Touching lives through innovation

Briefing Note 2021/007

November 2021

Decoupling South Africa's development from *energy* demand through a more circular economy

Circular Economy Briefing Note No. 7 in a series of 8

The intention of this short think piece on the circular economy in energy, is to initiate discussion on the sector opportunities for South Africa. These opportunities are framed within the context of the current challenges facing the South African energy sector.

"*Companies that traditionally have been heavily focused on hydrocarbons are using circularity principles as a basis for major strategic shifts in response to decarbonisation*." (PwC, 2020)

Xolile Msimanga, Linda Godfrey and Brian North

CSIR
PO Box 395
Pretoria, 0001
Tel: +27 12 841 7257
Email: *xmsimanga@csir.co.za*

CSIR Opinion Pieces and Briefing Notes provide perspectives on current science, technology and innovation developments, and related policy topics.

Introduction

The South African energy sector is a resource intensive sector characterised by high levels of inefficiency. An estimated 71% of South Africa's primary energy consumption comes from the burning of coal[1], with 2% of South Africa's water directed to energy generation[2] (*See CSIR Water Briefing Note*). The sector is also a highly linear, wasteful one, generating large quantities of gaseous, liquid, and solid waste[3,4]. Fly ash and bottom ash from the electricity and petroleum sectors, were the largest hazardous waste streams generated in South Africa in 2017, making up 75% of total hazardous waste generation[4]. Eskom's 14 coal-fired power stations consumed 116 Mt of coal in 2017, producing 202,106 GWh of power and 32 Mt of ash – an average of 156 T of waste ash for every GWh of power produced[4]. This is compounded by high transmission and distribution losses, with approximately 20% of total primary energy entering the system lost due to power generation processes[5]. The energy sector is also the largest contributor to national GHG emissions (80% in 2017) (excl. Forestry and Other Land Uses) and was responsible for 97% of the GHG increase over the period 2000-2017[6]. In 2020, CO_2 emissions were the 12th highest in the world, accounting for 1.3% of total global emissions[1].

South Africa has experienced constraints on its electricity system since 2008, resulting in ongoing loadshedding. Electricity supply problems have placed severe pressure on South Africa's economic growth sectors, particularly manufacturing and human settlements (*See CSIR Manufacturing and Human Settlements Briefing Notes*). Facing growing energy insecurity, South Africa's high reliance on fossil fuels for energy and the resulting waste, provides the perfect impetus for transitioning to a circular energy system[7] (Figure 1).

When applied to the energy sector, the circular economy principles – eliminating waste and pollution; closing resource loops; and regenerating natural systems – provide a framework for South Africa to address energy security[7, 8, 9]:

- **Design out waste**, e.g., energy efficiency (demand management), waste and emissions prevention, reducing materials-use in manufacturing energy technologies, increasing energy technology lifespans
- **Keep materials in use**, e.g., waste gas and heat valorisation; carbon capture use and storage (CCUS); repair and recycling of energy technologies (repurposing), waste-to-energy; fly-ash to building materials;
- **Regenerate natural systems**, e.g., renewable energy (RE), green hydrogen

Applying these circular economy principles within the South African energy sector – both in the manufacturing of energy technologies as well as in energy utility – creates opportunities for more efficient and sustainable use of resources in transitioning to a low-carbon economy. It creates opportunities for decoupling economic activity from the consumption of energy, reducing costs, driving greater competitiveness, unlocking new business opportunities, and building resilience to local and global shocks.

The implementation of a circular economy strategy within the energy sector, also creates opportunities for decarbonising a range of sectors, including agriculture, manufacturing, mobility, and human settlements (*see corresponding CSIR Briefing Notes*). As South Africa works towards a just energy transition, away from fossil fuels to cleaner energy, the circular economy provides the opportunity for greater inclusion of social dimensions by identifying socio-economic opportunities[10].

