Climate Change Mitigation at City Level through the Lens of South Africa's Regulatory Framework for Bioenergy

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Abstract

Climate change is one of the most significant challenges of the 21st century. To combat climate change the international community has agreed to keep the average temperature increase well below 2°C above pre-industrial levels. Despite this consideration, the latest scientific evidence suggests that the planet has already warmed by 1.1°C above pre-industrial levels. The slow reaction by national governments to reducing greenhouse gas emissions has prompted cities to take ownership of climate change mitigation action and drive global intervention from the sub-national level. These urban areas are home to more than half of the world's population and have immense energy requirements, and typically rely heavily on fossil fuels to meet this demand. Therefore, a shift to city level climate governance is significant as cities are both the victims and the culprits of climate change. Should cities supplant fossil fuels with renewable energy initiatives in meeting their energy demands, this would provide a significant boost to climate change mitigation efforts. Bioenergy as a form of renewable energy can potentially contribute to the energy mix in cities through biomass exploitation while simultaneously addressing climate change mitigation efforts. This article focusses on the role of bioenergy in the energy discourse in cities and the potential of law and policy to contribute to developing these biomass-based systems. The article provides insight into the South African bioenergy regulatory framework from an energy and climate change perspective and offers an account of what bioenergy can contribute to cities when considering the transition to a low-carbon economy.

Keywords

Climate change; mitigation; renewable energy; modern bioenergy; traditional bioenergy, city level governance; regulatory framework.

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1 Introduction

Climate change is one of the most pressing challenges of the 21st century.[1] The atmospheric anomaly is caused by the inability of the earth's system functions to self-regulate due to the copious amounts of greenhouse gas (GHG) emitted into the atmosphere from anthropogenic activities.[2] To address climate change and curb GHG emissions, the international community has adopted various instruments under the auspices of the *United Nations Framework Convention on Climate Change* (1992) (UNFCCC).[3] The climate regime requires *inter alia* mitigation action through human intervention to limit and reduce emissions at the source and to enhance and preserve GHG reservoirs and sinks.[4] Moreover, it has been agreed under the regime that the average temperature increase must remain well below 2 degrees Celsius (°C) above pre-industrial levels to prevent setting humanity on a pathway toward irreversible and catastrophic conditions.[5] Nevertheless, despite the global consensus, the latest scientific evidence suggests that the planet has already warmed by 1.1°C above pre-industrial levels and will continue to do so unless countries drastically reduce these emissions.[6]

The slow reaction by national governments has prompted cities to take ownership of mitigation action and help drive global intervention from a subnational level.[7] This gradual shift to city level climate governance is significant as cities are both the victims and the culprits of climate change.[8] These urban centres account for a significant portion of global GHG emissions, as they are home to more than half the world's population.[9] Thus, the energy requirements of urban areas are intensive, with many relying

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1 Rauland and Newman *Decarbonising Cities* 1.
2 Johnson *Power of Cities* 35.
3 Kuh "International Climate Change Treaty Regime" 6.
4 Maguire "Foundations of International Climate Law" 84.
5 Rodas "City Diplomacy" 311.
6 Umbers "Sub-National Climate Duties" 29; IPCC 2021 https://www.ipcc.ch/site/assets/uploads/2021/08/IPCC_WGI-AR6-Press-Release_en.pdf.
7 Hughes *Repowering Cities* 1; Du Plessis "SDG 11" 294. Across the globe, cities have adopted robust climate policies, joined transnational city networks and committed to emission reduction targets to help make their voices heard on the international stage.
8 Jones *Cities Responding to Climate Change* 29.
9 Lin *Governing Climate Change* 152.

heavily on fossil fuels to meet this energy demand.[10] South African cities are no exception, but they are faced with the dual problem of a carbon-intensive energy sector contributing to climate change on the one hand and a lack of electricity hindering development on the other.[11]

In this respect, the state-owned enterprise Eskom produces approximately 95% of South Africa's electricity, with around 85% of electricity needs coming from coal-fired power stations.[12] These power stations contribute to the GHG being emitted into the atmosphere, further destabilising the climate system.[13] The current approach to energy production in South Africa is ecologically and socially unsustainable and requires reformation in order to mitigate the country's contribution to changes in the global climate.[14] The challenges posed by climate change cannot be addressed without bearing the energy sector in mind, as these two concerns are inextricably linked.[15] It is worth noting that South Africa's energy sector is amid a severe electricity crisis, resulting in widespread power outages throughout the country.

The term load shedding has become part of the daily lives of South African citizens since its inception over 16 years ago.[16] The constant power outages have disrupted businesses, causing financial losses and impeding economic growth.[17] According to estimates the South African economy is projected to suffer a staggering loss of R900 million per day for every instance of load shedding in 2023.[18] The electricity issue is not only a financial burden but also a social one, as it severely impacts households, with many struggling to keep their homes lit and warm during the outages.[19] The lack of reliable electricity has widened the gap between the rich and

10 Rauland and Newman *Decarbonising Cities* 21.
11 Lawrence *South Africa's Energy Transition* 22.
12 Pollet, Staffell and Adamson *Energy Landscape* 17; International Trade Administration 2021 https://bit.ly/3EI59Gc.
13 Lin *Governing Climate Change* 14.
14 Lawrence *South Africa's Energy Transition* 4.
15 Rauland and Newman *Decarbonising Cities* 1.
16 Grootes 2019 https://www.dailymaverick.co.za/article/2019-12-09-twelve-years-of-load-shedding-written-starring-directed-by-the-anc/.
17 Staff Writer 2023 https://businesstech.co.za/news/property/671281/new-data-shows-how-load-shedding-is-tearing-through-businesses-in-south-africa/.
18 Lawrence 2020 *Renewable and Sustainable Energy Reviews* 1; Staff Writer 2023 https://businesstech.co.za/news/property/671281/new-data-shows-how-load-shedding-is-tearing-through-businesses-in-south-africa/.
19 Ramreddi 2023 https://theafrican.co.za/featured/load-shedding-violates-rights-of-vulnerable-communities-d6346e5f-f2d2-46ef-a147-d38870c72a54/; Dube and Moyo 2022 *PELJ* 16.

poor, with those living in poverty being hit the hardest.[20] In addition, the inability to access electricity has hindered the development and well-being of communities, making it difficult for them to access essential services such as healthcare.[21]

The current energy crisis in South Africa could help fast-track the move towards renewable energy alternatives as cities are poised to benefit from transitioning away from fossil fuels.[22] There is a clear nexus between climate change and the need to redirect the energy consumption pathways in urban areas toward more sustainable practices.[23] Consequently, replacing fossil fuels with renewable energy alternatives could reduce cities' carbon footprint while contributing to climate change mitigation efforts and nurturing local development aspirations.[24] As a form of renewable energy, bioenergy has the potential to step into this role and contribute to the energy mix of urban areas by harnessing the power of biomass.[25]

This article's objectives focus on the role of bioenergy in the climate change and energy discourse in cities and the potential of law and policy to contribute towards developing these biomass-based systems. Accordingly, the article explores bioenergy as a renewable energy resource, highlighting modern and traditional bioenergy systems and how these technologies can contribute to climate change mitigation. The discussion further provides insight into the South African bioenergy regulatory framework from an energy and climate change perspective, whereafter, the article offers an account of what bioenergy can contribute to South African cities when considering the transition to a low-carbon economy. Finally, the article concludes with brief recommendations and an overview.

2 Biomass as renewable energy and a climate change mitigation driver for cities

For millennia the biosphere has provided humankind with a tremendous amount of accumulated energy for heating and cooking, and as our society developed, so did our energy resources.[26] However, many people living in developing countries such as South Africa still heavily rely on organic matter

20 Mutsaa and Mangara 2023 https://inclusivecities.ukzn.ac.za/blog/tri-fold-impact-of-load-shedding-in-south-african-cities-power-outage-destruction-and-regression/.
21 Laher *et al* 2019 *South African Medical Journal* 899.
22 Pretorius and Blaauw "Residents' Perceptions of Coal Mining and Energy Generation" 140.
23 Creutzig *et al* 2015 *Proceedings of the National Academy of Sciences* 6283.
24 Papacostantis 2017 *CILSA* 278.
25 Maguire "Foundations of International Climate Law" 84.
26 Kurchania "Biomass Energy" 91.

to satisfy their daily energy needs.[27] This consideration is troublesome as the global population trajectory indicates that around 90% of anticipated growth will occur in these countries.[28] Therefore, insight into the opportunities and challenges of bioenergy is essential for meeting the energy demands of a rapidly expanding population.

