regularly maintain and optimise pump systems to ensure they operate at peak efficiency.
14. Repair ceiling insulation	Over time, insulation can degrade, reducing its effectiveness.	Inspect and repair existing ceiling insulation to maintain energy efficiency.
15. Repair compressed air leaks	Compressed air systems are prone to leaks, leading to energy loss.	Regularly inspect and repair leaks in the compressed air system to prevent energy wastage.



Focus area	Application	Intervention
16. Replace boilers with new boiler system	Older boilers are often less efficient and more costly to operate.	Upgrade to modern, high-efficiency boilers to reduce energy consumption and operational costs.
17. Replace water heaters with heat pumps	Traditional water heaters can be inefficient.	Use heat pumps for water heating, which are more energy efficient and cost-effective.
18. Replace pressure gauge	Accurate pressure monitoring is essential for efficient operation of brewing equipment.	Install new, reliable pressure gauges to ensure optimal system performance and energy use.
19. Solar panels for daytime lighting requirements	Daytime operations can significantly benefit from solar energy.	Install solar panels to meet daytime lighting needs, reducing dependence on grid electricity.
20. Upgrade conventional air conditioning to inverter models	Conventional air conditioning units are less efficient and consume more energy.	Replace with inverter models, which adjust the compressor speed to match cooling demand, saving energy.
21. Waste heat recovery from base load compressor	Compressors generate significant heat during operation.	Implement waste heat recovery systems to capture and reuse this heat, improving overall energy efficiency.
22. Anaerobic digestion as energy source	Breweries can utilise anaerobic digestion to treat organic waste and wastewater. This process breaks down organic matter to produce biogas, which can be used for thermal energy or converted into electricity.	Install anaerobic digesters to process brewery waste, reducing reliance on external energy sources and lowering waste disposal costs.
Water efficiency		
23. Water metering	Monitoring water usage helps identify areas for improvement and reduce consumption.	Install meters at various stages of the brewing process to track and manage water use effectively.
24. Upgrade effluent treatment process and install RO unit	Effective treatment of brewery wastewater is crucial for environmental compliance and water reuse.	Upgrade effluent treatment systems and install RO units to enhance water quality and enable reuse in non-potable applications.
25. Use of solar water heater for water heating	Solar energy can be harnessed to reduce the energy required for heating water.	Install solar water heaters to provide a renewable source of hot water, reducing the brewery's energy footprint.

Looking forward, it is crucial for this industry to remain innovative, with a strong focus on reducing carbon emissions. Historically, low carbon emissions have been correlated with the growth of the brewing industry. With increasing international and local pressure to decarbonise, the industry must prioritise efforts to reduce emissions. Failure to do so could lead to increased costs for locally produced goods due to carbon taxes, making them less competitive in the global market. This challenge is compounded by the fact that the majority of South Africa's energy comes from coal.

One measure currently being investigated is the use of renewable energy, particularly solar energy, to offset carbon emissions. While photovoltaic systems can reduce carbon emissions by decreasing reliance on grid electricity, solar thermal solutions should be further investigated for the local market. These solutions can significantly contribute to meeting the energy needs of brewery plants, thus offering a more substantial reduction in carbon emissions.

By implementing these energy and water-efficiency measures, breweries can significantly reduce their environmental impact, lower operational costs, and contribute to sustainable brewing practices.



8.2 FRUIT AND VEGETABLE SECTOR

8.2.1 Baselines and benchmarks

The fruit and vegetable processing sector is energy-intensive due to the heating, cooling, and mechanical operations required. It presents numerous opportunities for efficiency improvements (Masanet et al., 2008; Hackett et al., 2005). Energy-saving measures include implementing non-thermal processing and membrane technologies, which can reduce energy use (Nikmaram & Rosentrater, 2019). Water efficiency can be enhanced through reconditioning treatments and reuse strategies, minimising freshwater withdrawal (Nikmaram & Rosentrater, 2019; Ölmez, 2017).

Integrated renewable energy systems, such as solar photovoltaics and anaerobic co-digestion of organic waste, offer promising potential for sustainable energy production to power processing operations (Lopes et al., 2021). Refrigeration systems in the industry have shown energy-saving potential of up to 18.9% through optimisation (Nunes et al., 2014). Artificial intelligence can further optimise water consumption by analysing production structures and identifying opportunities for reduction (Trajer et al., 2021).

Future trends in the industry include developing sustainable, traceable, and personalised food products, as well as adopting innovative local processing technologies to minimise environmental impact and meet evolving consumer demands while maintaining product quality and safety (Liu et al., 2022). These advancements can help the fruit and vegetable processing sector reduce its environmental footprint, improve operational efficiency, and provide more sustainable, high-quality products.



416 to 833 kWh

Energy intensity per ton of product (Wojdalski et al., 2007)

Factors influencing energy intensity include the type of processing (canning, freezing, drying), the age and efficiency of equipment, and the implementation of energy-saving measures. Energy-efficiency opportunities exist at component, process, and facility levels, with potential savings of 17–19% [5] (Hackett et al., 2005) .

The following table presents the energy and water baselines, annual consumption, and benchmarks for various fruit and vegetable processing facilities (anonymised for the purposes of this document) in South Africa, based on a population of onsite NCPC-SA assessments. It includes specific data on energy usage (in kWh per ton) and water usage (in kL per ton), along with annual consumption figures and potential benchmarks for efficiency improvements.



Energy and water baseline and benchmarks (NCPC-SA assessments)

Facility	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6
Energy baseline (kWh/ton)	91 (including refrigeration) 21 (excluding refrigeration)	234 904 kWh 23 490 kWh/ton	135 kWh/ton (electrical) 0.225 tons/ton (coal)	-	-	-
Water baseline (kL/ton)	-	-	13.9 kL/ton	30.55 kL/ton	-	-
Annual energy consumption (kWh)	-	234 904	-	-	-	-
Annual water consumption (kL)	-	-	-	231 731 (freshwater) 152 073 (borehole)	-	420 000 (river) 50 000 (borehole)
Benchmark (Energy)	15–45 kWh/ton (fruit packhouses) 0.5–11 kWh/cold unit (refrigeration)	-	10% reduction achievable	-	-	-
Benchmark (Water)	-	-	15% reduction achievable	30 kL/ton (100% production capacity) 12.10–36.07 kL/ton (off-peak)	-	7 500 m ³ /hectare/ year

In South Africa, studies have highlighted the importance of benchmarking in the fruit and vegetable industry, particularly for energy management and carbon footprinting (Bouwer, 2011; Premraj et al., 2011, 2012).

While benchmarking is recognised as valuable, implementation challenges exist, such as difficulties in obtaining best-practice information and adapting practices [2] (Kleynhans & Roberson, 2017). The process involves identifying, understanding, and adapting outstanding practices to improve performance (Vermeulen, 2003). In the agricultural sector, benchmarking can support the establishment of vegetable and fruit markets (Maponya et al., 2014) and improve irrigation scheme efficiency (Çakmak et al., 2004).



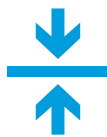
Energy: Standard baseline and benchmark summary

The following is a standard baseline for energy consumption, excluding outliers:



Energy:

- Baseline: 50–100 kWh/ton (including refrigeration).
- Benchmark: 15–45 kWh/ton for high efficiency.



Baseline:

- Global baseline: 416–833 kWh/ton (Wojdalski et al., 2007)
- South African baseline: 50–100 kWh/ton (including refrigeration)



Benchmark:

- Global benchmark: Energy-efficiency opportunities with potential savings of 17–19% (Hackett et al., 2005)
- South African benchmark: 15–45 kWh/ton for high efficiency

South Africa's energy baseline for the fruit and vegetable processing sub-sector (50–100 kWh/ton) is significantly lower than the global baseline (416–833 kWh/ton). This discrepancy suggests that South African facilities may already be more energy-efficient or that the data reflects a subset of more efficient operations. However, the data subset is not comprehensive and presents lower than anticipated values.

The benchmark for high efficiency in South Africa (15–45 kWh/ton) is ambitious and aligns with global energy-efficiency opportunities, indicating strong potential for further improvements in energy management practices within the sector.

While South Africa's current energy baseline appears more efficient compared to the global average, there remains substantial room for enhancement, particularly by aiming for the high-efficiency benchmark of 15–45 kWh/ton and ensuring more reliable data collection. This focus on energy efficiency can support the sector's sustainability goals and contribute to economic growth while mitigating environmental impacts.

Water: Global water baseline and benchmark

Globally, water is another critical resource for the fruit and vegetable processing industry, used for washing, processing, and cleaning operations. The water intensity can vary significantly based on the type of produce and the specific processing methods employed. Efficient water management practices, including recycling and treatment, are increasingly being adopted to reduce the sector's water footprint and ensure sustainability.



	1.5 to 10	Cubic meters of water per ton of product (Lehto et al., 2014; Trajer et al., 2021).
	90%	Of water consumption attributed to washing and rinsing.
	90%+	Organic load in wastewater from processing (Lehto et al., 2014).