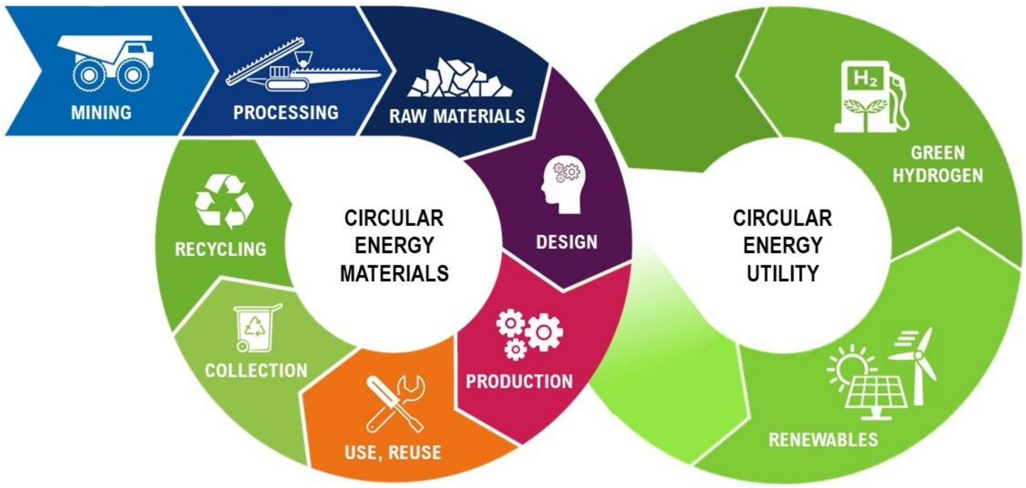

Figure 1. Circular materials and energy systems (adapted from EIT, 2018; PwC[9])

The current state of energy in South Africa

The South African energy sector is heavily reliant on fossil fuels (95% of primary energy consumption)[1]. This dependence has resulted in South Africa being one of the most carbon intensive countries in the world. In 2020, coal accounted for 71% of South Africa's primary energy consumption, followed by oil (21%), nuclear and renewable energy (5%), and natural gas (3%)[1]. The industrial sector is responsible for most of the final energy demand (52%), followed by transport (19%) (Figure 2)[11]. In terms of human settlements, the percentage of electrified households in South Africa was 85% in 2019[12].

South Africa's power utility, Eskom, is facing operational challenges due to its' ageing coal fleet (average age ~39 years) and the declining energy availability factor, and has had to intermittently implement rotational load shedding to meet demand. Despite this, South Africa has only progressed to ~10% installed renewable electricity as at 2020[13].

After the power sector, the South African transport sector is the most important to decarbonise as it is primarily dominated by internal combustion engine vehicles which rely on petroleum fuels for mobility. From an economic value perspective, the liquid fuels industry contributed R139 billion to GDP in 2019[14].

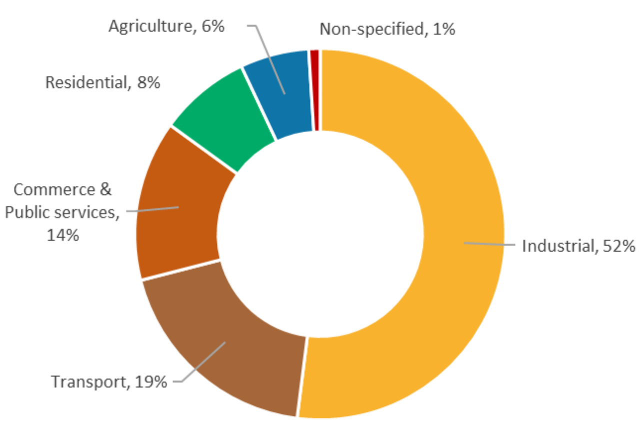

Figure 2. Energy demand in South Africa (DoE, 2019[11])

Due to the lack of exploitable oil resources, South Africa relies on imports for 95% of its' crude oil, most of which is processed at its refineries to produce liquid fuels[11]. Decarbonising the transport sector will require a shift to circular mobility solutions, including greater mobility sharing, while reduced personal mobility will shift to electric vehicles supported through renewable energy (*See CSIR Mobility Briefing Note*). This will also benefit South Africa's balance of trade, by reducing oil import demands. A transition from combustion engine vehicles to electric vehicles, without broader circular mobility solutions, will simply result in increased demand on the power sector[15].