The process of converting biomass into energy can occur through either modern or traditional methods, with these two broad categories each offering distinct aspects to consider.[29] On this point, modern bioenergy refers to advanced energy technologies that are utilised in the commercial sector for activities such as electricity generation and the manufacture of biofuels.[30] In contrast, traditional bioenergy refers to technologies used in domestic settings for cooking and heating, typically via low-efficiency conversion methods.[31] These two technologies are two sides of the same coin as they depend exclusively on biomass availability to satisfy energy needs.[32] Conversely, the potential exists for developing both modern and traditional forms of bioenergy to coexist and contribute to the energy mix in developing countries.[33]

2.1 A bird's eye view of modern bioenergy technology

Modern bioenergy production uses feedstocks such as energy crops, weeds, sewage, municipal solid waste, aquatic biomass and other biodegradable industrial residues.[34] These technologies utilise either thermochemical or biochemical processes to release the energy stored in biomass.[35] The thermochemical processes involve heat to break down the biomass through, for example, combustion, gasification or pyrolysis to release its energy.[36] In turn, biochemical processes use microorganisms to break down biomass and convert it into more suitable energy carriers, such

27 Rose *et al* 2014 *Climatic Change* 478; Karekezi, Lata and Coelho "Traditional Biomass Energy" 231.
28 Souza *et al* 2017 *Environmental Development* 57.
29 IRENA 2022 https://www.irena.org/Energy-Transition/Technology/Bioenergy-and-biofuels.
30 Stafford and Brent 2011 *Renewable Energy Law and Policy Review* 205; Goldemberg and Coelho 2004 *Energy Policy* 711. Although modern bioenergy technologies can be downscaled to the residential level with for example the use of smaller digesters for biogas production.
31 Goldemberg and Coelho 2004 *Energy Policy* 711.
32 Karekezi, Lata and Coelho "Traditional Biomass Energy" 233.
33 Smeets, Johnson and Ballard-Tremeer "Keynote Introduction" 4.
34 Abbasi, Tauseef and Abbasi *Biogas Energy* 4.
35 Ghosh 2016 *Procedia Environmental Sciences* 31.
36 Pande and Bhaskarwar "Biomass Conversion to Energy" 7.

as methane, through a process such as anaerobic digestion.[37] The resultant product can take a liquid, solid or gaseous form depending on the conversion method and characteristics of the biomass used.[38] Thus, the variety of conversion technologies and an extensive array of feedstock options provide flexibility to fit the heterogeneous nature of domestic energy demand.[39]

Some bioenergy initiatives can even create a closed carbon loop depending on the feedstock and technology used.[40] As biomass conversion to energy puts CO_2 into the atmosphere, growing biomass concurrently consumes CO_2 from the atmosphere.[41] This closed carbon loop can be considered carbon-neutral, unlike the production of electricity from fossil fuels, which is carbon positive.[42] This carbon neutrality is an essential aspect of bioenergy initiatives, as using biomass as a fuel source can reduce a city's carbon footprint and mitigate the impacts on the global climate.[43]

Moreover, cities produce their fair share of waste, and traditional disposal methods such as landfills and incineration have proved unsustainable due to their negative impact on the environment and human health.[44] Modern bioenergy technologies, such as the production of biogas and other waste-to-energy methods, can contribute to more sustainable waste management solutions for cities while contributing to the local energy mix.[45] Though not all bioenergy initiatives are created equal, and some may have negative implications, such as producing large-scale monoculture plantations for biofuels which may lead to soil exhaustion, compete with food production and negatively impact on biodiversity.[46] Accordingly, law and policy must guide the development of bioenergy and careful consideration must be given to questions of sustainability.

37 Kurchania "Biomass Energy" 95.
38 Pande and Bhaskarwar "Biomass Conversion to Energy" 8.
39 IEA 2009 http://www.ieabioenergy.com/wp-content/uploads/2013/10/MAIN-REPORT-Bioenergy-a-sustainable-and-reliable-energy-source.-A-review-of-status-and-prospects.pdf 55.
40 Pande and Bhaskarwar "Biomass Conversion to Energy" 3.
41 Pande and Bhaskarwar "Biomass Conversion to Energy" 3.
42 Pande and Bhaskarwar "Biomass Conversion to Energy" 3.
43 IEA Bioenergy 2023 https://www.ieabioenergy.com/iea-publications/faq/woody biomass/carbon-neutrality/.
44 Rasmeni and Madyira 2019 *Procedia Manufacturing* 1025.
45 Rasmeni and Madyira 2019 *Procedia Manufacturing* 1026.
46 Conserve Energy Future 2023 https://www.conserve-energy-future.com/advantages-disadvantages-examples-monoculture.php.

2.2 Traditional bioenergy: a hurdle for climate change mitigation and a sustainable urban future

Traditional bioenergy exploitation is typically the staple for low-income households in the developing world, with approximately 2.6 billion people relying extensively on biomass to satisfy their basic energy needs.[47] It is alarming that around 3.2 million deaths occur globally each year from illnesses associated with exploiting biomass.[48] To elaborate, using biomass resources such as wood, charcoal and animal dung for cooking and heating purposes can lead to indoor air pollution and the emission of harmful pollutants such as carbon monoxide and particulate matter.[49] These pollutants can cause respiratory illnesses, cardiovascular diseases and even cancer.[50] Women and children suffer the brunt of these fatalities as they are typically responsible for household chores and are more readily exposed to these harmful pollutants.[51]

The burning of biomass in these traditional systems emits black carbon aerosol particles into the atmosphere, which has detrimental effects on human health and the environment.[52] This particulate is a complex mixture of carbon and other organic and inorganic compounds and can remain in the atmosphere for from several days to weeks.[53] Black carbon is produced through incomplete combustion, contributing to air pollution and can influence the acceleration of atmospheric warming, thereby exacerbating climate change.[54] It stands to reason that reducing black carbon emissions at the source can reduce the effects of climate change and improve air quality for those reliant on these traditional technologies.

The trend surrounding traditional systems suggests that biomass availability near urban settlements is deteriorating, as indicated by the increased walking distances for biomass collection.[55] The overutilisation of biomass in the urban context will result in social, environmental and economic

47 Masera *et al* 2015 *Annual Review of Environment and Resources* 122.
48 Hivos People Unlimited 2019 https://hivos.org/blog/the-statistics-from-indoor-pollution-deaths-must-not-be-forgotten/.
49 Hivos People Unlimited 2019 https://hivos.org/blog/the-statistics-from-indoor-pollution-deaths-must-not-be-forgotten/.
50 Hivos People Unlimited 2019 https://hivos.org/blog/the-statistics-from-indoor-pollution-deaths-must-not-be-forgotten/.
51 WHO 2022 https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.
52 Smeets, Johnson and Ballard-Tremeer "Keynote Introduction" 6.
53 Shankman 2018 https://insideclimatenews.org/news/19032018/global-warming-arctic-air-pollution-short-lived-climate-pollutants-methane-black-carbon-hfcs-slcp/.
54 Masera *et al* 2015 *Annual Review of Environment and Resources* 137.
55 Sawe "Sustainable Charcoal and Firewood Production" 77.

difficulties for those dependent on these traditional technologies.[56] Nevertheless, despite these negative implications, the absence of alternatives continues to make biomass an essential energy resource for the most vulnerable in our society.[57]

Although developing nations advocate massive electricity roll-outs, it would be unrealistic to suggest immediate implementation as neither the country nor the people could financially cope with such an abrupt transition.[58] Consequently, the exploitation of biomass as a primary energy resource will likely remain prevalent in developing regions like South Africa for the foreseeable future.[59] Despite this consideration, inadequate efforts have been made to address the unsustainable nature of these traditional technologies.[60] To effectively tackle the issue of inadequacy, these concerns must be integrated into bioenergy strategies and policies that drive progression for modern systems and promote sustainability for their traditional counterparts. In this respect, the South African regulatory framework for bioenergy provides insight into these technologies and their potential for urban climate change mitigation in the country.

