Analysis of Energy Demand for Electrifying the Kenya Standard Gauge Railway (SGR)

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EXECUTIVE SUMMARY

This report performs an analysis using the Model for Analysis of Energy Demand (MAED) to simulate the energy demands for the transportation sector, mainly the Standard Gauge Railway (SGR) in Kenya between 2019 and 2054. Three different scenarios were modelled, using the available data. The first scenario was the Business As Usual (BAU), modeling the case as it is with little to no modifications. The second scenario improved the engines' efficiencies by 5% for the train and buses engine and 0.21% for the domestic airplanes, every 5 years from 2029 to 2054. The third scenario, fully electrified the SGR for both freight and passenger trains from 2019 - 2054. The results indicate that the energy demand for electric scenarios is lower than that of diesel-based scenarios, such as Business As Usual (BAU) and Improved Diesel Engine scenarios, this is due to the fact that electric engines are typically more energy-efficient than diesel trains.

1. Introduction

The World Bank reports that "the Paris Agreement targets require reducing transport-related emissions from the current 7.7 Gt (gigatons) CO2 equivalent to reach a goal of 2–3 Gt CO2 by 2050." It further notes that currently "the entire transport sector – the mobility of people and transportation of goods – accounts for approximately 23% of CO2 emissions from fossil fuels or 15% of global greenhouse gas emissions(*KETRACO to Electrify SGR in 28 Months* | KETRACO 2024). Moving from a high to a low-carbon transport sector requires combining tested success strategies that focus on urban integrated multi-modal transport and transit systems."

According to a joint report by International Union of Railways and Community of European Railway and Infrastructure Companies, travelling by rail is on average 3 to 10 times less CO2 intensive compared to road or air transport. Rail transportation emits about 0.2 pounds of CO2 per passenger mile. This number is much lower than those of air transportation, PSVs and personal cars (KETRACO, 2024)

Exactly two weeks before the start of the EMP-A in Ghana, Dr. WIlliam Ruto, President of Kenya hosted a delegation from Uganda led by President Yoweri Museveni. The delegation came to look at some of the issues Kenya and Uganda have been dealing with, especially the Non-Tariff Barriers hindering trade between the two countries. One that was so key was to allow the direct importation of fuel via the port of Mombasa by Uganda National oil Company. Another key outcome of the discussions was the commitment of Kenya extending the Standard Gauge Railway all the way to Malaba, and also the commitment of Uganda to build the SGR from Malaba to Kampala.

In a joint communique signed by the Minister of Works and Transport (GoU), Gen Katumba Wamala, and the Transport counterpart Kipchumba Murkomen, in Mombasa , Kenya, the two countries agreed on the financing and the development of the SGR to Kampala and beyond(*Uganda, Kenya Set to Build SGR*, 2024)

Based on the ambitions for the two countries and the East African region to

1. Increase trade among the member states, and
2. Improve the transport infrastructure focusing on rail,

- Objective and aims

The Kenyan case intends to analyse the transport sector focusing on energy demand on the SGR, if no action is taken in relation to the decarbonisation agenda (BAU), if one of the route to decarbonisation that is adoption of better efficient technologies is adopted during the transition period and finally a scenario of directly electrifying the SGR to handle long haul passenger and freight transport demand as per the initial plan to have it electric driven like the Tanzania SGR train and the proposed Uganda SGR train.

2. Methodology

The Kenya SGR Electrification case used MAED as a tool for the energy demand analysis. The choice of the tool was based on its capabilities where MAED evaluates future energy demands based on medium to long term scenarios of socioeconomic, technological and demographic development. The influences of social, economic and technological driving factors from a given scenario are estimated. These are combined to give an overall picture of future energy demand growth(*Model for Analysis of Energy Demand (MAED-2)*, 2006) (IEA, 2023)

The case building started with the use of the National data sources that were to capture the national economic surveys and the energy statistics data. We relied more on the data shared and captured in the Kenya National Bureau of Statistics (KNBS) as their reports were more accurate in comparison to data from multinational organisations. The following are the links to the data sources that were used to develop the case and the 3 scenarios