The vision for the South Africa energy sector is clearly outlined in an array of national policies. These include the NDP 2030, which calls for a transition to an environmentally sustainable, climate resilient, low-carbon and just society. This is supported by the National Climate Change Response White paper 2014. Several flagship programmes outlined in the White Paper support a circular economy transition. These include the Renewable Energy Programme; Energy Efficiency and Energy Demand Management Programme; and the Carbon Capture Storage and Use Programme[16]. In addition, South Africa has made official global commitments to decarbonization through the Paris Agreement (2015) under the UNFCCC. Most of the emission reductions will come from the energy sector, mainly the power sector – as the most carbon intensive and most affordable to mitigate considering the declining renewable energy costs[17]. In November 2021, at COP26, South Africa joined France, Germany, UK, US, and the EU in announcing a partnership to support a just transition to a low carbon economy and a climate resilient society. This will be supported by a commitment of USD131 billion to be mobilized over 5 years[18].

The Integrated Resource Plan (IRP) made allowance for renewable energy capacity additions of 17.8 GW by 2030, which paved the way for the establishment of the Renewable Energy Independent Power Producer Procurement Programme (REI4P). The Integrated Energy Plan (IEP), which aims to guide future energy infrastructure investments and policy, is anchored in the National Energy Act, 2008[19].

Circular economy opportunities in energy

While much of the focus of a circular energy transition has been on renewables, there are considerable opportunities in energy efficiency and energy productivity; and in the manufacturing and decommissioning of energy technologies. Possible circular economy opportunities in the energy sector are briefly highlighted here, aligned with the circular economy principles:

1. Circular economy for energy materials

As highlighted in the CSIR's mining sector response to a circular economy (*See CSIR Mining Briefing Note*), the uptake of renewable energy technologies and the transition to a low-carbon economy, as called for in the NDP 2030, will require more (and different) minerals and metals, with ever larger material footprints. While this resource demand has the potential to unlock new growth areas for the South African mining sector, it also has the potential to erode national resource security, with widespread environmental impacts. It is therefore important that the principles of a circular economy are applied to the sustainable use of resources – including critical raw materials – in the development and deployment of clean energy technologies, including battery technologies, in South Africa (Figure 1). This includes –

- Improved design of energy technologies to ensure greater repair, refurbishment, or recycling at end-of-life
- Designing energy technology manufacturing processes with reduced material and energy use
- Increasing energy technology lifetimes (greater resource productivity)

2. Circular economy in energy generation and use

Design out waste and pollution

The National Energy Efficiency Strategy was gazetted in 2005 and set an economy wide reduction target in energy intensity of 12% by 2015. The target was achieved and exceeded, reaching 23.7% by 2012. Programmes such as the Industrial Energy Efficiency Programme, funded by GEF and implemented by NCPC-SA in partnership with UNIDO has since 2011, assisted more than 450 industries to save 6.5 TWh of energy, resulting in cumulative cost savings of R5.3 billion. Energy efficiency projects have also extended into the building industry, with new building installations of solar panels, LED lighting, motion sensing automated lighting; and centralised heating and cooling. There is an opportunity for new infrastructure development to make use of low-carbon, high-thermal efficient building materials to reduce energy demand in the built environment. (*See CSIR Human Settlements Briefing Note*). The wind energy sector has the potential to increase resource efficiency by narrowing loops in the design and manufacturing of rare earth magnets[21].