3 Overview of South Africa's bioenergy regulatory framework

South Africa is blessed with abundant biospheric resources and is poised to benefit from bioenergy as it seeks to transition to a low-carbon economy.[61] The demand for renewable energy is increasing rapidly, and biomass can potentially contribute to the supply as a practical solution in the ongoing energy discussion.[62] The successful implementation of bioenergy requires a supportive regulatory framework to ensure the safe and sustainable advancement of the bioenergy sector.[63] At the same time the government must balance promoting bioenergy developments with climate change considerations, protecting natural resources, and ensuring that bioenergy projects benefit local communities.

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56 Sawe "Sustainable Charcoal and Firewood Production" 76.

57 Amugune et al 2017 https://play.google.com/books/reader?id=CRZQDwAAQBAJ&hl=en&pg=GBS.PP1 1; IEA 2017 http://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf 18; Rose *et al* 2014 *Climatic Change* 478.

58 Sawe "Sustainable Charcoal and Firewood Production" 78.

59 Ramagoma and Adendorff 2016 *Journal of Energy in Southern Africa* 80.

60 Barnard "Access to Bio-Energy" 322.

61 Department of Science and Technology 2016 https://www.dst.gov.za/images/2017/2017_pdfs/Bio-Energy-Atlas_DevV15.pdf 16.

62 Akinbami, Oke and Bodunrin 2021 *Alexandria Engineering Journal* 5081.

63 Akinbami, Oke and Bodunrin 2021 *Alexandria Engineering Journal* 5083.

3.1 Energy law and policy

The bioenergy regulatory framework encompasses energy and climate considerations, and thus the ensuing discussion considers these aspects.[64] Understanding the interplay between energy and climate change is imperative as this framework aims to balance the need for sustainable energy sources and environmental impact. As such, it is essential to delve deeper into the intricacies of the regulatory framework to appreciate what bioenergy can offer city level climate governance.

3.1.1 Energy White Paper

In the wake of the country's constitutional democracy, the Energy White Paper, 1998 marked the first comprehensive energy policy document to be drafted.[65] The document outlines the developmental energy aspirations of the country and provides objectives *inter alia* to increase access, decrease cost and improve energy governance.[66] Although the Energy White Paper emphasises the utilisation of coal for the foreseeable future, the document does recognise the importance of enhancing energy security through renewable energy initiatives.[67] Traditional and modern bioenergy forms are explicitly mentioned in the document to contribute to achieving the country's energy demands.[68] Consequently, bioenergy has been on South Africa's energy policy radar for the past two decades as a potential contributor to the country's energy security.

3.1.2 White Paper on Renewable Energy

Building on the foundation outlined in the Energy White Paper, the government promulgated the White Paper on Renewable Energy, 2004 (RE White Paper).[69] The document acknowledges the urgent need to transition towards sustainable energy resources as a mitigation strategy and security measure for the country's energy mix.[70] Despite the government not achieving the RE White Paper's renewable energy targets, the document identified biomass as a primary energy resource for electrification and non-

64 While the regulatory framework discussed below is not exhaustive, it provides a comprehensive overview of the key laws and policies governing bioenergy in the South African context.

65 Barnard 2012 *PELJ* 224; GN 3007 in GG 19606 of 17 December 1998 (Energy White Paper).

66 Energy White Paper 8.

67 Moyo *Role of the South African Renewable Energy Legal Framework* 39.

68 Energy White Paper 2, 80.

69 GN 513 in GG 26169 of 14 May 2004 (RE White Paper).

70 Murombo "South Africa's Energy Mix" 11.

electrification projects.[71] Moreover, the RE White Paper highlights how crucial ensuring increased efficiency for traditional bioenergy technologies is for achieving the policy's objectives.[72] The document reiterated the *status quo* of bioenergy in the South African energy policy regime with its potential for the electricity sector and as a fuel source in urban settings.

3.1.3 The National Energy Act

The *National Energy Act* 34 of 2008 (NEA) was enacted to strengthen the position of the abovementioned policies.[73] The Preamble of the NEA stipulates that increased production and the use of renewable energy at affordable prices would contribute significantly to poverty alleviation and sustainable development in the Republic.[74] The document acknowledges the harmful impacts of fossil fuels but is silent on the adverse effects of climate change from energy sector activities.[75] Furthermore, the NEA fails to provide specific timelines or targets and is a missed opportunity to legislatively position renewable energy resources at the forefront of South Africa's energy mix.[76] Nevertheless, despite these shortcomings, the document provides the legal foundation upon which South Africa's renewable intentions are formulated and defines renewable energy as energy generated from non-depleting resources, including *inter alia* biomass.[77] The acknowledgement of bioenergy in this legislative document further spurs its legitimacy as a viable alternative to fossil fuels.

3.1.4 The Electricity Regulation Act and the Integrated Resource Plan

The South African energy blueprint for creating a sustainable domestic energy mix was published under the auspices of the *Electricity Regulation Act* 4 of 2006 (ERA) and attempted to forecast the country's energy demand between 2010 and 2030.[78] The Integrated Resource Plan, 2011 (IRP 2010-2030) addresses various energy scenarios and a multitude of emission reduction trajectories.[79] The document supports the notion that a diversified

71 Du Plessis and Murombo "Energy" 19; Lehmann "South Africa's Climate Change Commitments" 18; RE White Paper 25.
72 RE White Paper 12.
73 Klees *Electricity Law* 12.
74 Barnard 2012 *PELJ* 228.
75 Murombo "South Africa's Energy Mix" 19.
76 Moyo *Role of the South African Renewable Energy Legal Framework* 59.
77 Section 1 of the *National Energy Act* 34 of 2008 (NEA); Murombo "South Africa's Energy Mix" 20.
78 The Integrated Resource Plan was originally gazetted in 2009 and later withdrawn and replaced in GN 25 in GG 32898 of 29 January 2010, which was subsequently overtaken by the IRP 2010-2030 gazetted in 2011.
79 Department of Energy 2011 https://www.energy.gov.za/IRP/irp%20files/IRP2010_2030_Final_Report_20110325.pdf (IRP 2010-2030) 6.

energy mix will reduce the inherent risks associated with expanding the national power-supply system.[80]

However, the document's vision still identifies fossil fuel utilisation, particularly coal, as indispensable to satisfy the nation's energy needs.[81] The document placed renewables such as bioenergy on the fringes of the energy mix, where they are seen as supplementary fuel sources.[82] The IRP 2010-2030 acknowledges bioenergy as a viable technology option but specifies the implementation of only minor electricity generation projects by 2030 of around 63 megawatts.[83] The document suggests that further investigation into bioenergy should be conducted as part of the research agenda for future IRPs.[84]

The IRP is a living plan and necessitates that the Department of Mineral Resources and Energy regularly revise the plan to accommodate varying energy conditions.[85] Several iterations of the IRP have followed, all of which refer to the viability and incorporation of bioenergy into the South African energy mix, setting forth anticipated generation capacity in the process.[86] The most recent version to be gazetted is the Integrated Resource Plan, 2019 (IRP 2019).[87] Keeping pace with previous adaptations, the IRP 2019 emphasises the potential and flexibility bioenergy offers to the South African energy mix through projects ranging from small (kilowatt) to large (megawatt) installations.[88] Additionally, the document identifies the nexus between biomass and biofuels for job creation in rural and urban centres and the potential for increasing municipal revenue streams through biogas projects.[89] Although the generation capacity is modest compared to other renewables, such as solar and wind, the inclusion has kept bioenergy in contention in the energy dialogue.

3.1.5 National Development Plan

A further key policy consideration that underpins the development aspirations of South Africa is the National Development Plan 2010-2030

80 IRP 2010-2030 17.
81 Murombo 2016 *Journal of World Energy Law and Business* 162.
82 Kidd and Couzens "Climate Change Responses in South Africa" 637.
83 Department of Science and Technology 2016 https://www.dst.gov.za/images/2017/2017_pdfs/Bio-Energy-Atlas_DevV15.pdf.
84 IRP 2010-2030 22.
85 Klees *Electricity Law* 31.
86 Department of Energy 2018 http://www.energy.gov.za/IRP/irp-2016.html; GN 897 in GG 41865 of 27 August 2018.
87 GN 1360 in GG 42784 of 18 October 2019 (IRP 2019).
88 IRP 2019 13.
89 IRP 2019 14.