Strategy documents

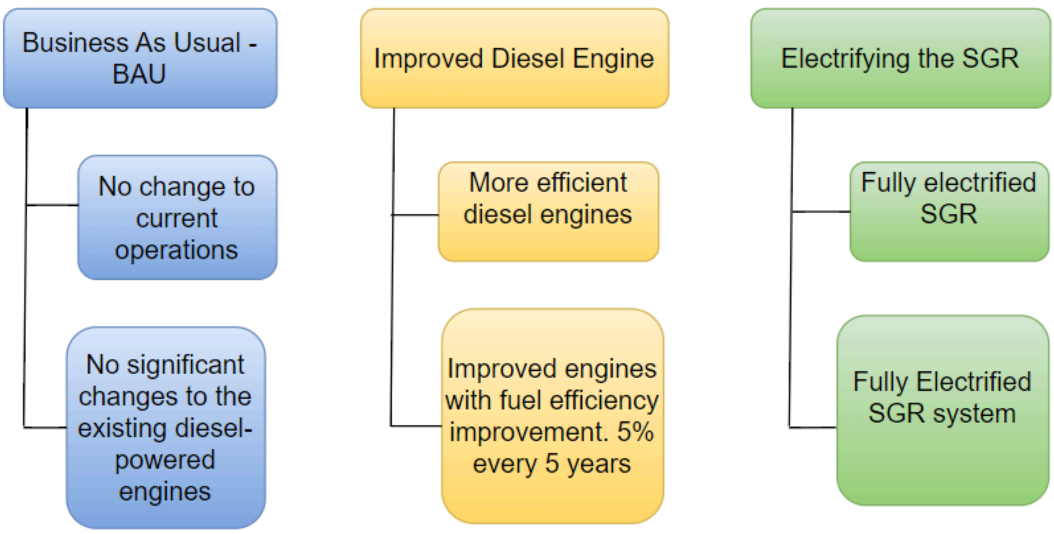
1. Kenya Energy Transition and Investment Plan
2. Least Cost Power Development Plan 2021-2030
3. Kenya Railways strategic document
4. Kenya Vision 2030

Data Sources

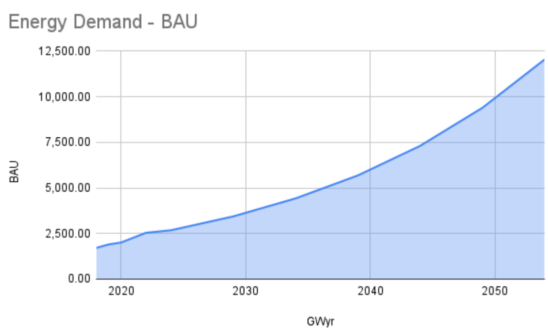
1. Kenya Transport Starter Data Kit 2022
2. KNBS Publications : For accessing the following (A) Economic Survey 2019, 2020, 2021, 2022, 2023. 2024. (B) Leading Economic Indicators (C) Kenya Statistical Quality Assurance Framework Booklet (D) Kenya Demographic and Health surveys, (E) 2019 Kenya Population and Housing Census Results
3. The National Treasury, The State Department for Planning
4. Energy Efficiencies for long distance trucks (freight), long distance buses, and the Airplane plying the Mombasa -Nairobi.
5. International references: (A) International Energy Agency : Energy Systems - Rail tracking (B) World Bank - Urban Population (C) FAO - FAOSTAT

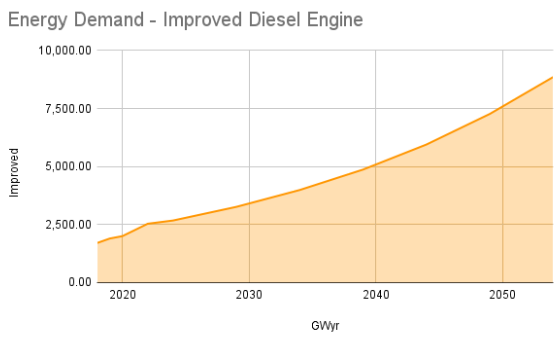
- Assumptions
  1. BAU Scenario: The country's Energy policies remain the same as set to meet the set SDG objectives, NDCs and Vision 2030 strategy documents.
  2. Improved diesel engine efficiency Scenario: Assumption is made that efficiency of the internal combustion engines will have a uniform increase in efficiency through the model years
  3. SGR Fully electric scenario: Assumption is made that as planned, the project for SGR electrification will end on time within budget and set targets