Specific water consumption (m^3/tonne of product) can vary significantly across different processing installations (see following table). For instance, higher specific water consumption levels have been reported for tomato processing, highlighting the variability in water needs depending on the type of produce and processing methods. Water recycling practices are commonly employed to mitigate the high levels of water usage, promoting sustainability and efficiency in water management.

Production of	Unit	Water consumption
Potatoes – fries	m^3/tonne raw potatoes	1.25–4.3
Potatoes – purée and other potato products	m^3/tonne raw potatoes	2.7–5
	m^3/tonne produced	10
Fruit and vegetables – cans	m^3/tonne raw product	1–16
	m^3/tonne	8–9
Fruit – cans	m^3/tonne produced	2.5–4.0
Vegetables – cans	m^3/tonne produced	3.5–6.0
	m^3/tonne raw product	10
Fruit and vegetables – frozen	m^3/tonne raw product	10–43
	m^3/tonne produced	5.0–8.5
	m^3/tonne raw product	5
Fruit and vegetables – washing	m^3/tonne raw product	3
Juice	m^3/tonne produced	6.5

Source: [54, EUPPA 2018], [87, Belgium-VITO 2015]

The following table gives the water usage benchmarks for various fruit and vegetable processing activities in South Africa (source: Water Study Commission). These benchmarks are critical for understanding the industry's water consumption patterns and identifying areas for improvement in water efficiency. The values indicate the average, minimum, and maximum water usage in litres per kilogram (l/kg) of product processed. The water usage benchmarks in South Africa for various fruit and vegetable processing activities align with the global context.

This data can help stakeholders in the fruit and vegetable processing industry benchmark their operations against industry standards and adopt best practices for water management.



Specific water consumption per sub-sector in South Africa

Product	Industry Average	Min	Max	Unit
Fruit & vegetable processing	7.13			l/kg
Apples (canned)	6.62	4.3	11.25	l/kg
Apples (juiced)	1.84			l/kg
Apricots (canned)	5.5	2.5	11.5	l/kg
Beans in tomato sauce (canned)	20	20	70	l/kg
Beetroot (bottling)	8	8	24.8	l/kg
Citrus (canned & juiced)	2.08	1.1	2.6	l/kg
Corn (canned)	9.25	6	11	l/kg
Green beans (canned)	7.4			l/kg
Guavas (canned)	6.4	4	7	l/kg
Peaches (canned)	6.88	2.5	12	l/kg
Pears (canned)	12.7	4.5	29	l/kg
Pears (juiced)	1.91			l/kg
Peas (canned)	22.8	19	25	l/kg
Pineapples (canned)	2.94	2.1	4.55	l/kg
Strawberries (canned)	17.8	6.8	21	l/kg
Tomatoes (canned)	2.44	2	3	l/kg
Broccoli (frozen)	25			l/kg
Cauliflower (frozen)	25			l/kg
Carrots (frozen)	8.1	6	26	l/kg
Corn (frozen)	4.63			l/kg
Green beans (frozen)	27	10	15	l/kg
Peas (frozen)	30			l/kg
Potatoes (frozen)	25.7			l/kg
Other (frozen)	19			l/kg
Other (canning)	9			l/kg
Berry (canning)	17	6.8	27.65	l/kg



Water: Usage benchmarks

Water:

- Baseline: 20–25 kL/ton
- Benchmark: 25 kL/ton with a 15% reduction target

Water consumption variability:

- Tomato processing: Globally, higher water consumption is noted for tomato processing. In South Africa, canned tomatoes use between two and three litres per kilogram (l/kg), reflecting the high water needs.
- Canned products: Water usage for canned fruits and vegetables in South Africa ranges from 1 to 43 l/kg, depending on the specific product (e.g. peaches, pears, and beans). This wide range indicates the different water needs for various canned products.

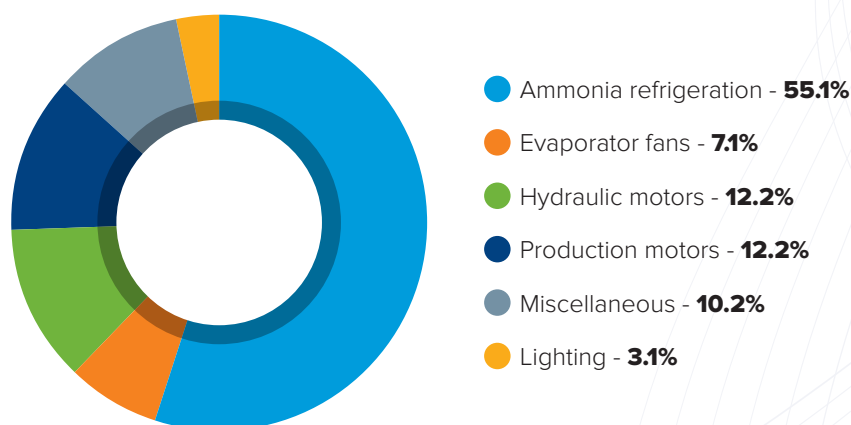
Global practices include water recycling to manage high water consumption. This approach is increasingly adopted in South Africa, where efficient water management practices are emphasised to reduce the water footprint. For example, water usage in the processing of beans in tomato sauce is notably high at 70 l/kg, necessitating the adoption of recycling practices to manage such high levels of consumption sustainably.

8.2.2 Fruit and vegetable sector SEUs and suggested interventions

The following graphs illustrate the annual electric energy usage by function for a vegetable processor and a fruit processor. For the vegetable processor, ammonia refrigeration accounts for the largest share at 55%, followed by hydraulic motors and production motors at 12% each, and miscellaneous uses at 10%. In contrast, the fruit processor's energy usage is dominated by ammonia refrigeration at 67%, with evaporator fans and miscellaneous uses contributing 10% and 12%, respectively. Applying Pareto's principle, the major points are that ammonia refrigeration is the most significant energy user in both processors, and addressing efficiency in this area could yield the most substantial savings. (Sources: Singh and Heldman, 2001, U.S. Census Bureau, 2005e, U.S. DOE, 1997a, U.S. DOE, 2005.)

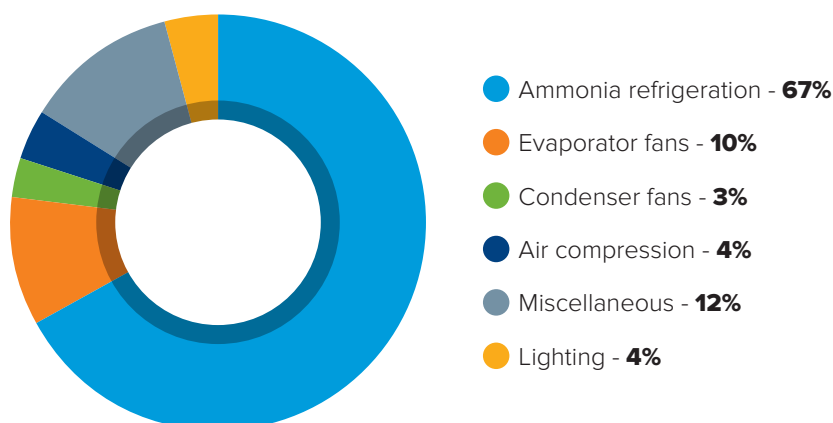
Electricity powers various essential components in processing plants, including motors, conveyors, compressed air systems, pumps, lighting, and HVAC systems. Refrigeration is a particularly significant end user, covering process cooling, cold storage, and freezing applications.

Annual electricity usage at a vegetable processor / annual electrical usage (%)





Annual electricity usage at a fruit processor / annual electrical usage (%)



Electricity consumption by process

The average weighting in the following table is determined by the count and percentage presented in the actual assessments. The graph illustrates the capacity utilisation percentage for each SEU.

Significant energy users: South Africa

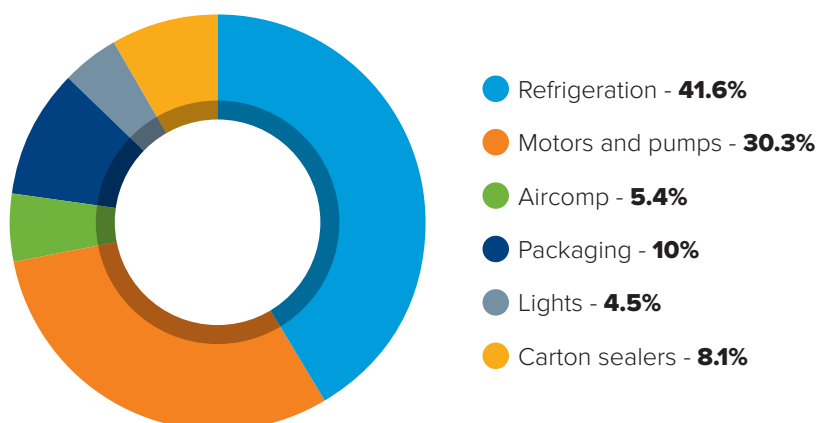
SEUs	Average weighting	Source
Refrigeration	92	Companies 1,2
Motors and pumps	67	Companies 2,7
Aircomp	12	Companies 6, 7
Packaging	22	Company 6
Lights	10	Company 7
Carton sealers	18	Company 7

In the assessments of the processing facilities, refrigeration stands out as the dominant energy user. For Company 1, refrigeration consumes 91 kWh/ton of produce, significantly higher than other processing activities at 21 kWh/ton, making it a critical area for energy-efficiency improvements. Company 2 also sees refrigeration as the largest energy consumer, where enhancing control systems and installing VSDs could save make a substantial saving annually (as identified in the report).