(NDP). The NDP aims to promote sustainable development while eliminating poverty and reducing inequality.[90] The document considers environmental concerns, especially regarding resource exploitation and energy generation.[91] While the NDP places coal at the centre of the country's energy system for the foreseeable future, the document promotes renewable energy utilisation.[92] The plan does not specify how the proportion of renewable energy will be allocated, but considering the common policy position, it is likely to include bioenergy technologies.[93] The NDP links renewable developments with the IRP, determining that South Africa should have significantly transitioned to a low-carbon economy by 2030, which is unlikely considering the current state of electricity in the country.

3.2 Environmental law and climate policy

Within this framework, the considerations outlined above shed light on the complex bioenergy narrative in South Africa's energy sector and emphasise its nuanced position in this discourse. The discussion to follow delves deeper into the environmental aspects of the framework and provides valuable insight into the country's position on climate change. South Africa's mitigation efforts must be geared towards a low-carbon energy future. However, it is essential to ensure that clean energy technologies like bioenergy are sustainable and do not exacerbate existing environmental problems.

3.2.1 Constitution of the Republic of South Africa

The energy debate cannot be separated from climate change concerns, as these aspects are inherently intertwined. The South African bioenergy regulatory framework should thus consider the impact of energy use on the environment. In this respect, section 24 of the *Constitution of the Republic of South Africa*, 1996 (the Constitution) provides that everyone has the right to an environment that is not harmful to their health and well-being.[94] The section further stipulates that the government is tasked with taking reasonable legislative measures to ensure environmental protection and sustainable development.[95] Accordingly, the transition from fossil fuels to

90 Klees *Electricity Law* 31.
91 Du Plessis and Murombo "Energy" 2; Papacostantis 2017 *CILSA* 298.
92 National Planning Commission *National Development Plan, 2030* (NDP) 163.
93 Moyo *Role of the South African Renewable Energy Legal Framework* 6.
94 Section 24(a) of the *Constitution of the Republic of South Africa*, 1996 (the Constitution).
95 Section 24(b) of the Constitution.

renewable energy is a significant step toward safeguarding this right, and bioenergy has the potential to contribute to this transition.[96]

3.2.2 National Environmental Management Act

The *National Environmental Management Act* 107 of 1998 (NEMA) was established to give effect to section 24 of the Constitution and provides a legislative framework for environmental sustainability.[97] The NEMA is further supported by subsidiary sector-based environmental laws to offer specific legislative protection to issues such as waste, biodiversity and air quality.[98] The protection of citizens' fundamental environmental rights is ensured through a combination of the Constitution's rights-based approach, the framework legislation and specific environmental statutes working in unison.[99]

Although South Africa is at the time of writing yet to enact a piece of legislation dedicated to climate change, as is further explained below, its existing environmental law currently regulates air quality-related matters.[100] Consequently, the *National Environmental Management: Air Quality Act* 39 of 2004 (NEMAQA) addresses GHG emissions from a pollution prevention and air quality perspective.[101] This specific environmental management act aims to reform the Republic's legislation regulating the protection and enhancement of ambient air quality through preventative action.[102] The piece of legislation does not define climate change but does identify GHGs, both natural and anthropogenic, including *inter alia* methane, carbon dioxide and nitrous oxide.[103] Climate change presents various issues, and while NEMAQA does not directly deal with them, it does provide an opportunity for focussing mitigation efforts on GHGs.

3.2.3 The Climate Change Bill

On 18 February 2022 the Climate Change Bill B9-2022 (the Bill) was formally introduced to Parliament, more than three years after it was first published for public comments.[104] Although the document is not legally

96 Lehmann "South Africa's Climate Change Commitments" 3.
97 Masonda and Rambau "Climate Change Mitigation" 710.
98 Du Plessis and Nel "An Introduction" 24.
99 Oosthuizen, van der Linde and Basson "National Environmental Management Act 107 of 1998 (NEMA)" 128.
100 Du Plessis and Kotzé 2014 *JAL* 162.
101 Kidd and Couzens "Climate Change Responses in South Africa" 622.
102 Section 2 of the *National Environmental Management: Air Quality Act* 39 of 2004 (NEMAQA).
103 Section 1 of the NEMAQA.
104 Centre for Environmental Rights 2022 https://cer.org.za/news/cer-welcomes-progress-of-climate-bill-in-parliament-calls-for-robust-climate-law.

binding, it provides insight into South Africa's proposed statutory position on climate change. The primary objective of the Bill is to give effect to South Africa's international obligations while enabling the country to respond to climate change in its transition to a climate-resilient and lower-carbon society.[105] The Bill must be read in conjunction with the NEMA and may be regarded as a specific environmental management Act in this established environmental framework.[106]

Additionally, specific reference is made to city level governance as mayors of metropolitan areas are required to factor climate change considerations into their constitutionally mandated functions to achieve the primary objectives of the Bill.[107] These municipalities are required to develop and review their climate change needs and response assessments and implementation plans that must coincide with their planning instruments, policies, and programmes.[108] These implementation plans must form part of the municipalities' integrated development plans, thereby mainstreaming climate considerations into urban development planning.[109]

3.2.4 The National Climate Change Response White Paper

For now, the most authoritative climate policy document in South Africa is the National Climate Change Response White Paper, 2011 (NCCRWP).[110] The NCCRWP provides integral policy considerations for mitigation action and energy sector reformation.[111] The document specifies two crucial objectives, the first of which acknowledges the unavoidability of climate change and the need to effectively manage such change to ensure sustainable development and climate resilience.[112] The second objective reiterates the goals of the UNFCCC, necessitating that the country reasonably contribute to combatting climate change.[113]

Relevant to the city context, the White Paper dedicates an entire section to human settlements.[114] It outlines climate-related challenges, such as poor urban management, water stress, energy demand, the vulnerability of

105 Section 2 of the Climate Change Bill (B9-2022).
106 Section 5 of the Climate Change Bill (B9-2022).
107 Section 15 1)(b) of the Climate Change Bill (B9-2022).
108 Sections 15(1)(a), 15(1)(c), 15(1)(d) and ss 15(1)(e) of the Climate Change Bill (B9-2022).
109 Sections 15 2), 15(3) and ss 15(5) of the Climate Change Bill (B9-2022).
110 National Climate Change Response White Paper (NCCRWP) (GN 757 in GG 34695 of 19 October 2011).
111 Murombo "South Africa's Energy Mix" 13.
112 NCCRWP 11.
113 Article 2 of the *United Nations Framework Convention on Climate Change* (1992) (UNFCCC); NCCRWP 11.
114 Du Plessis and Murombo "Energy" 23; Du Toit and Cilliers "Urban Ecology" 35.

informal settlements and the entrenched dependencies of cities on specific delivery mechanisms.[115] In response to these urban challenges, the government pledges to leverage opportunities and promote behavioural change, use climate-resilient technologies and develop practical monitoring tools to gauge the resilience of cities and towns.[116] The NCCRWP reinforces the importance of cities in the climate policy narrative through the demand for effective responses at the subnational level to impending climate-related threats.

3.2.5 Nationally Determined Contributions

South Africa's Nationally Determined Contributions (NDC) under the *Paris Agreement* is another essential consideration for mitigation action as part of the country's international climate obligations.[117] The NDC advocates achieving mitigation pathways through ensuring that legislative, policy and planning instruments work together to curb GHG emissions.[118] The document acknowledges the impending difficulties for cities and towns through extreme weather events and the subsequent socio-economic hardships that these events will cause.[119] In this respect, the document recognises the seriousness of climate change but contextualises national concerns such as unemployment, poverty alleviation and the need to address the adverse impacts of the COVID-19 crisis.[120]

The country intends to limit GHG emissions to 398 – 510 metric tons of carbon dioxide (CO_2) by 2025 and 350 – 420 metric tons of CO_2 by 2030.[121] The approach highlighted in the NDC identifies the country's developmental aspirations and the assumption of international support as significant considerations for meeting these targets.[122] Although bioenergy is not explicitly mentioned by the NDC or other climate regulatory instruments, renewable energy investment is a significant consideration for achieving the proposed emission limitations by 2030.[123] Subsequently, bioenergy could

115 NCCRWP 21.
116 NCCRWP 22.
117 Government of South Africa 2021 https://unfccc.int/sites/default/files/NDC/2022-06/South%20Africa%20updated%20first%20NDC%20September%202021.pdf (NDC). The *Paris Agreement* (2015) is a binding international treaty on climate change adopted by 196 parties at the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change in Paris, France, in December 2015 to which South Africa is signatory.
118 NDC 4.
119 NDC 7.
120 NDC 3-5.
121 NDC 17.
122 NDC 14.
123 NDC 5.