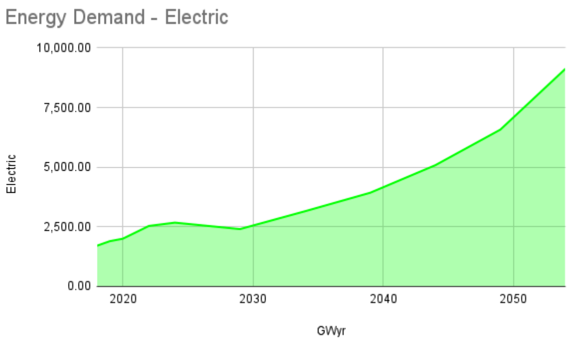
- Scenarios or sensitivity analysis (if applicable)

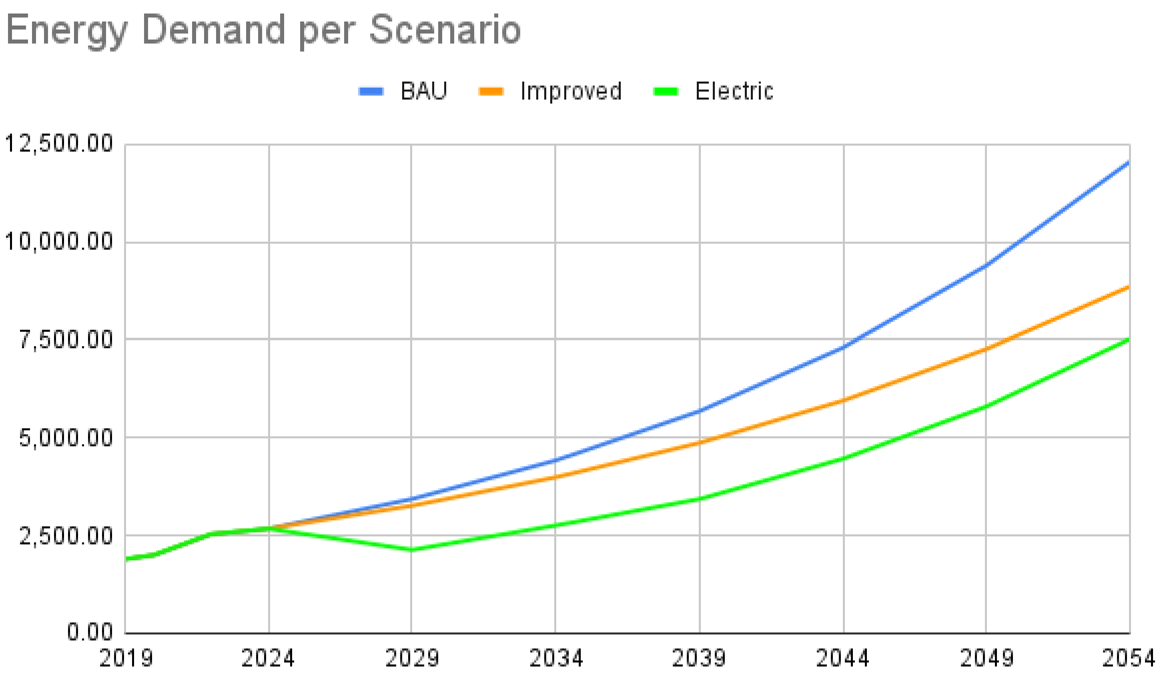


3. Results









The model analysis examined the energy demand of the transport industry mainly the long distance freight and passenger Standard Gauge Railway (SGR), long distance trailers and long distance buses from Mombasa to Nairobi to Kisumu. The analysis was based on three scenarios: Business As Usual (BAU), Improved Diesel

Engine, and Electrified SGR. The focus is on understanding the implications of each scenario in terms of energy demand.

In the BAU scenario, the SGR continues to operate using diesel-powered locomotives. Diesel engines are inherently less efficient, this results in high energy consumption for freight operations. The high energy demand of this scenario is primarily due to the inefficiency of diesel combustion. This translates into significant fuel consumption and associated costs. Moreover, the reliance on diesel fuel exposes the transport system to fluctuations in global oil prices, further exacerbating the operational costs. In terms of energy consumption, maintaining the status quo with increasing population and growing economy, represents a substantial and ongoing demand for fossil fuels.

