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for Sustainable, Co-Created Climate Action

Pathways for Sustainable Energy Transition in Kenya:

Insights from Climate, Land, Energy, Water systems (CLEWs) Modelling

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1 Motivation

Kenya's energy mix remains heavily reliant on fossil fuels despite extensive renewable resources. A full transition to a 100% clean, resilient energy system is feasible and urgently needed to meet national and global climate targets. Kenya's Vision 2030, National Energy Policy (2018), and Climate Change Act (2016) provide a foundation for clean energy leadership. As a signatory to the Paris Agreement, Kenya has committed to reducing emissions through enhanced Nationally Determined Contributions (NDCs). In the updated NDC, the Kenyan Government has set itself the goal to reduce GHG emissions by 35% by 2035, compared to a BAU scenario.[1]

The country is uniquely positioned with abundant solar, wind, geothermal, and bioenergy resources to achieve a 100% renewable energy system, driving sustainable growth and resilience. To harness these resources, the Energy Act of 2019 provides the legal foundation for the development of renewable energy in the country; the Least Cost Power Development Plan for the period between 2021 and 2030 aims to ensure that new energy projects are both cost-effective and sustainable.[2]

In the Land sector, Kenya has recently launched a campaign to plant 15 billion trees by 2032. This is part of the aim to increase 30% tree cover so as to reduce land degradation, reduce GHG emissions and reverse deforestation.[3] The implementation of this target will also greatly impact carbon sequestration as forests act as carbon sinks.

Total freshwater withdrawals in Kenya are currently approximated to about 4.03 billion cubic meters per year.[4] The National Water Resources strategy reiterates one of the provisions in the Kenya Constitution of 2010 that water access is a human right.[5] However, rising energy demands and the implementation of the forecasted expansion of coal and nuclear power[6] could hinder water access and increase water stress. These policy contexts motivate the exploration of policy impacts on multi-dimensional sectors and sustainable alternatives to policy contexts that do not align with Kenya's National targets.

[1] Republic of Kenya (2025): Kenya's Second Nationally Determined Contribution (2031-2035). Nairobi, Kenya: Ministry of Environment Climate Change and Forestry. https://unfccc.int/sites/default/files/2025-05/KENYAS%20SECOND%20NATIONALLY%20DETERMINED%20CONTRIBUTION%202031_2035.pdf
[2] https://www.nature.com/articles/d44148-025-00092-7
[3] https://kippra.or.ke/from-tree-planting-to-tree-growing-a-paradigm-shift-towards-30-tree-cover/
[4] https://data.apps.fao.org/aquastat/?lang=en
[5] https://faolex.fao.org/docs/pdf/ken214249.pdf
[6] https://www.energy.go.ke/sites/default/files/Final%20Draft%20%20National%20Energy%20Policy%2018022025.pdf

2 Scenario Design

A CLEWs-based modelling analysis using the OSeMOSYS tool with the MUIO v5.3 user interface was conducted to assess Kenya's energy transition options between 2020 and 2050. The model captures the interlinkages between land use, water availability, emissions, and energy demand across three developing scenarios.

Business-as-Usual (BAU) Scenario

Under the BAU scenario, Kenya's energy system continues to rely heavily on geothermal and hydropower, with minimal additions of wind and solar. A proposed 960 MW coal plant significantly increases greenhouse gas emissions and exacerbates water stress due to high cooling requirements. While electrification improves slightly, rural areas remain reliant on biomass. The BAU pathway also reflects land use policy implications, particularly as reforestation policy heavily impacts the NDC through carbon sequestration making it easier to achieve NDC targets.

High-Renewables Scenario

This scenario reflects accelerated investment in solar, wind, and geothermal technologies. Emissions decrease significantly due to reduced reliance on fossil fuels. Water withdrawals decline as non-thermal technologies dominate the energy mix. Despite challenges in managing intermittency and grid stability, this scenario emerges as the least-cost pathway and aligns best with Kenya's climate and development goals.