potentially be a vehicle to facilitate compliance with the country's climate obligations in the transition to a low-carbon economy.[124]

4 The potential of bioenergy as a new energy dynamic and climate change mitigation driver for South African cities

The bioenergy regulatory framework provides an enabling environment for the development and growth of this industry. Nevertheless, despite being on South Africa's policy agenda for over twenty years, little has been done to utilise its potential fully. Accordingly, to propel bioenergy forward and overcome its current state of stagnation, cities as the developmental engines of the country must embrace its utilisation. There are two potential ways in which bioenergy can contribute to climate change mitigation at the city level; firstly, it can reduce the dependence on non-renewables, and secondly, it can help curb the unsustainable exploitation of biomass.[125] In this way, bioenergy may address both aspects of climate change mitigation by limiting and reducing GHG emissions at the source while enhancing and preserving reservoirs and sinks through human intervention.[126] Biomass is a hopeful prospect for renewable energy generation in cities, as only a modest proportion of its potential has been harnessed.[127]

Until recently, the local sphere of government was barred from the energy debate apart from its role in electricity reticulation.[128] However, the current energy crisis has spurred national government to loosen the bureaucratic reins and provide pathways to support the national grid from the sub-national level.[129] The amendments to Schedule 2 of the ERA published in 2021 increased the licensing threshold from 1 megawatt to 100 megawatts, and the amendments to the *Electricity Regulations on New Generation Capacity*, 2011 confer authority upon cities to procure or generate electricity.[130] Following these developments, it would appear that national government is supporting cities in exploring alternative financing to pursue

124 Humphris *South Africa's Law and Policy Framework* 27.

125 IEA 2009 http://www.ieabioenergy.com/wp-content/uploads/2013/10/MAIN-REPORT-Bioenergy-a-sustainable-and-reliable-energy-source.-A-review-of-status-and-prospects.pdf 55.

126 Maguire "Foundations of International Climate Law" 84.

127 UNIDO 2021 https://www.unido.org/sites/default/files/files/2021-07/New-Publication-Bioenergy.pdf 11; Surridge and Trois 2021 https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_SouthAfrica_final.pdf.

128 Schedule 4 Part B of the Constitution; Elsässer, Hickmann and Stehle 2018 *Case Studies in the Environment* 3.

129 Ciaran 2023 https://www.citizen.co.za/business/metros-in-a-race-to-get-eskom-off-their-backs/.

130 GN 1093 in GG 43810 of 16 October 2020; GN 1000 in GG 42784 of 5 October 2021.

low-carbon energy developments.[131] These electricity procurement and generation pathways could create a new energy dynamic for South African cities, one anchored in a broader strategy that shifts the focus away from coal and towards cleaner, more sustainable energy resources.

4.1 Policy considerations for modern bioenergy at the city level

The failure of the country's energy monopoly and the newly opened pathways for electricity procurement and generation have motivated cities to seek energy options elsewhere to meet demand.[132] The doubts that cities have regarding the resilience of South Africa's coal-based energy structure are well-founded, as this system has been unable to recover from load shedding and return to its normal state.[133] Be that as it may, cities are well situated to contribute to decentralising the national energy system by diversifying the local energy mix to include various energy sources.[134] In this regard, all biomass has energy potential and could be converted into beneficial bioenergy when coupled with technologies that maximise the output of this renewable resource.[135] These technologies could significantly contribute to cities' prospects and aspirations in developing resilient and sustainable pathways for energy production.[136]

Modern bioenergy technologies are underutilised and undervalued in South Africa, but there is potential for them to integrate into the local energy mix of cities.[137] Cities will require robust bioenergy policies and systematic planning across multiple sectors, including land, water, agriculture, waste and other related areas.[138] These policies and planning instruments should generate synergies between the bioenergy sector and other industries tailored to the cities' specific needs and biomass availability. Thereby establishing opportunities to draw investment, create job opportunities, advance energy security and reduce GHG emissions. However, the ability of cities to develop and implement bioenergy policy will depend significantly

131 Lin *Governing Climate Change* 125.
132 Pretorius and Blaauw "Residents' Perceptions of Coal Mining and Energy Generation" 140.
133 Jasiunas, Lund and Mikkola 2021 *Renewable and Sustainable Energy Reviews* 2; Behera and Varma *Bioenergy for Sustainability and Security* 60.
134 Hughes *Repowering Cities* 76.
135 Craggs and Gilbert "Sustainable Greenhouse Gas Reductions" 6.
136 World Bioenergy Association 2016 https://www.worldbioenergy.org/news/108/47/The-important-role-of-bioenergy-in-European-cities/ 5.
137 IRENA 2020 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Sep/CC_05_Recycle_bioenergy_2020.pdf 9.
138 Cutz *et al* 2017 *Energy* 515; Souza *et al* 2017 *Environmental Development* 62.

on the capacity available to them and the ability to reconcile these policies with other pressing urban issues.[139]

4.2 Policy considerations for traditional bioenergy at the city level

The load shedding dilemma is placing greater reliance on traditional bioenergy systems to fill the energy gap and help South African citizens meet energy demands, especially those unable to afford alternatives.[140] The policy landscape at the city level should, among other things, consider the energy efficiency of traditional bioenergy systems.[141] For example, cooking with an open three-stone fire stove has an efficiency of around 10% and requires considerable biomass to provide low-grade heat.[142] In other words, only one-tenth of the energy available in the wood goes towards the cooking process. Should improved cooking stoves be used, they would require less fuel for the same results.[143] Consequently, better efficiency would assist in decreasing unsustainable biomass utilisation, limiting the total GHG emitted from traditional bioenergy systems.

Additionally, providing more energy options through fuels or devices could give low-income households more possibilities depending on the task, availability and preference.[144] Cutz *et al*[145] theorise that introducing modern bioenergy technologies coupled with introducing improved traditional technologies into the energy portfolio of households would achieve the highest net reduction of GHGs. The duality of the approach differs from the energy ladder assumption that households move linearly toward modern energy, positing instead that combinations of fuels and devices could contribute to these energy needs.[146]

Improving traditional bioenergy technologies through policies that take a holistic approach to energy poverty could assist in enhancing the resilience of communities that depend extensively on biomass for their energy needs

139 Johnson *Power of Cities* 51.
140 Grootes 2019 https://www.dailymaverick.co.za/article/2019-12-09-twelve-years-of-load-shedding-written-starring-directed-by-the-anc/.
141 REN21 2015 http://www.ren21.net/status-of-renewables/ren21-interactive-map/sadc-data/ 59.
142 REN21 2015 http://www.ren21.net/status-of-renewables/ren21-interactive-map/sadc-data/ 59.
143 REN21 2015 http://www.ren21.net/status-of-renewables/ren21-interactive-map/sadc-data/ 59.
144 Masera *et al* 2015 *Annual Review of Environment and Resources* 138.
145 Cutz *et al* 2017 *Energy* 535.
146 Masera *et al* 2015 *Annual Review of Environment and Resources* 138.

while contributing to the overall air quality in these areas.[147] For instance, some of the poorest households in South Africa are receiving free basic alternative energy products and devices to satisfy their essential energy demands.[148] Ten municipalities in KwaZulu-Natal and the Eastern Cape are receiving free bio-ethanol as a cleaner alternative fuel for cooking purposes, ultimately reducing indoor air pollution and the associated health risks.[149]

5 Recommendations

Against this backdrop, it is recommended that South African cities should:

- Place greater emphasis on the exploitation of bioenergy projects, as many cities are well-endowed with biomass resources that can be tailored to fit the heterogeneity of local energy needs.

- Cities should balance promoting bioenergy developments with climate change considerations, protecting natural resources, and ensuring that bioenergy projects benefit local communities.

- This balance requires cities to develop robust policy instruments that address both traditional and modern bioenergy technologies. The combined development of these systems could increase household and industrial energy options.

- Increasing research and investigation into local biomass trends and feasibility studies on bioenergy should be a vital consideration in these proposed instruments.

- A comprehensive policy landscape could aid cities in improving the advantages of bioenergy while minimising any adverse impacts that it might have on the environment and human health. Bioenergy is a step towards a greener future that can benefit local communities and contribute to the global effort to combat climate change.