Additionally, pumping systems at Company 2, used for irrigation and water supply, are the second-largest energy consumers. Implementing VSDs on pumps could result in substantial annual energy savings, especially important during irrigation seasons when pumps operate for extended periods. While lighting and other equipment, such as motors for conveyors and fans, contribute less to overall energy consumption, interventions like switching to energy-efficient lighting and using occupancy sensors can still yield energy savings.



SEU consumption



Focus area	Suggested intervention
1. Boiler efficiency	- Insulating steam pipes: This reduces heat loss, improving overall boiler efficiency. - Reducing flue gas temperature: By lowering the temperature of the flue gases, less energy is wasted. - Using a tarpaulin over stored coal: This minimises heat loss and moisture absorption, enhancing fuel efficiency.
2. Alternative drying tunnel technology	Implementing new technologies to reduce energy consumption in drying processes.
3. Control of old Danfoss refrigeration system	Updating control systems to improve energy management.
4. Electrical metering and monitoring	Installing meters to monitor and manage electrical usage more effectively.
5. EnMS	Deploying systems to manage and optimise energy use – refer to Section 7.1.1 (Best practice: Implementing Energy Management Systems).
6. High-efficiency motors	Replacing old motors with high-efficiency models to reduce energy consumption.
7. Improved control on the new refrigeration systems	Enhancing control mechanisms to increase efficiency.
8. Lighting switch off	Encouraging the practice of switching off lights when not in use.
9. Micro-hydro power	Utilising small-scale hydro power systems.
10. Optimise refrigeration control	Improving control systems to optimise refrigeration processes.
11. Pump control improvement and system optimisation	Enhancing the efficiency of pump systems.
12. Repositioning of drying tunnel blower	Adjusting the position of blowers to improve drying efficiency.
13. Tariff structure optimisation	Modifying tariff structures to encourage energy savings.
14. Use of natural light	Maximising the use of daylight to reduce the need for artificial lighting.
15. Lighting controls	Installing sensors and timers to control lighting usage. Reduces energy waste by ensuring lights are only on when needed.



Focus area	Suggested intervention
16. Lighting replacement	Replacing traditional lighting with energy-efficient LED lights. LED lights use up to 75% less energy, reduce maintenance frequency, and last significantly longer.
17. Heat pumps for geysers	Installing heat pumps to improve the efficiency of water heating systems.
18. VSDs	Installing VSDs on motors and pumps to adjust their speed based on demand. Reduces energy consumption by matching motor speed to the actual load required. An agricultural processing plant applied VSDs to their irrigation pumps and refrigeration compressors. By reducing the motor speed during lower demand periods, they achieved a 20% decrease in energy use and extended the lifespan of their equipment.
19. High-efficiency equipment	Replacing old, inefficient equipment with newer, energy-efficient models. Significant reductions in energy consumption and maintenance costs. A food processing facility can upgrade to high-efficiency boilers, chillers, and HVAC systems. This investment can lead to a 30% reduction in energy costs and a substantial decrease in maintenance issues, ultimately enhancing their overall productivity.
20. Building insulation and envelope improvements	Enhancing the insulation and sealing of buildings to reduce heat loss or gain. Lowers heating and cooling energy requirements, leading to significant energy savings. Industrial facilities could add insulation to walls and roofs, sealed windows and doors, and install energy-efficient windows. These improvements could result in a 20% reduction in heating and cooling costs.
21. Process optimisation	Streamlining industrial processes to improve energy efficiency. Reduces energy consumption and increases productivity. Processing plants could implement energy-efficient practices such as heat recovery and optimised production scheduling, leading to a 10% reduction in energy use and increased throughput.
22. Renewable energy integration	Incorporating renewable energy sources such as solar, wind, and biomass into the energy mix. Reduces dependency on non-renewable energy sources and lowers greenhouse gas emissions. Installing solar panels on its rooftops and using biomass boilers for heating, could cut non-renewable energy use by 25% and significantly reduce carbon footprint.
23. Combined heat and power systems	Using a single fuel source to generate both electricity and useful heat. Increases overall energy efficiency by utilising waste heat. Implementing a combined heat and power system, could result in a 30% improvement in energy efficiency and substantial cost savings.
24. Behavioural and operational changes	Encouraging energy-saving behaviours and optimising operational practices. Many plants have educated employees about energy conservation, implemented energy-saving policies, and scheduled equipment use to avoid peak demand periods, and have published case studies to show that potentially achieving a 10% reduction in energy use through behavioural changes alone is achievable with top management's commitment and allocated resources.

By implementing these common energy-saving techniques, organisations can significantly reduce their energy consumption, lower operating costs, and contribute to environmental sustainability.



8.2.3 Fruit and vegetable sector SWUs and suggested interventions

Washing operations are highly water-intensive, using up to 9 m³/ton, accounting for up to 90% of water usage (Lehto et al., 2014). Processing operations vary widely, from 1.5 to 10 m³/ton (Trajer et al., 2021). Cleaning operations also consume significant water, with a defined usage of 7 m³/ton (Ölmez, 2017; Klemeš et al., 2009). Cooling and refrigeration have variable water needs, around 5 m³/ton (Dupont & Renzetti, 1998). Transport and packaging also show variable water usage, approximately 3 m³/ton (Dupont & Renzetti, 1998). Wastewater treatment uses a high amount of water for recycling, about 8 m³/ton (Bailone et al., 2022). Optimising water use in these key areas can lead to substantial savings and efficiency improvements.

In the assessments of the South African processing facilities:

Company 3 has a water use baseline of 30.55 kL/ton, with annual freshwater consumption of 231,731 kL and borehole water consumption of 152,073 kL. Only 17% of the water is recycled, indicating significant potential for improving water reuse practices.

Company 2 uses water mainly for washing fruit, cleaning equipment, and ablutions, sourced from a shared dam. Implementing water-saving measures, such as better cleaning systems, can reduce overall consumption.

In agricultural operations, Company 7 extensively uses water for irrigating potato crops and domestic purposes, drawing from three boreholes with a combined allocation of 340 000 m³/year. Enhanced irrigation techniques and water management practices can significantly improve water use efficiency.

At another company, the baseload for fresh water consumption was 8 388 kL per month, which is 43% of the total water consumption. The equation to be used to predict future water consumption is represented by the following: $-Y = 0.01 \times \text{production units (kg)} + 8388$.

Focus area	Suggested intervention
1. Cooling tower	Water minimisation by reducing the water used in cooling towers.
2. Expansion of overflow water storage system	Increasing storage capacity to capture and reuse overflow water.
3. Install water meters	Installing meters to monitor and manage water usage.
4. Prevent evaporation	Implementing measures to reduce water loss through evaporation.
5. Rainwater harvesting system	Collecting and storing rainwater for later use, typically for irrigation and non-potable purposes. Reduces reliance on municipal water supplies and takes advantage of natural precipitation.
6. Reduce fruit washing water	Implementing practices to use less water in fruit washing processes.
7. RO plant	Using RO plants to treat and reuse water.
8. High-pressure, low-volume sprays	Using high-pressure, low-volume sprays for cleaning surfaces and equipment. Reduces the amount of water used while maintaining effective cleaning performance. High-pressure, low-volume sprays are utilised to clean floors, walls, and equipment efficiently. This technique could reduce water usage for cleaning by 40%, maintaining hygiene standards while saving water.



Focus area	Suggested intervention
9. Water recycling and reuse	Recycling wastewater for non-potable uses such as irrigation, cooling, or cleaning. Reduces the demand for fresh water and lowers wastewater discharge. Treating and reuse wastewater for cooling towers and landscape irrigation, could reduce freshwater consumption by 30%.
10. Efficient irrigation systems	Delivers water directly to the root zone of plants, minimising evaporation and runoff. Reduces water use by 30–50% compared to traditional irrigation methods. Drip irrigation for their grapevines, reducing water usage and improving crop yield.
11. Leak detection and repair	- Regular inspection of plumbing systems to detect and repair leaks promptly. Prevents water loss and reduces unnecessary water usage. - Implement a rigorous leak detection and repair program, identifying and fixing leaks, potentially saving approximately 15% of annual water consumption.
12. Low-flow fixtures	Installing low-flow faucets, showerheads, and toilets that use less water per use. Significantly reduces water consumption in domestic and commercial settings. Replace all fixtures with low-flow alternatives, reducing water use by 25%.
13. Behavioural changes and education	Encouraging water-saving habits and raising awareness about water conservation. Promotes long-term sustainable water use practices. Launch an internal campaign to educate employees on water-saving techniques.
14. Greywater systems	Reusing greywater from sinks, showers, and laundry for irrigation or toilet flushing. Reduces fresh water demand and wastewater generation.
15. Advanced water treatment technologies	Using technologies such as RO, ultrafiltration, and UV disinfection to treat and recycle water. Provides high-quality reclaimed water for various uses, reducing the need for freshwater.
16. Smart water management systems	Implementing integrated water management systems that use sensors, automation, and data analytics to optimise water use. Enhances water use efficiency and provides real-time monitoring and control.