Biofuel Integration Scenario

Building upon the BAU, the biofuel integration scenario focuses solely on tapping into biomass as a resource through anaerobic digestion of agricultural waste. Agricultural methane emissions are reduced by converting organic waste into bioenergy. This circular solution supports electricity generation, clean cooking, and rural energy access. It also reduces pressure on landfills and enhances resource efficiency. Water usage is optimized, and overall system emissions decline substantially.

Transport Electrification Scenario

The transport sector is currently the second-largest emissions source after agriculture. Transitioning 50% of transport to electricity by 2050 reduces emissions significantly while leveraging Kenya's clean energy base. The shift requires targeted investments in charging infrastructure, policy incentives, and vehicle supply chains. This scenario also builds on the BAU however for best results combining this scenario with the High renewable scenario would be best for optimum emission reduction.

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3 Model Results

In Figure 1, a comparison of the installed capacity for power plants in the different scenarios is shown. The Business-as-Usual Scenario sees an installation of Coal and Nuclear by 2030 and 2034 respectively. The High renewables scenario focuses on the renewable energy potential. The Biofuel Integration scenario increases biofuel capacity by 2040, while the renewable transport scenario has a similar capacity to BAU.

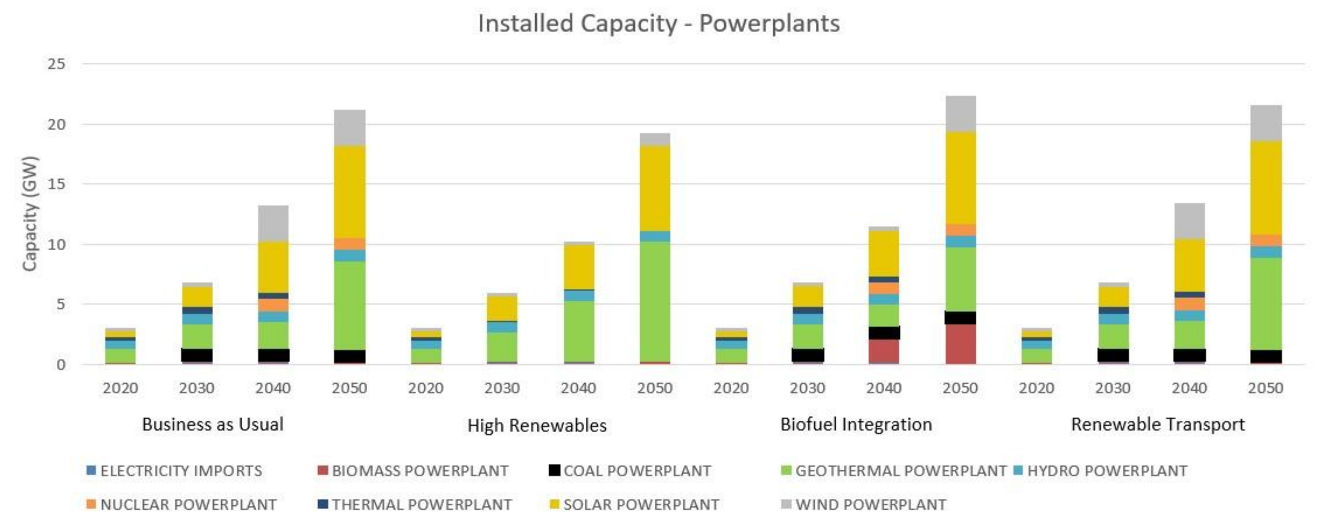

Figure 1: Powerplants Installed Capacity Comparison – Scenario Analysis

In Figure 2, land use is shown, which is similar across the different scenarios due to lack of change in land use policies across the different scenarios. Afforestation targets are implemented according to the afforestation policy to have 30% forest cover by 2050. Currently, other land uses occupy almost 40% of the country's total land area. Due to aggressive afforestation targets, alongside urbanization and Industrialization both grasslands and other land uses are expected to decline in size.