The Improved Diesel Engine scenario involves the adoption of advanced diesel technologies, which incorporate improvements such as turbocharging and advanced fuel injection systems. The assumption made was that these technological advancements can increase the fuel efficiency of diesel engines by 5%, every five years, reducing energy consumption for freight and passenger operations.

Despite the improvements, the energy demand in this scenario remains relatively high compared to electric alternatives. While advanced diesel engines offer better fuel economy, they still suffer from the fundamental inefficiencies associated with internal combustion engines. This scenario represents a moderate reduction in energy demand compared to BAU but does not achieve the substantial energy savings possible with electrification.

The Electrified SGR scenario envisions a fully electric rail system, where electric locomotives replace diesel engines. Electric trains are significantly more efficient. This high efficiency is due to the direct use of electricity to power the motors, which reduces energy losses typical in combustion engines. Electric trains also benefit from regenerative braking, which recovers and reuses energy that would otherwise be lost during braking.

The lower energy demand in the electrified scenario is a result of the higher efficiency of electric traction and the ability to utilize renewable energy sources for power generation. The electrification of the SGR leads to a reduction in energy demand, providing a more sustainable and cost-effective solution for rail transport. The reduction in energy consumption also translates into lower operational costs over the long term, despite the high initial investment required for electrification infrastructure.

5. Discussion:

- Insights and results implications

These findings suggest substantial cost savings in the long term, despite the high initial investment required for electrification infrastructure. Furthermore, reduced energy demand implies lower greenhouse gas emissions, especially if electricity is sourced from renewable energy, aligning with Kenya's environmental sustainability objectives. Additionally, the transition to electric trains is expected to improve operational efficiency, reducing delays and enhancing service quality.

- Potential technologies/areas worth exploration/policy recommendations (where applicable)

1. Grid Upgrades: Strengthening the national grid to handle the additional load from the electrified railway. This includes investments in transmission infrastructure and smart grid technologies to ensure a stable and reliable power supply.
2. Financial Incentives: Implementing subsidies, tax breaks, and low-interest loans to support the transition to electric trains and related infrastructure.
3. Renewable Energy Integration: To maximize the environmental benefits of electrification, integrating renewable energy sources such as solar, wind, and hydroelectric power into the electricity supply for the SGR is crucial. This would further reduce the carbon footprint of railway operations.
4. Energy Storage Systems: Investing in energy storage solutions like batteries and supercapacitors can enhance the reliability of power supply and enable the efficient use of intermittent renewable energy sources.

- Limitations of study

1. Data Accuracy: The analysis relies on estimated data for energy consumption and efficiencies. Real-world operational data from existing electrified railways would enhance the accuracy of projections.
2. Technological Assumptions: The study assumes certain technological advancements and efficiencies which may not be universally applicable. Variability in technology performance and operational conditions should be considered.
3. Initial Investment Costs: The study highlights the long-term benefits of electrification but does not fully address the significant initial capital investment required. Detailed financial models accounting for funding mechanisms and phased investment plans would be beneficial.

- Potential areas for future research (potential interventions and implementation challenges)

1. Real-World Data Collection: Conducting comprehensive field studies and pilot projects to gather real-world data on energy consumption, operational costs, and performance of electric trains under various conditions.
2. Economic Impact Analysis: Developing detailed economic models to assess the long-term financial viability of electrification, including cost-benefit analyses and sensitivity studies on fuel price fluctuations and maintenance costs.
3. Implementation Challenges: Investigating the logistical and technical challenges of transitioning from diesel to electric, including infrastructure requirements, workforce training, and integration with existing transport networks.
4. Environmental Impact Studies: Conducting in-depth studies on the environmental impacts of electrification, including lifecycle assessments of electric trains and renewable energy infrastructure.
5. Policy and Regulatory Frameworks: Researching and developing policy frameworks that support the adoption of electrified railways, including regulations on emissions, standards for renewable energy integration, and incentives for sustainable practices.
6. Technological Innovations: Exploring advancements in electric train technologies, such as high-efficiency motors, energy recovery systems, and autonomous operation capabilities to further enhance efficiency and reduce costs.