These steps not only improve a production plant's efficiency but also align with broader environmental goals, creating a win-win situation for the facility and the planet.



8.3 POULTRY SECTOR

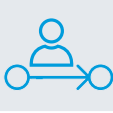
8.3.1 Sector snapshot

The poultry industry is the largest agricultural sector in South Africa, contributing 19.7% to agricultural income, with poultry meat making up 15.5% and eggs 4.2% (SAPA, 2014d). In 2014, poultry products represented 42.2% of all animal products (SAPA, 2014d). The gross primary agricultural production values for poultry meat and eggs in 2014 were R33 810 billion and R9 195 billion, respectively.

Approximately 76% of birds in the South African poultry industry are used for meat production, with the remaining 24% allocated to the egg industry (SAPA, 2014d). Ostrich feathers and products contributed R410.6 million to the agricultural production in 2014, accounting for 0.19% of total agricultural production and 0.40% of total animal products (DAFF, 2014).

The day-old chick supply industry provides inputs for both the egg and broiler industries. Pure lines are primarily imported at the great-grandparent or grandparent level, with minimal parent-level imports. There are no commercial imports of day-old chicks or fertile eggs (SAPA, 2014d).

By December 2018, South African broiler hatcheries produced 21 691 million day-old chicks weekly, indicating a robust poultry sector. On average, these hatcheries processed 17 843 million broilers weekly, showcasing the industry's capacity to meet significant domestic demand.

	56 218	People directly employed by the sector.
	108 000	People indirectly employed by the sector.
	275	Known poultry farmers.
	231	Contract growers in the commercial broiler sector.
	383	Commercial egg producers (SAPA, 2012b).
	2 742	Million tonnes poultry meat and eggs consumed in 2015 (1 507 million tonnes of beef, pork, mutton, and goat (SAPA, 2015a)).
	~26/5 l	Litres of water required per bird in poultry processing.
	230 billion+	Litres of water annually, excluding the water needed to raise the birds (Dada et al., 2023).



8.3.2 Water consumption during poultry processing

Poultry processing typically consumes large amounts of water, which is used in various stages including cleaning carcasses, washing cages and trucks, scalding, cleaning the plant, and cooling machinery (Matsumura and Mierzwa, 2008). Water reuse in this industry is particularly challenging due to contamination with faeces, which contain pathogens such as *Salmonella* spp. and *Campylobacter jejuni*, making the water unsafe for reuse (Matsumura and Mierzwa, 2008).

According to a study conducted by Matsumura and Mierzwa (2008) in a poultry processing plant in Brazil:

	80%	Of water consumption occurs in scalding/production area, machinery room/cooling system, evisceration, bird receiving area, and chillers (entire poultry).
	49%	Of water consumption by processing steps such as cage cleaning, production of ice, defeathering, water heating, gizzard removal, cooling with pre-chiller (room temperature water), cooling with main chiller (cold water and ice), tail feather removal, and feet scalding.

Stages of large water consumption adapted from Kist et al (2009)

Process	Flow (m ³ day ⁻¹)	Percentage (%)
Receiving/slaughtering/exsanguination	1466	82
Scalding	24	1.3
Pre-chilling and chilling	300	16.7
Treated wastewater	1500	-

8.3.3 Energy consumption during poultry processing

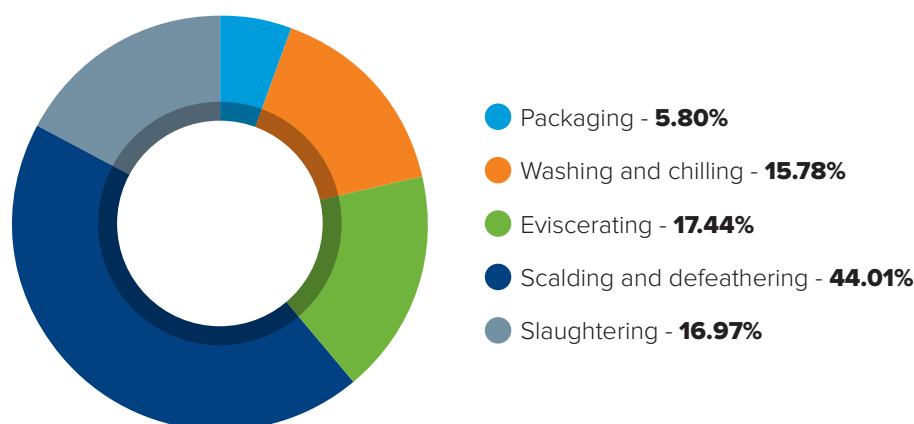
Poultry processing requires energy consumption, and the percentage increases with the level of automation and mechanisation of the facility (Baxevanou et al., 2017). In poultry processing, energy is consumed for internal climate control – heating, cooling, ventilation, lighting, and humidity control – as well as for the operation of equipment such as worm conveyors (Kist et al., 2009; Baxevanou et al., 2017). All processing stages require some form of energy, either from fossil fuels, electricity, or human labour (Jekayinfa, 2007). Most stages require electricity, while fossil fuels are used for producing hot water for defeathering (Jekayinfa, 2007).

The condition of machinery correlates with the amount of energy consumed. For example, a study conducted in a poultry processing plant in Saskatchewan, Canada, which processed 10 000 birds at the time, found that a well-insulated broiler consumed 188 000 kWh annually, while a poorly insulated one consumed 214 000 kWh annually (Baxevanou et al., 2017).



A study in southeast Nigeria (Jekayinfa, 2007) identified the following processes as using the most energy:

Energy usage



The study also revealed that the least mechanised plant (plant A) consumed the most energy at 50.36 MJ, followed by plant B at 28.04 MJ, and plant C (the most mechanised) at 17.83 MJ – each value representing electricity consumption per 1 000 birds. It was found that the high energy consumption in plant A was due to rudimentary and increasingly obsolete processing methods (Jekayinfa, 2007).

These findings highlight the significant impact that modernisation and mechanisation can have on energy efficiency in poultry processing plants.

8.3.4 Poultry sector SEUs and suggested interventions

The NCPC-SA reviewed reports from multiple poultry processing facilities to an analysis of significant energy and water-saving interventions. These measures are aimed at enhancing resource efficiency and reducing operational costs. The interventions are taken from the NCPC-SA assessment reports and should be consulted with professional engineering advice as they have not been validated. They are listed to provide an initial frame of reference for potential energy-saving measures.

SEU	Suggested interventions
Refrigeration systems	Implement enhanced control systems, install VSDs, and optimise insulation and maintenance routines.
Processing equipment	Upgrade to energy-efficient models, implement regular maintenance schedules, and automate processes to reduce energy waste.
Heating and cooking equipment	Transition to biomass boilers or geothermal heat pumps, and utilise heat recovery systems.
Water heating systems	Install solar water heaters or high-efficiency electric geysers, and insulate pipes to minimise heat loss.
Compressed air systems	Optimise system pressure, fix leaks, and install VSDs to match air supply with demand.



8.3.5 Poultry sector SWUs and suggested interventions

SWU	Suggested interventions
Chilled water system	Implement closed-loop systems, optimise cooling cycles, and use water-efficient chillers.
Facility cleaning	Use high-pressure, low-volume cleaning systems, implement dry cleaning methods where possible, and optimise cleaning schedules.
Processing equipment cooling	Utilise recirculating cooling systems, improve heat exchanger efficiency, and optimise cooling processes.
Boiler make-up water	Use condensate return systems, implement water treatment to reduce blowdown, and use efficient boiler operation practices.
Sanitation and hygiene	Install low-flow fixtures, use automated and timed water dispensers, and implement water recycling and reuse systems.

8.3.6 Common poultry processing energy- and water-saving techniques

Focus area	Suggested intervention
Energy efficiency	
1. Anaerobic digestion as energy source	Utilising anaerobic digestion to generate energy, with two options explored – thermal/gas and electrical.
2. Develop and implement energy management policy	Establishing policies to manage and optimise energy use across the facility.
3. Electronic condensate drain trap or equivalent	Implementing electronic condensate drain traps to improve system efficiency.
4. Fan maintenance and repair and optimisation	Regular maintenance and optimisation of fans to ensure efficient operation.
5. Install a solar water heater	Using solar energy to heat water, reducing reliance on conventional energy sources.
6. Install a solar water pump and make use of the natural spring on the farm	Harnessing solar power to operate water pumps and utilise natural water sources.
7. Install boiler stack economiser	Adding economisers to boiler stacks to recover waste heat and improve efficiency.
8. Install ceiling insulation	Enhancing thermal insulation in ceilings to reduce energy consumption for heating and cooling.
9. Install geyser blankets	Insulating geysers to retain heat and reduce energy usage.
10. Install geyser timers	Using timers to control geyser operation and minimise unnecessary energy use.
11. Install light occupancy sensors	Installing sensors to automatically control lighting based on occupancy.
12. Install new incubators and hatchers	Upgrading to more energy-efficient incubators and hatchers.
13. Install VSDs on motors	Using VSDs to optimise motor operation and reduce energy consumption.
14. Insulation of broiler houses using polyurethane foam	Applying polyurethane foam insulation to improve energy efficiency in broiler houses.
15. LED lighting	Replacing traditional lighting with energy-efficient LED lights to reduce energy consumption.
16. Optimise condensate recovery	Enhancing systems to recover condensate and improve efficiency.
17. Power factor correction	Implementing measures to improve the power factor and reduce energy losses.