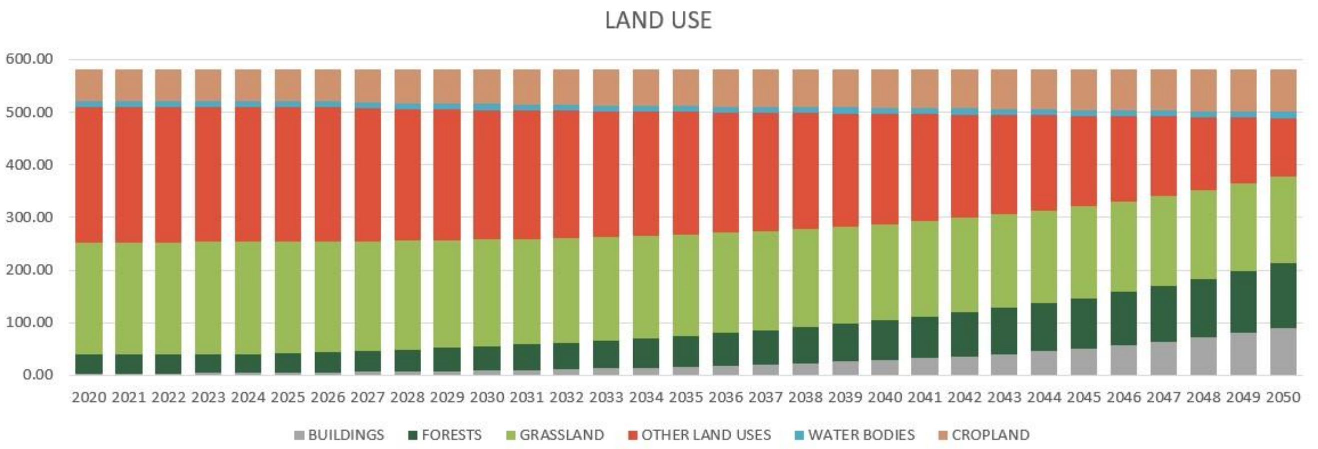

Figure 2: Land use

Figure 3 demonstrates the water withdrawals as according to the BAU and High renewables scenario. Due to the implementation of Coal and Nuclear power plants in BAU, a steep increase in water demand for cooling thermal power plants is seen, which can be avoided if the high renewables scenario is implemented instead.

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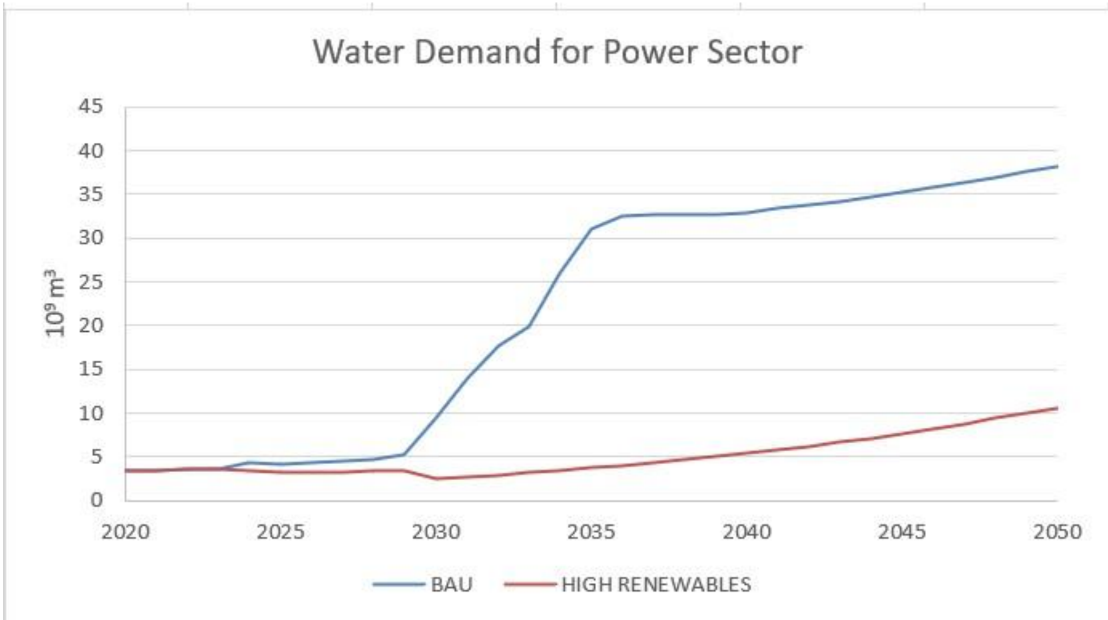