****7. Conclusion** (100-200 words):**

- Recap and lessons learnt

There are quite a number of of lessons learnt through this process of making an analysis of demand case of SGR electrification which include:

1. Search for data that is correct, verifiable and complete. This

- Recommendations

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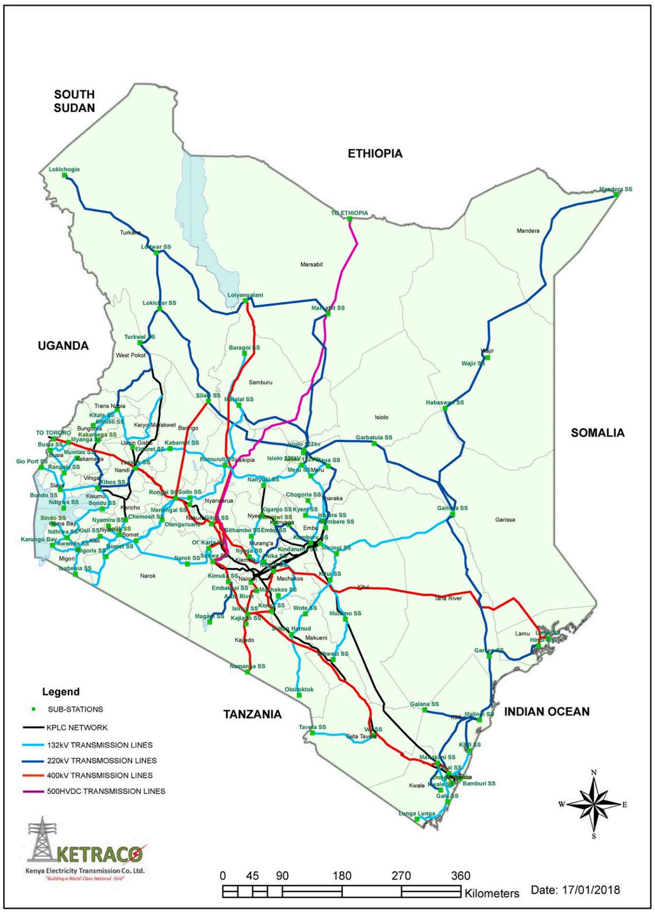
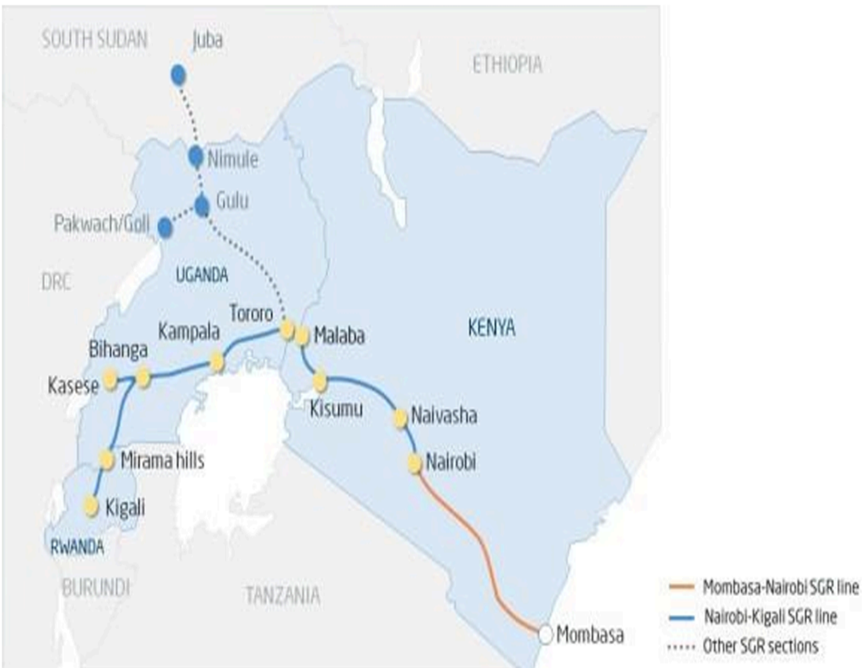
Appendices (as needed, no specific word limit)

1. Kenya National Grid Network by 2030

NATIONAL GRID NETWORK BY 2030





Source: ALG Newsletter, 2017