Focus area	Suggested intervention
18. Proper coal storage area	Establishing a proper storage area for coal to ensure efficient usage.
19. Pump efficiency improvement	Enhancing the efficiency of pump systems.
20. Repair ceiling insulation	Fixing and improving existing ceiling insulation to enhance energy efficiency.
21. Repair compressed air leaks	Identifying and repairing leaks in the compressed air system to prevent energy loss.
22. Replace boilers with new boiler system	Upgrading to more efficient boiler systems.
23. Replace geysers/water heater with heat pumps	Using heat pumps to improve the efficiency of water heating systems.
24. Replace pressure gauge	Installing new pressure gauges to ensure accurate monitoring and control.
25. Sealing/repair of broiler houses building envelope	Sealing and repairing the building envelope to improve energy efficiency.
26. Solar panels for daytime lighting requirements	Using solar panels to meet daytime lighting needs.
27. Thermometer and humidity meter (hygrometer)	Using thermometers and hygrometers to monitor and control environmental conditions.
28. Upgrade conventional aircon to inverter	Replacing conventional air conditioning units with more efficient inverter models.
29. Upgrade effluent treatment process and install RO unit	Improving effluent treatment and installing RO units to enhance water management.
30. Use of solar water heater for water heating	Using solar energy for water heating to reduce energy consumption.
31. Variable header pressure on condenser	Adjusting header pressure on condensers to improve efficiency.
32. VSD on air compressor	Using VSDs on air compressors to optimise performance.
33. Waste heat recovery from base load compressor	Recovering waste heat from compressors to improve overall energy efficiency.
Water efficiency	
34. Dry-cleaning techniques	The adoption of dry-cleaning methods over traditional wet cleaning can significantly reduce water usage in poultry abattoirs. Techniques such as scraping fat and grease off conveyor belts, installing strainers along the evisceration line, and sweeping or shovelling materials off the floor before wet cleaning are effective. By-products from poultry processing can be managed without water, which also reduces the biological oxygen demand and total suspended solids in wastewater.
35. Pressure washing	Using a pressurised spray for cleaning surfaces is another effective water conservation strategy. This method uses less water compared to traditional methods and should be preceded by dry-cleaning to maximise efficiency. Initial wash-downs can utilise recycled water, further conserving fresh water.
36. Water metering	Implementing metering systems for daily and annual water use helps monitor and manage water consumption. These meters can identify areas of water overuse and inefficiency, aiding in the planning of pollution prevention measures and effluent treatment. Monitoring high water-use equipment such as chillers and evaporators can pinpoint fluctuations and wastage. (Refer to Section 7.1.4 Best practice: Metering and monitoring).
37. Pressure reducers	Installing pressure reducers and automatic shut-off valves helps in controlling water flow and reducing unnecessary water consumption.



Focus area	Suggested intervention
38. Training personnel	Educating abattoir management and staff on water conservation techniques is crucial. Training programmes should cover the minimum water requirements for various tasks and effective cleaning practices, leading to more efficient water use.
39. Equipment modifications	Modifying equipment to include screens and traps can prevent solid materials from entering the effluent stream. Regular checks and maintenance of spray nozzles and repairing leaks can further reduce water loss.
40. Solar water pump installation	One of the most impactful water-saving interventions is the installation of solar water pumps, particularly those utilising natural springs on the farms. This measure can reduce water consumption by approximately 20–30%. Solar water pumps are advantageous as they leverage renewable energy, decreasing both water and energy use.
41. Water-efficient devices	The implementation of water-efficient devices in various stages of poultry processing is a common recommendation. This includes high-efficiency nozzles for cleaning and disinfection, as well as advanced humidification systems in hatcheries. These devices can reduce water consumption by about 15–20% by optimising water usage and minimising waste.
42. Rainwater harvesting	Some reports suggest the adoption of rainwater harvesting systems. This involves collecting and storing rainwater for use in non-potable applications such as irrigation and cleaning. Rainwater harvesting can contribute to a reduction in municipal water use by around 10–15%, depending on the facility's location and rainfall patterns.
43. Improved water management practices	Enhancing water management practices is another key intervention. This includes regular monitoring of water usage, identifying leaks, and ensuring timely repairs. Proper water management can lead to savings of approximately 10–15% by reducing unnecessary water loss and optimising usage patterns.
44. Wastewater treatment and reuse	The installation of wastewater treatment systems to treat and reuse water within the facility is recommended. Treated wastewater can be reused for non-potable purposes, significantly reducing fresh water intake. This intervention can achieve water savings of about 20–25%, making it a highly effective measure for water conservation.
45. Bio-security and sanitation measures	Enhanced bio-security and sanitation measures, such as foot-dip trays, hand-washing basins, and proper cleaning protocols, can reduce water wastage. These measures ensure that water is used efficiently and only when necessary, contributing to overall water savings of approximately 5–10%.
46. Leak detection and repair	Regular inspection of plumbing systems to detect and repair leaks promptly. Prevents water loss and reduces unnecessary water usage. Implement a rigorous leak detection and repair programme, identifying and fixing leaks, potentially saving approximately 15% of annual water consumption.
47. Low-flow fixtures	Installing low-flow faucets, showerheads, and toilets that use less water per use. Replace all fixtures with low-flow alternatives, reducing water use by 25%.
48. Advanced water treatment technologies	Using technologies such as RO, ultrafiltration, and UV disinfection to treat and recycle water. Provides high-quality reclaimed water for various uses, reducing the need for freshwater.

Effective water conservation in the poultry industry requires a multifaceted approach, incorporating dry-cleaning techniques, pressure washing, water metering, pressure reducers, personnel training, and equipment modifications. These strategies, supported by extensive literature, provide a robust framework for reducing water usage and enhancing sustainability in poultry processing operations. Integrating these measures into industry practices can lead to significant environmental and economic benefits.



8.4 SUGAR CANE SECTOR

8.4.1 Sector snapshot

The South African sugar cane milling industry is a significant contributor to the country's economy, both in terms of employment and export revenues. This industry is centered in the coastal regions of KwaZulu-Natal, Mpumalanga, and the Eastern Cape, where the climate is conducive to sugar cane cultivation.

The South African sugar industry produces approximately 2.5 million tons of sugar annually from 22 million tons of cane (Meyer, 2007).

Production is influenced by various factors, including climate, irrigation, pests, diseases, and economic conditions (Singels et al., 2010). The industry has faced challenges such as declining output and changes in ownership due to land reform (James & Woodhouse, 2017). However, some regions have increased their market share despite these challenges (James & Woodhouse, 2017). Cane quality and yield have fluctuated over the years, with variations in performance across different mill areas (Smith et al., 2014; Smith et al., 2011). To improve production forecasting, a model-based operational yield forecasting system has been developed, integrating climate data, crop management, and seasonal rainfall outlook information (Bezuidenhout, 2005). The industry has also made advances in field technology and environmental management to maintain competitiveness (Meyer, 2007).

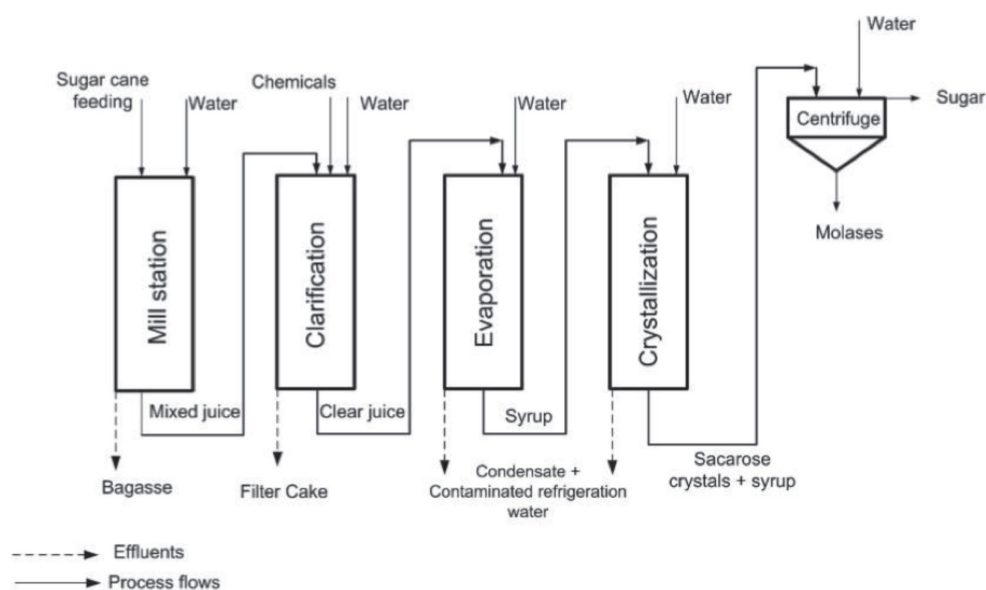
	85 000	People directly employed by the sector.
	350 000	People indirectly employed by the sector through related industries such as transportation, machinery maintenance, and agricultural services (Nemarumane & Mbohwa, 2015) (South African Sugar Association, 2023).
	33kg	Per capita sugar consumption in South Africa (International Sugar Organization, 2023).