Figure 3: Water withdrawals by Power Sector

Figure 4 shows a decrease in emissions due to utilisation of crop waste for biofuel production. Agriculture is one of the leading sectors in methane emissions with contributions from both crop residue decomposition as well as livestock. Converting these residues to energy instead of leaving them to decay reduces methane release, allowing for both reduction in GHG emissions and meeting local energy needs.

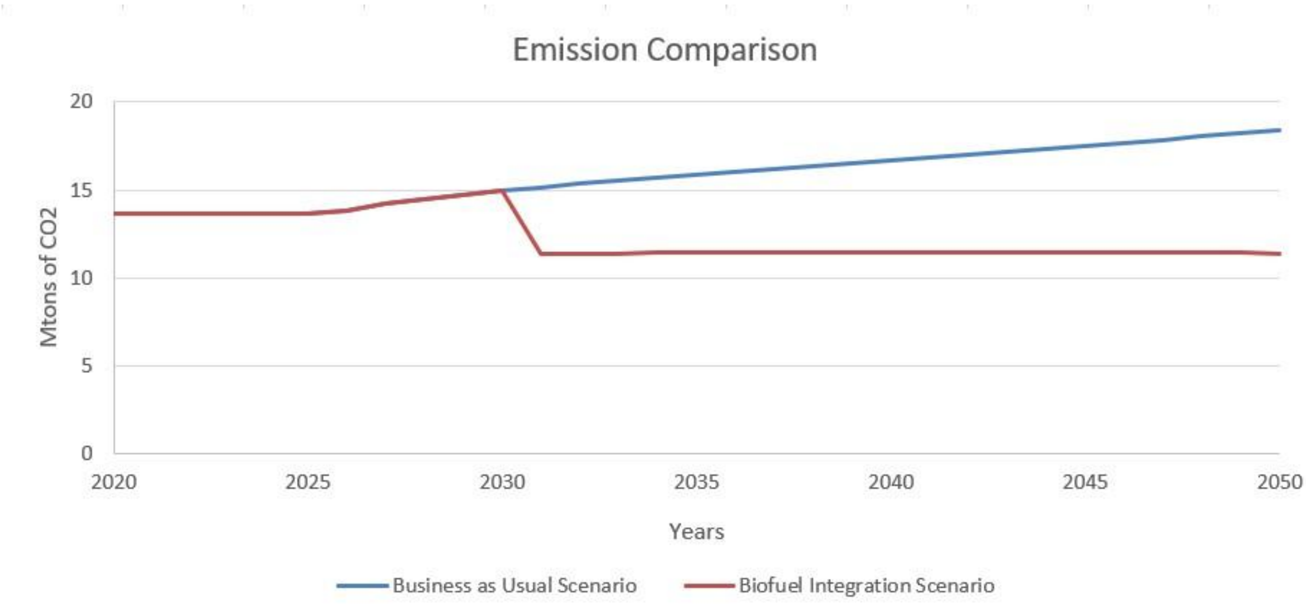

Figure 4: Emission Comparison – Biofuel Integration Scenario

In Figure 5, a reduction of up to 1 Mtons of GHG emissions is seen with the transition of the transport sector to electric vehicles. Kenya's transport sector is heavily reliant on fossil fuels making it one of the major contributors to Kenya's total emissions. On the other hand Kenya's energy sector is currently highly renewable. If transition is made from fossil fuels to electric vehicles we would see a huge reduction in emissions in the sector as see in figure 5. However, if Kenya truly wants to compound on this emission reduction then it would be best to adopt

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the high renewable scenario which would allow for lower total emissions.