6 Conclusion

As a signatory to the UNFCCC and other instruments adopted under this regime, South Africa recognises the global concerns regarding anthropogenic GHG emissions, especially from energy sector activities. The

147 Cutz *et al* 2017 *Energy* 525; Burger 2022 https://www.engineeringnews.co.za/article/study-shows-potential-of-off-grid-anaerobic-biogas-energy-in-south-africa-sanedi-2022-05-12/rep_id:4136.

148 Stats SA 2018 https://www.statssa.gov.za/?p=11181.

149 Lawrence *South Africa's Energy Transition* 41.

role of cities in addressing climate change must not be overlooked, as the practices, policies, and strategies adopted at the sub-national level have the potential to contribute to enhancing sustainability. As the urban population increases, citizens will require more resources to meet their energy demands. This article has looked at one such potential resource, namely biomass, that can contribute to the local energy mix and help to reduce emissions while contributing to energy security.

Although the use of bioenergy has long been a consideration in the country's energy policy and developmental agenda, the utilisation of bioenergy has not picked up as much momentum in the renewable energy market as wind and solar. The versatility and adaptability of biomass make it a practical and economically viable resource for many cities to assist in meeting their energy demands through traditional or modern technologies, whether on a small or a large scale. These technologies must be seen holistically as part and parcel of a larger bioenergy paradigm that provides for the interim energy needs of the most vulnerable people in society while the country progresses toward a low-carbon economy.

Bibliography

Literature

Abbasi, Tauseef and Abbasi *Biogas Energy*
Abbasi T, Tauseef S and Abbasi S *Biogas Energy* (Springer New York 2012)

Akinbami, Oke and Bodunrin 2021 *Alexandria Engineering Journal*
Akinbami OM, Oke SR and Bodunrin MO "The State of Renewable Energy Development in South Africa: An Overview" 2021 *Alexandria Engineering Journal* 5077-5093

Barnard "Access to Bio-Energy"
Barnard M "Access to Bio-Energy vis-à-vis Biodiversity Conservation in SADC: Conflicting Objectives?" in Kotzé LJ and Marauhn T (eds) *Transboundary Governance of Biodiversity* (Brill Nijhoff Boston 2014) 320-341

Barnard 2012 *PELJ*
Barnard M "The Role of International Sustainable Development Law Principles in Enabling Effective Renewable Energy Policy: A South African Perspective" 2012 *PELJ* 207-243

Behera and Varma *Bioenergy for Sustainability and Security*
Behera B and Varma A *Bioenergy for Sustainability and Security* (Springer New Delhi 2019)

Craggs and Gilbert "Sustainable Greenhouse Gas Reductions"
Craggs L and Gilbert P "Sustainable Greenhouse Gas Reductions from Bioenergy Systems – Climate Change: A Bioenergy Driver and Constraint" in Thornley P and Adams P (eds) *Greenhouse Gas Balances of Bioenergy Systems* (Elsevier London 2022) 1-10

Creutzig *et al* 2015 *Proceedings of the National Academy of Sciences*
Creutzig F *et al* "Global Typology of Urban Energy Use and Potentials for an Urbanization Mitigation Wedge" 2015 *Proceedings of the National Academy of Sciences* 6283-6288

Cutz *et al* 2017 *Energy*
Cutz L *et al* "Switching to Efficient Technologies in Traditional Biomass Intensive Countries: The Resultant Change in Emissions" 2017 *Energy* 513-526

Du Plessis "SDG 11"
Du Plessis A "SDG 11: Make Cities and Human Settlements Inclusive, Safe, Resilient and Sustainable" in Ebbesson J and Hay E (eds) *The Cambridge Handbook on the Sustainable Development Goals and International Law* (Cambridge University Press Cambridge 2022) 281-303

Du Plessis and Kotzé 2014 *JAL*
Du Plessis A and Kotzé L "The Heat is On: Local Government and Climate Governance in South Africa" 2014 *Journal of African Law* 145-174

Du Plessis and Murombo "Energy"
Du Plessis W and Murombo T "Energy" in Du Plessis A (ed) *Environmental Law and Local Government in South Africa* 2nd ed (Juta Cape Town 2021) 1-43

Du Plessis and Nel "An Introduction"
Du Plessis A and Nel JG "An Introduction" in Du Plessis A (ed) *Environmental Law and Local Government in South Africa* 2nd ed (Juta Cape Town 2021) 3-40

Du Toit and Cilliers "Urban Ecology"
Du Toit M and Cilliers S "Urban Ecology" in Du Plessis A (ed) *Environmental Law and Local Government in South Africa* 2nd ed (Juta Cape Town 2021) 1-43

Dube and Moyo 2022 *PELJ*
Dube F and Moyo C "The Right to Electricity in South Africa" 2022 *PELJ* 1-21

Elsässer, Hickmann and Stehle 2018 *Case Studies in the Environment*
Elsässer JP, Hickmann T and Stehle F "The Role of Cities in South Africa's Energy Gridlock" 2018 *Case Studies in the Environment* 1-7

Ghosh 2016 *Procedia Environmental Sciences*
Ghosh S "Biomass and Bio-Waste Supply Chain Sustainability for Bio-Energy and Bio-Fuel Production" 2016 *Procedia Environmental Sciences* 31-39

Goldemberg and Coelho 2004 *Energy Policy*
Goldemberg J and Coelho S "Renewable Energy: Traditional Biomass vs Modern Biomass" 2004 *Energy Policy* 711-714

Hughes *Repowering Cities*
Hughes S *Repowering Cities* (Cornell University Press New York 2019)

Humphris *South Africa's Law and Policy Framework*
Humphris D *South Africa's Law and Policy Framework for the Regulation of the Clean Development Mechanism* (LLM-dissertation North-West University 2011)

Jasiunas, Lund and Mikkola 2021 *Renewable and Sustainable Energy Reviews*
Jasiunas J, Lund P and Mikkola J "Energy System Resilience – A Review" 2021 *Renewable and Sustainable Energy Reviews* 1-18

Johnson *Power of Cities*
Johnson CA *The Power of Cities in Global Climate Politics: Saviours, Supplicants or Agents of Change?* (Palgrave Macmillan London 2018)

Jones *Cities Responding to Climate Change*
Jones S *Cities Responding to Climate Change* (Palgrave Macmillan Cham 2018)

Karekezi, Lata and Coelho "Traditional Biomass Energy"
Karekezi S, Lata K and Coelho S "Traditional Biomass Energy: Improving its Use and Moving to Modern Energy Use" in Assmann D, Laumanns U and Uh D (eds) *Renewable Energy: A Global Review of Technologies, Policies and Markets* (Earthscan London 2006) 230-261

Kidd and Couzens "Climate Change Responses in South Africa"
Kidd M and Couzens E "Climate Change Responses in South Africa" in Hollo EJ, Kulovesi K and Mehling M (eds) *Climate Change and the Law* (Springer Dordrecht 2013) 619-638

Klees *Electricity Law*
Klees A *Electricity Law in South Africa* (Juta Cape Town 2014)

Kuh "International Climate Change Treaty Regime"
Kuh KF "International Climate Change Treaty Regime" in Coplan KS *et al* (eds) *Climate Change Law: An Introduction* (Edward Elgar Cheltenham 2021) 5-22

Kurchania "Biomass Energy"
Kurchania A "Biomass Energy" in Baskar C, Baskar S and Dhillon R (eds) *Biomass Conversion* (Springer Berlin 2012) 91-122

Laher *et al* 2019 *South African Medical Journal*
Laher AE *et al* "'Getting Out of the Dark': Implications of Load Shedding on Healthcare in South Africa and Strategies to Enhance Preparedness" 2019 *South African Medical Journal* 899-900

Lawrence 2020 *Renewable and Sustainable Energy Reviews*
Lawrence A "Energy Decentralization in South Africa: Why Past Failure Points to Future Success" 2020 *Renewable and Sustainable Energy Reviews* 1-8

Lawrence *South Africa's Energy Transition*
Lawrence A *South Africa's Energy Transition* (Palgrave Macmillan Cham 2022)

Lehmann "South Africa's Climate Change Commitments"
Lehmann K "South Africa's Climate Change Commitments and Regulatory Response Potential" in Humby TL *et al* (ed) *Climate Change: Law and Governance in South Africa* (Juta Cape Town 2016) 1-27

Lin *Governing Climate Change*
Lin J *Governing Climate Change: Global Cities and Transnational Lawmaking* (Cambridge University Press New York 2018)