Environmental challenges pose a significant threat, including water scarcity and the need for sustainable farming practices to mitigate the impacts of climate change (WWF South Africa, 2023).

Several trends are shaping the future of the sugar cane milling industry in South Africa. There is a growing focus on sustainability and environmental responsibility, with mills investing in renewable energy sources such as biomass from cane waste (South African Sugar Association, 2023). Additionally, there is a trend towards diversification, with sugar companies exploring the production of biofuels and bioplastics as alternative revenue streams. Technological advancements in precision agriculture and automation are also being adopted to improve efficiency and reduce costs (Agricultural Research Council, 2023).

Energy requirements vary because of seasonal temperature variations. Thus, seasonal variations in the energy budget will occur across all plants and such effects will be reflected in the energy index. These seasonal variations in the index can be accounted for by appropriate averaging.

The typical sugar production process involves several steps: sugar cane harvesting, cane preparation, juice extraction, clarification, filtration, evaporation, sugar boiling (crystallisation), centrifugation, and sugar drying. The following figure illustrates a simplified sugar production process from sugar cane.



Simplified sugar cane process

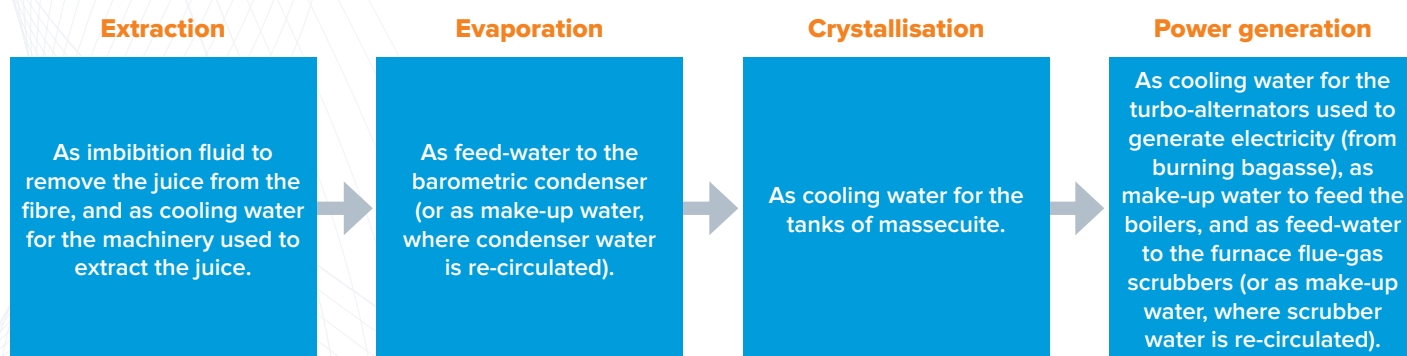
8.4.2 Water consumption in sugar mills

During the sugar milling process, a significant amount of water becomes contaminated through various stages (Birru et al., 2016; Srichaipanya and Chuan-Udom, 2020). This includes water recovered from processes such as evaporation, crystallisation, and refining (Srichaipanya and Chuan-Udom, 2020); water recovered from imbibition – when water is applied to bagasse after the crushing stage to assist with juice extraction (Birru et al., 2016); and water recovered from machinery like refrigerators and condensers (Srichaipanya and Chuan-Udom, 2020).

This water must be recycled to reduce the volume of inlet water required for the sugar milling process (Birru et al., 2016; Srichaipanya and Chuan-Udom, 2020).

To reduce water use during processing, it is important that mills accurately measure the amount of imbibition water required (Birru et al., 2016). This can be achieved by varying the flow of the imbibition water, which in turn affects the amount of sugar produced (Birru et al., 2016). Many sugar mills tend to use imbibition water in excess, which does not necessarily increase the sucrose content extracted, as it also depends on factors such as hydraulic pressure, fibre content of the sugarcane, and the amount of cane milled (Birru et al., 2016).

Water supply is required for the following processes:



Miscellaneous usages include cooling waters for pumps, factory washings and milk of lime preparation.



8.4.3 Energy use in sugar mills

The energy used in sugar mills is primarily for temperature control and operating machinery. Larger sugar mills require more machinery, which increases energy consumption (Srichaipanya and Chuan-Udom, 2020). The throughput of milling equipment is related to the amount of cane solids that must be crushed (Mackintosh, 2024). If the cane has a high fibre content, due to soil matter and trash, the crushing rate is reduced, prolonging the initial milling stage and increasing energy use (Mackintosh, 2024).

Significant heating is needed during the sugar-making process. For instance, after clarification, the raw sugar juice must be heated to approximately 75°C during liming, and further to about 102°C to eliminate pathogens (Mackintosh, 2024). In most sugar mills, bagasse is used as boiler fuel to generate steam, which drives turbines that power the extraction crushers (Li et al., 2011).

Energy consumption during sugar processing varies across mills; however, maintaining well-functioning machinery and turbines and supplementing thermal power with bagasse improves energy efficiency (Li et al., 2011).

Increasing soak water enhances juice extraction, thereby reducing power consumption (Srichaipanya and Chuan-Udom, 2020). Birru et al. (2016) proposed utilising waste heat from wastewater for thermally driven cooling to reduce electricity reliance.

In the absorption cooling cycle, a cooling effect is achieved when heat is absorbed during refrigerant evaporation at low pressure. The resulting refrigerant vapor is absorbed by an absorbent, forming a solution that is pumped to a generator, where heat causes the refrigerant to evaporate at high pressure. The vapor moves to a condenser, releases heat, and the absorbent returns to the absorber, repeating the cycle. This system can operate with low-grade heat sources, such as waste heat from sugar mills at temperatures as low as 75°C, producing a cooling effect down to 6°C (Birru et al., 2016).

Sugarcane mills are generally categorised into two major types based on the technology they employ:

Conventional sugar mills:

- Low-pressure boilers
- Back-pressure turbines
- Do not produce surplus electrical power
- Use steam turbine-driven mechanical equipment (such as rollers, shredders, and pumps)
- May have an adjacent ethanol distillery, although this is not always the case.

Modern sugar mills:

- High-pressure and high-temperature boiler installations
- Typically have a co-generation unit equipped with condensing extraction steam turbines, leading to the production of surplus electrical power
- Use electrical drives instead of steam turbines for producing mechanical power
- Are increasingly adopting diffusers for the cane juice extraction process.

8.4.4 Baselines and benchmarks

The energy consumption in sugar mills ranges from 250 to 400 kWh per ton of cane processed (Ng Inman-Bamber et al., 2007; C. Chou, 2005). Bagasse, a by-product of sugarcane milling, is commonly used as a biofuel to generate electricity and steam, significantly reducing dependency on external energy sources, with some mills even exporting surplus electricity to the grid (Kriengkrai Assawamartbunlue et al., 2018). Despite this, overall energy efficiency varies due to differences in technology, operational practices, and equipment age. Modern mills equipped with advanced cogeneration systems exhibit higher energy efficiency compared to older mills (Birru, 2016; Martin, 2016).



Water consumption in sugarcane milling is substantial, primarily due to cane washing, juice extraction, and process cooling. The global average water use in sugarcane mills is estimated to be around 20–30 m³ per ton of cane processed (P. Avram et al., 2004; Guido Colombo et al., 2014). Water recycling and reuse practices, such as multiple-effect evaporation and condensate recovery systems, are increasingly adopted to mitigate water consumption (S. V. Lemos et al., 2021). Variations in water usage are influenced by climatic conditions, water management practices, and regulatory requirements in different regions.

The sugarcane milling industry worldwide is focusing on improving energy and water efficiency to enhance competitiveness and sustainability. Benchmarking is crucial for measuring performance and identifying areas for improvement (Ng Inman-Bamber et al., 2007; C. Chou, 2005). Studies have established baseline energy consumption and specific energy consumption for sugar mills, with factors like power plant ownership affecting these metrics (Kriengkrai Assawamartbunlue et al., 2018).

Integrated sugar, ethanol, and cogeneration plants are emerging as benchmarks for minimising emissions and maximising electricity generation (P. Avram et al., 2004; Guido Colombo et al., 2014). Best practices for improving efficiency include optimising agricultural, industrial, and managerial dimensions (S. V. Lemos et al., 2021). Advanced power generation systems and replacing mechanical steam turbines with electric drives can significantly improve energy efficiency (Birru, 2016; Martin, 2016). These strategies aim to reduce fossil fuel dependence, increase renewable energy production, and enhance overall process efficiency in the sugarcane industry.