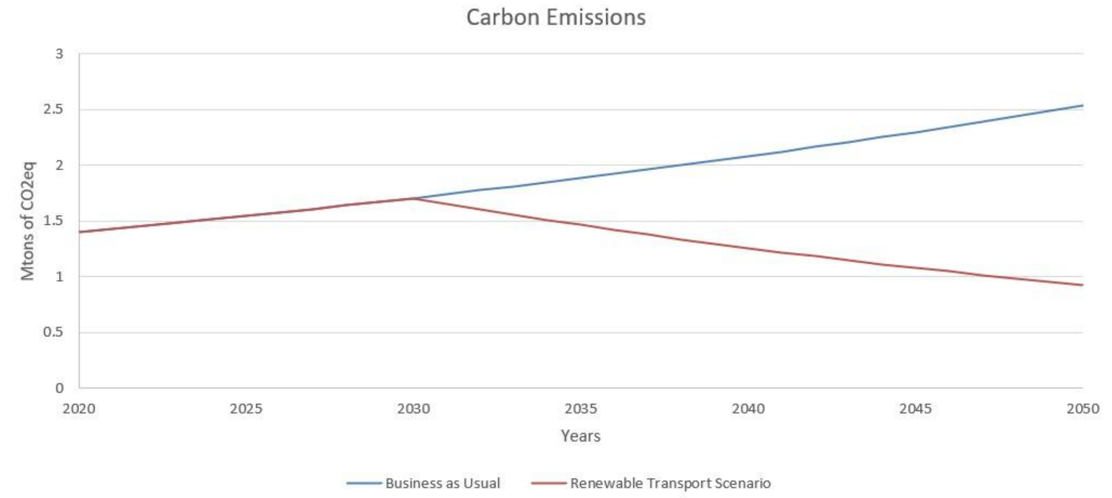

Figure 5: Emission Comparison – Renewable Transport Scenario

Finally, in Figures 6 we can see the cumulative capital and fixed cost comparison between all the modelled scenarios. The high renewable scenario proves to be least cost long term as well as being the best option environmentally. The renewable transport scenario and biofuel integration scenario are both built upon the BAU rather than the High renewable scenario which leads them to having even higher costs.