Keep products and materials in use

Waste materials provide the opportunity to generate energy, through various waste-to-energy technology solutions, including low temperature landfill gas recovery; and bio-energy generation from organic and biomass waste streams. eThekwini Municipality's waste-to-electricity landfill gas project, a CDM project, had avoided 2.5 $MTCO_2$ equivalent emissions as at 2017[22]. An increased focus has been placed on diverting organic waste from landfills through composting and energy recovery through the production of biogas[23]. DRAX power station, the largest and most efficient coal-fired power station, based in the UK, converted half of its units to run on biomass. By deploying bioenergy with carbon capture and storage (BECCS), Drax will have minimal emissions. SAPPI has a 25MW biomass power plant in Mpumalanga which uses the biomass waste from its production processes to produce electricity, they could close the loop through CCUS technology. Biorefinery of various organic waste streams, creates opportunities to recover high-value resources. The concept is already being applied in the pulp and paper, and sugar sectors in South Africa. Biomass, or captured "unavoidable" CO_2, can also be used as the carbon source in the production of synthetic liquid and gaseous fuels and chemicals. The destruction of resources through high-temperature processes such as incineration, pyrolysis, gasification, while potentially generating energy is typically considered to fall outside of the circular economy, due to the loss of resources through burning.

Fly ash from the burning of coal is used in the production of aluminosilicate-based cement replacement geopolymers, with some South African companies already doing this[24]. Waste heat recovery systems are used by companies to recycle the waste heat from its' processes back to produce electricity. Anglo Platinum established a project to produce 5MW of electricity from its Waterval smelter complex in Rustenburg, which was to feed 4.3 MW power back to the grid[25]. Battery energy storage systems (BESS), solar panels, and wind turbines will all require sustainable end-of-engineered life solutions to recover valuable resources.

Although South Africa is undergoing an energy transition, fossil fuels may still be a part of its' future for the foreseeable future – considering government has highlighted the importance of developing CCUS technology to minimise the impact from harmful CO_2 emissions. This was supported by the establishment of the South African Centre for Carbon Capture and Storage (SACCCS), a division of the Council for Geoscience. The DMRE sees CCUS technology as one of the avenues for continuing to take advantage of coal. In 2019, the government launched the Coal CO_2-to-X programme, which focuses on the production of green chemicals such as green ammonia and green hydrogen from flue gas[26].

Regenerate natural systems

The REI4P was introduced in 2011 as the official procurement mechanism for renewable energy in South Africa. The programme managed to procure 6,327 GW of renewable energy through four bidding rounds. The IRP released in 2019 makes provision for 14,4 GW of wind power and 6 GW of solar PV power by 2030[27], resulting in an ambition for an additional 20,4 GW of renewable energy by 2030. This will result in the share of installed renewable energy increasing to ~33%. It also makes allowance for the decommissioning of several Eskom coal power stations equalling 11.7 GW by 2030. In 2021, the DMRE announced that the threshold on embedded generation without licensing requirements would be increased to 100MW[28]. Effectively, allowing private power generation power purchase agreements (PPAs) for larger facilities from renewable energy resources. Eskom plans to repurpose decommissioned coal-fired power plants using renewable energy, battery storage, gas conversion and agri-voltaics – the symbiotic use of solar energy and crops, resulting in energy for agricultural processes and reduced water consumption[29]. A pilot is already underway, and the plan is to start repurposing Komati Power Station in 2022 once it is fully decommissioned. Other repurposing options could be establishing green manufacturing facilities at the power plant sites to supply renewable energy components.

"*Green hydrogen could play a pivotal role in a sector-coupled circular economy, offering a solution for decarbonising a range of sectors, including transportation, heating, chemicals, and iron and steel*."[9]. Green hydrogen production is a major component of the government's strategy to decarbonise. The development of the hydrogen economy increases the business case for renewable energy. Establishing electric vehicle (EV) infrastructure and increasing penetration, complimented by electricity sourced from renewable energy resources instead of fossil fuel-based energy, provides an opportunity for green mobility (*See CSIR Mobility Briefing Note*). Conversion of trucks to EV fuel cell technology will reduce consumption of diesel significantly and establish further demand for hydrogen. Furthermore, biofuels and synthetic green fuels can also be pursued. Sustainable aviation fuel is being explored to further reduce the emissions from the transport sector.

Solar PV and wind mini-grids in unelectrified communities reduces the use of burning charcoal, wood and other substances for cooking, heating and lighting. It also has the potential to create new businesses and jobs in communities, especially if the model gives them some form of ownership of the mini-grids.