300–500

kWh per ton of cane processed in South African mills.

⚡ Energy consumption is relatively efficient compared to the global average. South African mills have made significant strides in implementing cogeneration systems, allowing them to produce their own electricity and steam. However, technological advancement varies, and some older mills still lag in energy efficiency (Kriengkrai Assawamartbunlue et al., 2018; Birru, 2016; Martin, 2016). The industry is exploring opportunities to enhance energy efficiency through modernisation and upgrading of milling equipment, along with adopting more efficient operational practices (Ng Inman-Bamber et al., 2007; C. Chou, 2005).

💧 Water consumption in South African sugarcane mills is estimated to be slightly lower than the global average, at around 15–25 cubic meters per ton of cane processed. Various water-saving measures have been adopted, such as recycling process water, using treated effluent for cane washing, and implementing drip irrigation systems in sugarcane fields to reduce overall water demand. The industry also faces water scarcity challenges, particularly in regions prone to drought, prompting efforts to improve water use efficiency and invest in sustainable water management practices (P. Avram et al., 2004; Guido Colombo et al., 2014; S. V. Lemos et al., 2021).

The baseline

To set rational energy-saving targets for the sugar mill sector, it's essential to understand both its BEC and potential energy savings. Sugar mills are categorised into two groups: those with their own power plants and those without. The BEC and SEC vary significantly between these two groups. Additionally, energy consumption within a sugar mill differs between the juice extraction season and the off-season. The developed regression equations predict baseline BEC and SEC based on known factors.

The process of producing granulated sugar includes juice extraction, clarification, preheating and evaporation, syrup treatment, crystallisation, centrifugalisation, and drying.



Each stage consumes significant amounts of thermal and electrical energy, especially during juice extraction. During the non-extraction season, energy consumption is notably lower.

In Kriengkrai's study (2018), sugar mills are classified based on their energy sources: mills with their own power plants generate steam and electricity using bagasse, while mills without power plants purchase steam and electricity from nearby utility suppliers. The regression equations developed for Thai sugar mills serve as benchmarks for energy consumption in this sector.

The developed equations can predict BEC and SEC within acceptable tolerances, relying on four variables: the fraction of electricity sold compared to total production, the fraction of sugar cane input to installed capacity by mass, average sugar production per hour, and the fraction of electrical power consumption compared to steam consumption.

The developed formulae for BEC and SEC are as follows:

For sugar cane mills with their own power plant:

• Juice extraction season:

$$1. \text{BEC} = 192,671.510 + 43,279.532x_3, R^2 = 0.740$$

$$2. \text{SEC} = 146.442 + 1.297x_1 + 1.431x_2 + 2.924x_3 - 0.00031x_1x_2x_3 - 0.026x_1^2 + 0.000135x_2^2 - 0.007x_3^2, R^2 = 0.949$$

• Non-extraction season:

$$3. \text{BEC} = 4,297,731.45 - 120.44x_1 - 284,688.17x_3 + 3,537.05x_1x_3 - 901.37x_1^2 + 2,116.70x_3^2, R^2 = 0.990$$

$$4. \text{SEC} = 81.760 + 0.796x_1 - 5.054x_3 + 0.08446x_1x_3 - 0.031x_1^2 + 0.004809x_3^2, R^2 = 0.890$$

For sugar cane mills without own power plant:

• Juice extraction season:

$$5. \text{BEC} = 944,939.448 + 26,508.163x_3, R^2 = 0.760$$

$$6. \text{SEC} = 89.833 - 1.468x_2 + 0.085x_3 - 1,056.518x_7 - 0.019x_2x_3x_7 + 0.012x_2^2 - 0.000090x_3^2 + 8,353.778x_7^2, R^2 = 0.948$$

• Non-extraction season:

$$7. \text{BEC} = 24,853,148.348 - 90,849.491x_3 - 831,740,428.121x_7 + 3,389,141.656x_3x_7 - 756.388x_3^2 + 6,338,708,287.370x_7^2, R^2 = 0.786$$

$$8. \text{SEC} = 159.781 - 0.303x_3 - 5,130.529x_7 + 20.968x_3x_7 - 0.012x_3^2 + 38,139.774x_7^2, R^2 = 0.790$$

Annually, data for these variables are gathered and used in the equations to calculate BEC and SEC, which serve as benchmarks. These benchmarks are then compared with actual BEC and SEC for the same year to assess energy usage efficiency. Unlike previous studies that focused on specific equipment, systems, or product performance, this study emphasises whole plant performance, making it practical and convenient for industry application.



Benchmarking

Many sugar mills in South Africa use bagasse to generate electricity primarily for their own use, with some exporting excess electricity to the national grid. The power output per ton of sugarcane crushed is approximately 30 kWh.

Technological comparison:

- South Africa: 30 KWh/ton of cane, generating 742 GWh annually.
- Brazil: 40 KWh/ton of cane.
- Mauritius: 65 KWh/ton of cane.
- Advanced technologies (e.g. Biomass integrated gasifier): Up to 517 KWh/ton of cane, but with higher costs.

8.4.5 Sugar cane sector SEUs and SWUs



Meter key energy-consuming equipment such as refrigeration units, processing machinery, and lighting systems.



Meter significant water-consuming areas such as irrigation systems, washing stations, and cooling systems.

8.4.6 Common sugar cane energy- and water-saving techniques

Focus area	Intervention	Explanation
Energy efficiency		
Energy audits and monitoring	1. Conduct regular energy audits (Potential savings: 5–15%)	Energy audits involve a comprehensive analysis of energy flows within the plant. This includes measuring power consumption of individual equipment, analysing operational data, and identifying inefficiencies. Advanced tools such as infrared thermography, ultrasonic flow meters, and data loggers can be used to pinpoint energy losses in processes like steam generation, electrical systems, and motor operations.
	2. Implement EnMS (Potential savings: Up to 10%)	Installing a real-time EnMS allows for continuous tracking of energy use. These systems use sensors and smart meters to collect data, which is then analysed using energy management software. EnMS helps in identifying peak load periods, unusual consumption patterns, and inefficiencies, enabling timely corrective actions. (Refer to Section 7.1.1 Best practice: Implementing energy management systems)
Process optimisation	3. Optimise crushing operations (Potential savings: 10–15%)	Crushing operations can be optimised by replacing fixed-speed motors with variable frequency drives (VFDs), which adjust motor speed to match process demands. This reduces energy consumption during lower demand periods. Regular maintenance of crushers and proper alignment of rollers can also improve efficiency.
	4. Improve juice extraction efficiency (Potential savings: 5–8%)	Transitioning to diffusers from traditional milling increases extraction efficiency by allowing more complete juice recovery with lower energy input. Regular calibration and maintenance of extraction equipment ensure optimal performance. Monitoring extraction efficiency and adjusting operational parameters based on real-time data can further enhance energy savings.



Focus area	Intervention	Explanation
Boiler and steam systems	5. Enhance boiler efficiency (Potential savings: 10–20%)	Upgrading to high-efficiency boilers involves selecting units with better heat transfer, lower excess air levels, and enhanced combustion controls. Automated boiler controls optimise fuel-to-air ratio, improving combustion efficiency. Regular maintenance, including cleaning of heat exchanger surfaces and proper insulation also contributes to energy savings.
	6. Utilise cogeneration systems (Potential savings: 30–40%)	Cogeneration (combined heat and power) systems generate electricity and useful heat simultaneously. By using bagasse as a fuel source, mills can produce both power and process steam, maximising energy utilisation. The efficiency of cogeneration systems can reach up to 80%, significantly higher than conventional separate heat and power generation.
	7. Optimise steam distribution (Potential savings: 10–20%)	Insulating steam pipes minimises heat loss. Steam traps remove condensate and non-condensable gases, maintaining steam quality and efficiency. Condensate recovery systems capture and reuse condensate, reducing the need for fresh water and energy for reheating.
Electrical systems	8. Upgrade electrical motors (Potential savings: 10–15%)	Energy-efficient motors, such as those meeting IE3 or IE4 standards, offer lower losses compared to standard motors. VFDs provide precise control of motor speed and torque, optimising energy use. Proper sizing and maintenance of motors also contribute to efficiency.
	9. Improve power factor (Potential savings: Up to 10%)	Power factor correction involves adding capacitors or synchronous condensers to the electrical system to counteract inductive loads. This reduces the apparent power drawn from the grid, lowering energy losses and improving system efficiency.
Cooling and refrigeration	10. Optimise cooling systems (Potential savings: 15–20%)	Upgrading to energy-efficient chillers and cooling towers involves selecting units with higher coefficient of performance and better heat exchanger designs. Implementing VFDs on pumps and fans allows for variable speed operation, matching cooling capacity with demand and reducing energy use.
	11. Regular maintenance (Potential savings: 5–10%)	Regular maintenance ensures cooling and refrigeration systems operate at peak efficiency. This includes cleaning heat exchangers, checking refrigerant levels, and ensuring proper airflow. Preventive maintenance can identify and address issues before they lead to significant energy losses.
Lighting systems	12. Upgrade to energy-efficient lighting (Potential savings: 50–60%)	Replacing incandescent and fluorescent lights with LED fixtures provides higher efficiency and longer lifespan. LEDs convert more electrical energy into light with less heat generation. Installing motion sensors and timers ensures lights are only used when necessary, further reducing energy consumption.