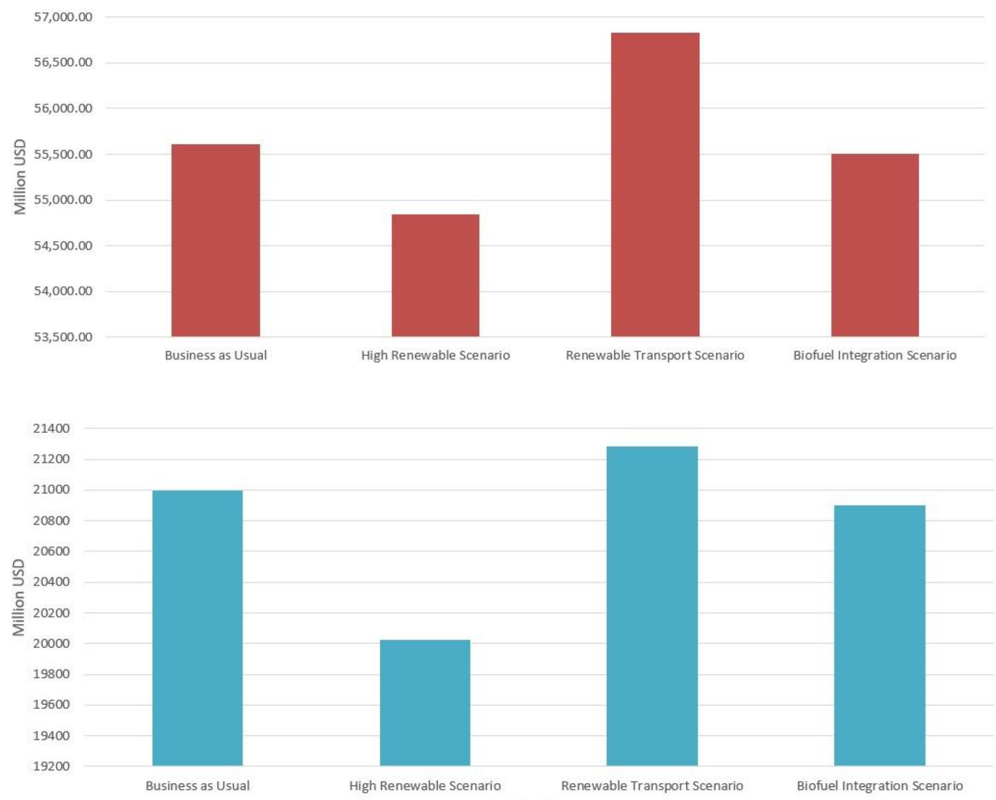

Figure 6: Cumulative Capital Costs (up) and Cumulative Fixed Costs (down)

4 Policy Implications

Kenya's clean energy transition offers a powerful pathway to economic resilience, environmental sustainability, and regional leadership. The right mix of policy, finance, and community engagement can make Kenya a model for green development in Africa. Targeting national energy independence based on clean, abundant indigenous renewable energy sources appears to be the most sustainable solution, as underlined by the High Renewables scenario: renewables are found considerably more cost-effective in the least-cost modelling approach, even when accounting for the considerable external costs of non-renewable energy that are typically excluded from formalized technoeconomic analyses. To achieve this vision, Kenya should:

- **Adopt Integrated Planning**: Avoid siloed approaches by incorporating land and water constraints into energy planning. Modeling shows that the expansion of coal power and large-scale afforestation can lead to increased water stress.
- **Rescind Support for Coal and Nuclear**: Coal significantly raises emissions and water use; nuclear is not cost-effective in the model. Redirect investment toward renewables, including small-scale solar and biogas systems.
- **Promote Agricultural Waste-to-Energy**: Leverage methane from agricultural waste to produce biofuels, supporting clean cooking and electricity while reducing emissions.
- **Electrify the Transport Sector**: Gradually transition up to 50% of transport to electric power by 2050, backed by EV infrastructure, import incentives, and supportive policies.
- **Invest in Energy Storage**: Address renewable intermittency by financing storage solutions, which can stabilize supply and create future revenue from energy exports.
- **Incentivize Decentralized Systems**: Support solar mini-grids and local biomass power plants to expand rural access without relying solely on national grid extension.
- **Strengthen Regulatory Coherence**: Establish cross-ministerial coordination platforms to integrate land, energy, and water planning in line with Kenya's NDC targets.
- **Engage the Private Sector**: Attract investment in emerging technologies such as battery storage and geothermal through transparent, stable incentives

Policy Brief

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In a nutshell

IAM COMPACT supports the assessment of global climate goals, progress, and feasibility space, and the design of the next round of Nationally Determined Contributions (NDCs) and policy planning beyond 2030 for major emitters and non-high-income countries. It uses a diverse ensemble of models, tools, and insights from social and political sciences and operations research, integrating bodies of knowledge to co-create the research process and enhance transparency, robustness, and policy relevance. It explores the role of structural changes in major emitting sectors and of political, behaviour, and social aspects in mitigation, quantifies factors promoting or hindering climate neutrality, and accounts for extreme scenarios, to deliver a range of global and national pathways that are environmentally effective, viable, feasible, and desirable. In doing so, it aligns climate action with broader sustainability goals, while developing technical capacity and promoting ownership in non-high-income countries.

Corresponding Author(s):	Project Coordination
Ioannis Tsipouridis, Salsabilah Abdulhalim [**TUM**] anemologia99@gmail.com, salsabilaabdulhalim@gmail.com, **Renewable Energy & Climate Change Research Centre, Technical University of Mombasa**	Alexandros Nikas, Natasha Frilingou (NTUA) anikas@epu.ntua.gr nfrilingou@epu.ntua.gr

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