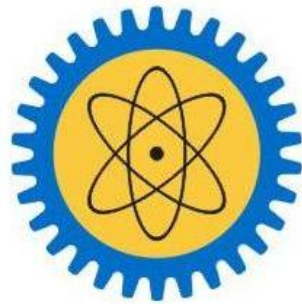




**BUSITEMA
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FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL AND PROCESS

ENGINEERING

FINAL YEAR MASTER'S DISSERTATION

**DESIGN AND MODELLING OF AN AIR CONDITIONING
SYSTEM FOR KAYOOLA ELECTRIC BUSES.**

CASE STUDY: 12 M KAYOOLA EVS

By

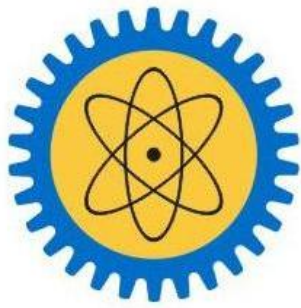
MASEDE JOB

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**This Dissertation is Submitted to the Directorate of Graduate Studies,
Research and Innovation in Partial Fulfillment of the Requirements for the
Award of the Degree of Master of Science in Sustainable Energy Engineering
of Busitema University**

AUGUST 2025



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SUPERVISORS

Eng. Dr. Joseph Ddumba Lwanyaga

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AUGUST 2025

DECLARATION

I, Masede Job, candidate for the Master of Science in Sustainable Energy Engineering of Busitema University declare that this thesis report is my original work, except where due acknowledgement has been made and has never been presented for a degree in any other University and no part of this thesis is plagiarized work.

Signature:

Date:

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APPROVAL

This master's research titled “**Design and Modelling of an Air-Conditioning System for Kayoola Electric Buses**” prepared and submitted by Masede Job in partial fulfillment of the requirements for the Master of Science in Sustainable Energy Engineering of Busitema University has been supervised and is ready for assessment.

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DEDICATION

This research is dedicated to my beloved wife Mirriam Buyinza for the tireless efforts to take care of home and our son during the time when I was so busy with the research and work obligations.

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ABBREVIATIONS OR ACRONYMS

AC	Air Conditioning
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEB	Battery Electric Buses
COP	Coefficient of Performance
DTM	Deep Thermal Mass (J/K)
EVS	Electric Vehicle Solution
FEMP	Federal Energy Management Program
GWP	Global Warming Potential
HBM	Heat Balance Method
HP	Heat Pump
HVAC	Heating, Ventilation and Air Conditioning
kW	Kilowatt
LAT	Low Ambient Temperature
LCCA	Life Cycle Cost Analysis
m_a	Mass of bus cabin air
MAC	Mobile Air Conditioner
MBSE	Model Based Systems Engineering
RTSM	Radiant Time Series Method
SDG	Sustainable Development Goals
SPV	Single Present Value
t_c	Air Conditioning System pull down constant
t_p	Air Conditioning System pull down time
T_{Comf}	Target Bus cabin air temperature
TR	Ton of Refrigeration (12,000 BTU per hour)
UPV	Uniform Present Value
VCC	Vapour Compression Cycle

ABSTRACT

The study aimed to design and model an air conditioning system for the 12 m Kayoola Electric Vehicle Solution (EVS) bus operating under Uganda's tropical climatic conditions. The main objective was to develop, simulate, and validate an optimized AC system that enhances energy efficiency, passenger comfort, and driving range. The specific objectives were: (i) to design the AC system; (ii) to model and simulate the system thermodynamically to obtain optimum performance parameters; (iii) to evaluate field performance in terms of thermal comfort and energy consumption; and (iv) to assess the system's financial viability. The research applied the HBM to compute the total cooling load, yielding 46.245 kW, with motor heat, radiation, and metabolic load contributing the largest share of cabin heat gains. The system was then modelled and simulated in Engineering Equation Solver (EES) software to analyse the vapour compression cycle performance, resulting in an optimum cooling capacity of 41.79 kW at an evaporator temperature of 11 °C. A multi-criteria decision analysis (MCDA) guided the selection of a variable-speed scroll compressor, brushless fans, an electronic expansion valve, and R134a refrigerant, which were integrated into a roof-mounted commercial variable-frequency AC unit. Field tests conducted under sunny and rainy conditions showed that the proposed system reduced specific energy consumption to 0.926 kWh/km, compared to 1.2916 kWh/km for the existing system, extending the driving range from 232 km to 382 km per charge. Cabin temperatures averaged 22.6 °C, maintaining comfort within ISO 7730 standards, with 96% passenger satisfaction recorded. Financial evaluation using the Federal Energy Management Program (FEMP) life cycle cost model revealed long-term savings of USD 18,929.25 over 20 years despite a slightly higher initial cost. The results confirm that a variable-capacity AC system, optimized for local climatic conditions, can significantly improve energy efficiency, passenger comfort, and operational economy of electric buses, supporting the advancement of sustainable urban mobility in Sub-Saharan Africa.

Keywords

Kayoola EVS, AC Systems, Energy Efficiency, Tropical Climates, Life Cycle Cost Analysis

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