The principles of a circular economy are not new to the South African energy sector. Many activities are underway to transition the sector. However, given the magnitude of the impact of the South African energy sector, and the current high levels of energy insecurity which negatively impact on all sectors, this is a sector that does not have the luxury of time to achieve scale and impact of circular energy interventions.

Conclusion

The legacy of the energy sector in South Africa has gone against the principles of a circular economy and remains highly resource intensive and wasteful, with a continued overreliance on fossil fuels. However, there have been several projects and ongoing efforts to reduce this wastage and recycle waste for alternative energy use or high-value product recovery. Furthermore, energy efficiency has been prioritized to reduce energy consumption, while reducing GHG emissions. As South Africa grapples with securing energy, it must decarbonize simultaneously. Energy is required in all economic sectors and circular economy solutions in this sector positively impacts other sectors e.g., a more sustainable and globally competitive manufacturing sector; improved transportation and living conditions for all citizens. Undoubtedly, as South Africa embarks on the energy transition, the circular economy also provides the opportunity for positive socio-economic impacts such as improved health and job creation. The energy sector has a long way to go to achieve circularity, however the actions that are being taken and promoted by government and industry signal a need to achieve greater resource-security in support of socio-economic development, through sustainable resource utilisation.

Acknowledgements: The authors acknowledge the funding from the Department of Science and Innovation through the CSIR's Parliamentary Grant.

References

1. BP (2021). BP statistical review of world energy 2021 [online]
2. DWS (2017). Strategic overview of the water sector in South Africa [online]
3. Von Blottnitz, *et al.* (2021). Challenging but promising: South Africa's transition towards a circular economy [online]
4. DEA (2018). South Africa State of Waste [online]
5. IEA (2020). IEA Sankey. International Energy Agency [online]
6. DFFE (2021). 7th National Greenhouse Gas Inventory [online]
7. Korhonen, J., *et al*. (2018). Circular economy: The concept and its limitations. *Ecol. Econ*., 143, 37-46. [online]
8. EMF, 2017. Towards the Circular Economy vol 1. [online]
9. PwC (2020). Taking on tomorrow: The rise of circularity in energy, utilities and resources [online]
10. Mutezo, G. & Mulopo, J. (2021). A review of Africa's transition from fossil fuels to renewable energy using circular economy principles. *Renew. Sustain. Energy Rev*., 137, 110609. [online]
11. DoE (2019). The South Africa Energy Sector Report [online]
12. StatsSA (2020). General Household Survey (GHS)
13. Eskom (2021). Eskom integrated report 2021 [online]
14. SAPIA (2021. The economic contribution of the downstream oil industry to South Africa in 2019 [online]
15. Mikulčić, H., *et al.* (2021). Energy transition and the role of system integration of the energy, water and environmental systems. *J. Clean. Prod*., 126027. [online]
16. DEA (2014). National Climate Change Response White Paper [online]
17. Steyn, G., *et al*. (2021. The Just Transition Transaction: A Developing Country Coal Power Retirement Mechanism [online]
18. Presidency. (2021). Presidency on international partnership to support a just transition to a low carbon economy and a climate resilient society. [online]
19. DoE. (2016). Integrated Energy Plan. [online]
20. DoE (2016). Draft Post-2015 National Energy Efficiency Strategy [online]
21. The Danish Environmental Protection Agency. (2018). Designing out waste. [online]
22. UNEP (2018). Green warriors in Durban convert trash to treasure [online]
23. GreenCape (2021). Waste Market Intelligence Report [online]
24. Veolia (2018). Poland: Coal ash is greening cement! #LivingCircular [online]
25. Anglo American (2015). Anglo Platinum opens a clean energy power plant, Eternity Power Anglo American [online]
26. Maserumule, R. (2020). Overview of the energy RDI programme / strategy to leverage funds for demonstration. [online]
27. DMRE (2019). Integrated Resource Plan 2019 [online]
28. DMRE. (2021). Mineral resources and energy on amended schedule 2 of Electricity Regulation Act 4 of 2006. [online]
29. OSU (2021). Sustainable farm agrivoltaic. Oregon State University [online]