Maguire "Foundations of International Climate Law"
Maguire R "Foundations of International Climate Law: Objectives, Principles and Methods" in Hollo EJ, Kulovesi K and Mehling M (eds) *Climate Change and the Law* (Springer Dordrecht 2013) 83-110

Masera *et al* 2015 *Annual Review of Environment and Resources*
Masera O *et al* "Environmental Burden of Traditional Bioenergy Use" 2015 *Annual Review of Environment and Resources* 121-150

Masonda and Rambau "Climate Change Mitigation"
Masonda H and Rambau F "Climate Change Mitigation in South Africa" in Van Calster G, Vandenberghe W and Riens L (eds) *Research Handbook on Cliamte Change Mitigation Law* (Edward Elgar Cheltenham 2015) 705-723

Moyo *Role of the South African Renewable Energy Legal Framework*
Moyo E *The Role of the South African Renewable Energy Legal Framework in Climate Change Mitigation: A Focus on the Construction of Buildings* (LLM-dissertation North West University 2016)

Murombo 2016 *Journal of World Energy Law and Business*
Murombo T "Legal and Policy Barriers to Renewable and Sustainable Energy Sources in South Africa" 2016 *Journal of World Energy Law and Business* 142-165

Murombo "South Africa's Energy Mix"
Murombo T "South Africa's Energy Mix: Towards a Low-Carbon Economy" in Humby TL *et al* (ed) *Climate Change: Law and Governance in South Africa* (Juta Cape Town 2016) 1-26

National Planning Commission *National Development Plan, 2030*
National Planning Commission *National Development Plan, 2030 - Our Future: Make It Work* (National Planning Commission Pretoria 2012)

Oosthuizen, Van der Linde and Basson "National Environmental Management Act 107 of 1998 (NEMA)"
Oosthuizen M, Van der Linde M and Basson E "National Environmental Management Act 107 of 1998 (NEMA)" in King ND, Strydom HA and Retief FP (eds) *Environmental Management in South Africa* (Juta Cape Town 2018) 125 - 208

Pande and Bhaskarwar "Biomass Conversion to Energy"
Pande M and Bhaskarwar A "Biomass Conversion to Energy" in Baskar C, Baskar S and Dhillon R (eds) *Biomass Conversion* (Springer Berlin 2012) 1-90

Papacostantis 2017 *CILSA*
Papacostantis H "Renewable Energy Regulation in South Africa: Lessons from the Chinese Experience" 2017 *CILSA* 275-302

Pollet, Staffell and Adamson *Energy Landscape*
Pollet B, Staffell I and Adamson K *The Energy Landscape in the Republic of South Africa* (Springer International New York 2016)

Pretorius and Blaauw "Residents' Perceptions of Coal Mining and Energy Generation"
Pretorius A and Blaauw D "Residents' Perceptions of Coal Mining and Energy Generation" in Lochner M *et al* (eds) *Coal and Energy in South Africa* (Edinburgh University Press Edinburgh 2021) 135-149

Ramagoma and Adendorff 2016 *Journal of Energy in Southern Africa*
Ramagoma J and Adendorff C "Managing a Transition to Green Energy Sources: The Perspectives of Energy Practitioners in the Southern African Development Community Region" 2016 *Journal of Energy in Southern Africa* 77-90

Rasmeni and Madyira 2019 *Procedia Manufacturing*
Rasmeni ZZ and Madyira DM "A Review of the Current Municipal Solid Waste Management Practices in Johannesburg City Townships" 2019 *Procedia Manufacturing* 1025-1031

Rauland and Newman *Decarbonising Cities*
Rauland V and Newman P *Decarbonising Cities Mainstreaming Low Carbon Urban Development* (Springer New York 2015)

Rodas "City Diplomacy"
Rodas M "City Diplomacy: Experience from the Ground" in Aust HP and Nijman JE (eds) *Research Handbook on International Law and Cities* (Edward Elgar Cheltenham 2020) 305-319

Rose *et al* 2014 *Climatic Change*
Rose S *et al* "Bioenergy in Energy Transformation and Climate Management" 2014 *Climatic Change* 477-493

Sawe "Sustainable Charcoal and Firewood Production"
Sawe E "Sustainable Charcoal and Firewood Production and Use in Africa" in Janssen R and Rutz D (eds) *Bioenergy for Sustainable Development in Africa* (Springer Dordrecht 2012) 75-80

Smeets, Johnson and Ballard-Tremeer "Keynote Introduction"
Smeets E, Johnson F and Ballard-Tremeer G "Keynote Introduction: Traditional and Improved Use of Biomass for Energy in Africa" in Janssen R and Rutz D (eds) *Bioenergy for Sustainable Development in Africa* (Springer Dordrecht 2012) 3-12

Souza *et al* 2017 *Environmental Development*
Souza G *et al* "The Role of Bioenergy in a Climate-Changing World" 2017 *Environmental Development* 57-64

Stafford and Brent 2011 *Renewable Energy Law and Policy Review*
Stafford W and Brent A "Bioenergy Systems Sustainability Assessment and Management" 2011 *Renewable Energy Law and Policy Review* 205-222

Umbers "Sub-National Climate Duties"
Umbers L "Sub-National Climate Duties: Addressing Three Challenges" in Moss J and Umbers L (eds) *Climate Justice and Non-State Actors: Corporations, Regions, Cities, and Individuals* (Routledge New York 2022) 29-44

Legislation

Constitution of the Republic of South Africa, 1996

Electricity Regulation Act 4 of 2006

National Energy Act 34 of 2008

National Environmental Management Act 107 of 1998

National Environmental Management: Air Quality Act 39 of 2004

Government publications

Climate Change Bill (B9-2022)

GN 3007 in GG 19606 of 17 December 1998 (Energy White Paper)

GN 513 in GG 26169 of 14 May 2004 (Renewable Energy White Paper)

GN 757 in GG 34695 of 19 October 2011 (National Climate Change Response White Paper)

GN 25 in GG 32898 of 29 January 2010

GN 897 in GG 41865 of 27 August 2018 (Integrated Resource Plan 2019)

GN 1360 in GG 42784 of 18 October 2019

GN 1093 in GG 43810 of 16 October 2020

GN 1000 in GG 42784 of 5 October 2021

International instruments

Paris Agreement (2015)

United Nations Framework Convention on Climate Change (1992)

Internet sources

Amugune *et al* 2017 https://play.google.com/books/reader?id=CRZQDwAAQBAJ&hl=en&pg=GBS.PP1
Amugune I *et al* 2017 *Small Flame But No Fire: Wood Fuel in the (Intended) Nationally Determined Contributions of countries in Sub-Saharan Africa* https://play.google.com/books/reader?id=CRZQDwAAQBAJ&hl=en&pg=GBS.PP1 accessed 15 June 2023

Burger 2022 https://www.engineeringnews.co.za/article/study-shows-potential-of-off-grid-anaerobic-biogas-energy-in-south-africa-sanedi-2022-05-12/rep_id:4136
Burger S 2022 *Study Shows Potential of Off-Grid Anaerobic Biogas Energy in South Africa – SANEDI* https://www.engineeringnews.co.za/article/study-shows-potential-of-off-grid-anaerobic-biogas-energy-in-south-africa-sanedi-2022-05-12/rep_id:4136 accessed 20 May 2022

Centre for Environmental Rights 2022 https://cer.org.za/news/cer-welcomes-progress-of-climate-bill-in-parliament-calls-for-robust-climate-law
Centre for Environmental Rights 2022 *CER Welcomes Progress of Climate Bill in Parliament, Calls for Robust Climate Law* https://cer.org.za/news/cer-welcomes-progress-of-climate-bill-in-parliament-calls-for-robust-climate-law accessed 20 August 2022

Ciaran 2023 https://www.citizen.co.za/business/metros-in-a-race-to-get-eskom-off-their-backs/
Ciaran R 2023 *Metros in a Race to Get Eskom off their Backs* https://www.citizen.co.za/business/metros-in-a-race-to-get-eskom-off-their-backs/ accessed 13 April 2023

Conserve Energy Future 2023 https://www.conserve-energy-future.com/advantages-disadvantages-examples-monoculture.php
Conserve Energy Future 2023 *Advantages and Disadvantages of Monoculture Farming* https://www.conserve-energy-future.com/advantages-disadvantages-examples-monoculture.php accessed 13 April 2023