Focus area	Intervention	Explanation
Building and facility management	13. Improve insulation (Potential savings: 10–15%)	Insulating buildings and processing areas involves using materials with high R-values to reduce heat transfer. Reflective roofing materials minimise solar heat gain, reducing the load on HVAC systems. Proper insulation maintains consistent temperatures, enhancing energy efficiency.
	14. Implement energy-efficient HVAC systems (Potential savings: 10–15%)	Energy-efficient HVAC systems use advanced compressors, variable speed fans, and optimised refrigerant flow to improve performance. Programmable thermostats and building management systems provide precise control over HVAC operations, ensuring energy is used efficiently.
Renewable energy integration	15. Solar power (Potential savings: Up to 30%)	Installing photovoltaic panels involves assessing solar potential and selecting appropriate panel types and configurations. Solar energy systems can be grid-tied or include battery storage for off-grid capability. Integrating solar power reduces reliance on external electricity sources.
	16. Biogas production (Potential savings: 20–25%)	Biogas production from organic waste involves anaerobic digestion, where microorganisms break down organic material in the absence of oxygen, producing biogas (methane and carbon dioxide). The biogas can be used as a renewable energy source for boilers and other equipment, reducing fossil fuel consumption.
Employee training and awareness	17. Energy-efficiency training programmes (Potential savings: 5–10%)	Training programmes educate employees on energy-saving practices and the importance of energy efficiency. These programmes include workshops, on-site training, and continuous improvement initiatives. Engaging employees in identifying and implementing energy-saving measures fosters a culture of energy efficiency.
Water efficiency		
Water audits and monitoring	18. Conduct regular water audits (Potential savings: 5–15%)	Water audits involve a comprehensive analysis of water use throughout the plant. This includes measuring water flow rates, identifying leaks, and evaluating water usage in different processes. Tools such as flow meters, ultrasonic leak detectors, and data loggers are used to identify inefficiencies and potential savings opportunities.
	19. Implement water monitoring systems (Potential savings: Up to 10%)	Installing real-time water monitoring systems allows continuous tracking of water use. These systems use sensors and smart meters to collect data, which is analysed using water management software. Monitoring helps identify excessive water use, leaks, and inefficiencies, enabling timely corrective actions.
Process optimisation	20. Optimise juice extraction processes (Potential savings: 10–20%)	Optimising juice extraction processes can significantly reduce water use. This includes using high-efficiency extraction equipment and recycling process water. Implementing continuous monitoring and control systems ensures that water use is minimised while maintaining extraction efficiency.



Focus area	Intervention	Explanation
	21. Improve cane washing efficiency (Potential savings: 20–30%)	Cane washing is a major water-consuming process. Upgrading to high-efficiency washers and optimising the washing process can reduce water use. Recycling wash water and using counter-current washing techniques can further enhance water savings.
Cooling and boiler feed water	22. Optimise cooling water systems (Potential savings: 10–20%)	Cooling water systems can be optimised by implementing closed-loop cooling systems, which recycle cooling water. Using high-efficiency cooling towers and regularly maintaining them ensures minimal water loss through evaporation and drift.
	23. Improve boiler feed water treatment (Potential savings: 10–15%)	Efficient boiler feed water treatment reduces the need for blowdown, which in turn saves water. Implementing RO and demineralisation systems for water treatment can improve water quality, reducing scale formation and blowdown frequency.
Condensate recovery	24. Implement condensate recovery systems (Potential savings: 15–25%)	Condensate recovery involves capturing and reusing steam condensate, which is typically pure water. This reduces the need for fresh boiler feed water and minimises energy use for heating. Installing efficient condensate recovery systems and regularly maintaining them ensures maximum recovery.
Effluent treatment and reuse	25. Install advanced effluent treatment systems (Potential savings: 20–30%)	Advanced effluent treatment systems, such as membrane bioreactors and anaerobic digesters, treat wastewater to high standards, allowing it to be reused in the plant. Treating and reusing effluent for non-potable purposes like irrigation and cooling can significantly reduce fresh water use.
Leak detection and repair	26. Implement leak detection programmes (Potential savings: 5–10%)	Regular leak detection and repair programmes help identify and fix water leaks promptly. Using ultrasonic leak detectors and regular inspections ensures that leaks are detected early and repaired, preventing water wastage.
Employee training and awareness	27. Water-efficiency training programmes (Potential savings: 5–10%)	Training programmes educate employees on water-saving practices and the importance of water efficiency. These programmes include workshops, on-site training, and continuous improvement initiatives. Engaging employees in identifying and implementing water-saving measures fosters a culture of water efficiency.

Implementing these common practices in the sugarcane milling sub-sector in South Africa can lead to energy savings. By continuously monitoring energy and water use, engaging employees, and adopting advanced technologies, sugarcane mills can achieve and maintain high levels of energy and water efficiency, contributing to sustainability and profitability.



9. Conclusion

These guidelines provide a brief overview of the four target sectors and recommend several interventions to help industry move towards decarbonisation and a greener, sustainable future.

In short:

- The brewery sector should implement energy-efficient brewing processes and equipment, considering the transition to solar, wind, or biomass energy. It should adopt carbon capture technologies for fermentation emissions, improve water-use efficiency and implement advanced wastewater treatment systems.
- The fruit and vegetable sector should upgrade to energy-efficient irrigation systems, refrigeration units, and transportation methods. It should consider installing solar panels or wind turbines, and implement sustainable farming practices such as crop rotation, organic farming, and reduced tillage. It should utilise organic waste for composting or bioenergy production.
- The poultry sector should optimise feed formulations to reduce methane emissions from digestion. It should use anaerobic digestion to convert manure into biogas, and upgrade heating, ventilation, and lighting systems in poultry houses. It should also consider installing solar panels or wind turbines.
- The sugar cane milling sector should increase its utilisation of bagasse for biomass cogeneration. It should optimise milling processes and upgrade to more efficient equipment. In addition, it should incorporate solar and wind energy, and reduce emissions from cane burning and adopt sustainable agricultural practices.

Implementing these recommendations and sharing the lessons learnt with others starting on their green industrial journeys will boost South Africa's national adaptation and mitigation efforts on its own decarbonisation pathway.

Industrial decarbonisation involves phasing out atmospheric greenhouse gas (GHG) emissions from the industrial sector, with a particular focus on carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases.

The *Sustainable Decarbonisation Roadmap for South African Priority Agro-processing Sub-sectors* identifies four main pillars essential for decarbonisation:

- Energy efficiency: Improving energy consumption patterns to minimise waste.
- Industrial electrification: Transitioning to electric power for industrial processes, reducing reliance on fossil fuels.
- Low-carbon fuels, feedstocks, and energy sources: Integrating alternative fuels and renewable sources that minimise carbon emissions.
- Carbon capture, utilisation, and storage: Implementing technologies to capture CO₂ emissions produced during industrial processes and utilise or store them to prevent atmospheric release.

Decarbonisation is not just an environmental imperative but a strategic necessity for South Africa's agro-processing and broader industrial sectors. As global markets increasingly prioritise low-carbon products, industries that proactively reduce their carbon footprints will gain significant competitive advantages, including enhanced market access, improved brand reputation, and compliance with international regulations. The transition to cleaner technologies, renewable energy, and more efficient processes presents an opportunity for South Africa to not only mitigate its environmental impact but also drive economic growth, job creation, and energy security.



The roadmap recommends a phased approach to decarbonisation:



South Africa's Decarbonisation Intervention Framework is designed to help prioritise actions for reducing carbon emissions within the agro-processing sub-sectors. This framework builds on foundational methodologies and aims to facilitate the implementation of effective decarbonisation strategies. The framework provides a clear pathway for prioritising interventions based on financial returns, emission reductions, and feasibility. This structured approach ensures that industries can make informed decisions, allocate resources effectively, and achieve meaningful progress towards their decarbonisation targets.

As South Africa navigates its transition to a low-carbon economy, collaboration between industry stakeholders, government, and the private sector will be crucial. Strong policies, financial incentives, and a commitment to innovation will drive the necessary changes.

By embracing decarbonisation, South African industries can not only safeguard their future but also position themselves as leaders in the global shift towards sustainability. This transition is not without challenges, but the rewards of a cleaner, more resilient economy far outweigh the costs, making decarbonisation a vital and urgent priority.

Get in touch – get involved

UNIDO South Africa

Mr Mchenge Nyoka

National SAIA Project Coordinator

m.nyoka@unido.org

Ms Petro de Wet

Senior Stakeholder Engagements Expert

p.dewet@unido.org

UNIDO HQ Vienna

Ms Karin Reiss-Haimbala

Project Manager

k.reiss@unido.org

 www.saia-project.co.za