Department of Energy 2011 https://www.energy.gov.za/IRP/irp%20files/IRP2010_2030_Final_Report_20110325.pdf
Department of Energy 2011 *Integrated Resource Plan for Electricity 2010-2030*

https://www.energy.gov.za/IRP/irp%20files/IRP2010_2030_Final_Report_20110325.pdf accessed 15 June 2023

Department of Energy 2018 http://www.energy.gov.za/IRP/irp-2016.html
Department of Energy 2018 *Integrated Resource Plan 2016* http://www.energy.gov.za/IRP/irp-2016.html accessed 15 June 2023

Department of Science and Technology 2016 https://www.dst.gov.za/images/2017/2017_pdfs/Bio-Energy-Atlas_DevV15.pdf
Department of Science and Technology 2016 *Bioenergy Atlas for South Africa: Synopsis Report* https://www.dst.gov.za/images/2017/2017_pdfs/Bio-Energy-Atlas_DevV15.pdf accessed 15 June 2023

Government of South Africa 2021 https://www.dffe.gov.za/sites/default/files/reports/draftnationalydeterminedcontributions_2021updated.pdf
Government of South Africa 2021 *South Africa First Nationally Determined Contribution under the Paris Agreement* https://www.dffe.gov.za/sites/default/files/reports/draftnationalydeterminedcontributions_2021updated.pdf accessed 12 May 2022

Grootes 2019 https://www.dailymaverick.co.za/article/2019-12-09-twelve-years-of-load-shedding-written-starring-directed-by-the-anc/
Grootes S 2019 *Twelve Years of Load Shedding – Written, Starring & Directed by the ANC* https://www.dailymaverick.co.za/article/2019-12-09-twelve-years-of-load-shedding-written-starring-directed-by-the-anc/ accessed 20 May 2022

Hivos People Unlimited 2019 https://hivos.org/blog/the-statistics-from-indoor-pollution-deaths-must-not-be-forgotten/
Hivos People Unlimited 2019 *The Statistics from Indoor Pollution Deaths Must Not Be Forgotten* https://hivos.org/blog/the-statistics-from-indoor-pollution-deaths-must-not-be-forgotten/ accessed 19 August 2022

IEA 2009 http://www.ieabioenergy.com/wp-content/uploads/2013/10/MAIN-REPORT-Bioenergy-a-sustainable-and-reliable-energy-source.-A-review-of-status-and-prospects.pdf
International Energy Agency 2009 *Bioenergy – A Sustainable and Reliable Energy Source* http://www.ieabioenergy.com/wp-content/uploads/2013/10/MAIN-REPORT-Bioenergy-a-sustainable-and-reliable-energy-source.-A-review-of-status-and-prospects.pdf accessed 6 June 2018

IEA 2017 http://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf

International Energy Agency 2017 *Technology Roadmap: Delivering Sustainable Bioenergy* http://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf accessed 7 June 2018

IEA Bioenergy 2023 https://www.ieabioenergy.com/iea-publications/faq/woodybiomass/carbon-neutrality/
International Energy Agency Bioenergy 2023 *Carbon Neutrality* https://www.ieabioenergy.com/iea-publications/faq/woodybiomass/carbon-neutrality/ accessed 13 April 2023

International Trade Administration 2021 https://bit.ly/3EI59Gc
International Trade Administration 2021 *South Africa - Country Commercial Guide* https://bit.ly/3EI59Gc accessed 20 October 2022

IPCC 2021 https://www.ipcc.ch/site/assets/uploads/2021/08/IPCC_WGI-AR6-Press-Release_en.pdf
Intergovernmental Panel on Climate Change 2021 *Climate Change Widespread, Rapid, and Intensifying – IPCC* https://www.ipcc.ch/site/assets/uploads/2021/08/IPCC_WGI-AR6-Press-Release_en.pdf accessed 5 August 2022

IRENA 2020 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Sep/CC_05_Recycle_bioenergy_2020.pdf
International Renewable Energy Agency 2020 *Recycle: Bioenergy* https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Sep/CC_05_Recycle_bioenergy_2020.pdf accessed 4 August 2022

IRENA 2022 https://www.irena.org/Energy-Transition/Technology/Bioenergy-and-biofuels
International Renewable Energy Agency 2022 *Bioenergy and Biofuels* https://www.irena.org/Energy-Transition/Technology/Bioenergy-and-biofuels accessed 13 April 2023

Mutsaa and Mangara 2023 https://inclusivecities.ukzn.ac.za/blog/tri-fold-impact-of-load-shedding-in-south-african-cities-power-outage-destruction-and-regression/
Mutsaa E and Mangara F 2023 *Tri-fold Impact of Load-Shedding in South African Cities: Power Outage, Destruction, and Regression* https://inclusivecities.ukzn.ac.za/blog/tri-fold-impact-of-load-shedding-in-south-african-cities-power-outage-destruction-and-regression/ accessed 13 April 2013

Ramreddi 2023 https://theafrican.co.za/featured/load-shedding-violates-rights-of-vulnerable-communities-d6346e5f-f2d2-46ef-a147-d38870c72a54/
Ramreddi K 2023 *Load Shedding Violates Rights of Vulnerable Communities* https://theafrican.co.za/featured/load-shedding-violates-rights-of-vulnerable-communities-d6346e5f-f2d2-46ef-a147-d38870c72a54/ accessed 13 April 2023

REN21 2015 http://www.ren21.net/status-of-renewables/ren21-interactive-map/sadc-data/
REN21 2015 *SADC Renewable Energy and Energy Efficiency Status Report* http://www.ren21.net/status-of-renewables/ren21-interactive-map/sadc-data/ accessed 8 June 2018

Shankman 2018 https://insideclimatenews.org/news/19032018/global-warming-arctic-air-pollution-short-lived-climate-pollutants-methane-black-carbon-hfcs-slcp/
Shankman S 2018 *These Climate Pollutants Don't Last Long, but They're Wreaking Havoc on the Arctic* https://insideclimatenews.org/news/19032018/global-warming-arctic-air-pollution-short-lived-climate-pollutants-methane-black-carbon-hfcs-slcp/ accessed 13 April 2023

Staff Writer 2023 https://businesstech.co.za/news/property/671281/new-data-shows-how-load-shedding-is-tearing-through-businesses-in-south-africa/
Staff Writer 2023 *New Data Shows How Load Shedding is Tearing through Businesses in South Africa* https://businesstech.co.za/news/property/671281/new-data-shows-how-load-shedding-is-tearing-through-businesses-in-south-africa/ accessed 13 April 2023

Stats SA 2018 https://www.statssa.gov.za/?p=11181
Stats SA 2018 *Energy and the Poor: A Municipal Breakdown* https://www.statssa.gov.za/?p=11181 accessed 30 May 2022

Surridge and Trois 2021 https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_SouthAfrica_final.pdf
Surridge K and Trois C 2021 *Implementation of Bioenergy in South Africa – 2021 Update* https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_SouthAfrica_final.pdf accessed accessed 15 June 2023

UNIDO 2021 https://www.unido.org/sites/default/files/files/2021-07/New-Publication-Bioenergy.pdf
United Nations Industrial Development Organisation 2021 *The Role of Bioenergy in the Clean Energy Transition and Sustainable Development: Lessons from Developing Countries* https://www.unido.org/sites/default/files/files/2021-07/New-Publication-Bioenergy.pdf accessed 15 June 2023

WHO 2022 https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health
World Health Organisation 2022 *Household Air Pollution and Health* https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health accessed 20 August 2022

World Bioenergy Association 2016 https://www.worldbioenergy.org/news/108/47/The-important-role-of-bioenergy-in-European-cities/
World Bioenergy Association 2016 *The Role of Bioenergy in European Cities* https://www.worldbioenergy.org/news/108/47/The-important-role-of-bioenergy-in-European-cities/ accessed 15 June 2023

List of Abbreviations

CILSA	Comparative and International Law Journal of Southern Africa
ERA	Electricity Regulation Act 4 of 2006
GHG	Greenhouse Gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
JAL	Journal of African Law
NCCRWP	National Climate Change Response White Paper
NDC	Nationally Determined Contributions
NDP	National Development Plan
NEA	National Energy Act 34 of 2008
NEMA	National Environmental Management Act 107 of 1998
NEMAQA	National Environmental Management: Air Quality Act 39 of 2004
PELJ	Potchefstroom Electronic Law Journal

RE	renewable energy
SDG	Sustainable Development Goals
UN	United Nations
UNIDO	United Nations Industrial Development Organisation
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation