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Energy Efficiency Infrastructure and Regulatory Readiness for Small-Scale Industrial Buildings in Tanzania: A Systematic Review of Technologies, Policy Gaps, and Implementation Pathways

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Abstract

Small-scale industrial buildings are vital to Tanzania's local manufacturing, agro-processing, and employment sectors, but their Energy Efficiency (EE) is hampered by inefficient motors, poor lighting, limited metering, inadequate maintenance, weak audit practices, and fragmented regulations. A systematic review was employed to assess EE infrastructure and policy readiness in these buildings, focusing on technologies, policy gaps, barriers, and implementation strategies. Using a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-guided approach, literature was selected from ScienceDirect, Google Scholar, and supported by policy and standards documents. Out of 10,112 records plus 53 additional sources, 105 studies and documents were included in the analysis. The review indicates significant energy savings are possible through the adoption of high-efficiency motors, variable-speed drives, Light-Emitting Diode (LED) lighting, power-factor correction, leak control in compressed air, efficient refrigeration, improved building envelopes, heat recovery, smart meters, and simpler Energy Management Systems (EMS). Yet, barriers such as poor baseline data, limited funding, low awareness, technical skill gaps, fragmented institutional roles, and weak enforcement hinder implementation. The study offers an integrated framework connecting baseline auditing, benchmarking, loss detection, technology choices, funding, regulation, monitoring, verification, and ongoing improvement. Future research should develop standardized energy-use benchmarks and evaluate cost-effective retrofit models for Tanzanian small industrial facilities. These insights support data-driven policies to promote a sustainable industrial energy transition nationwide.

Keywords: Energy efficiency, Small-scale industrial buildings, Regulatory readiness, Energy audit, Smart metering.

1 | Introduction

Energy Efficiency (EE) is widely recognized as one of the lowest-cost pathways for reducing energy demand, improving productivity and supporting climate-resilient economic development [1]. In industrial buildings,

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energy is consumed by both production equipment and building services, including motors, pumps, compressors, welding machines, dryers, refrigeration systems, lighting, ventilation and auxiliary office loads [2]. For small-scale industries, energy saving is not only an environmental issue but also a competitiveness issue because electricity and fuel costs directly affect production cost, product price and business survival [3].

Small-scale industrial buildings are important for Tanzania because they support employment, local manufacturing, agro-processing, repair services, food processing and value addition to agricultural products [4], [5]. Their energy performance, however, is usually shaped by incremental construction, low capital availability, weak design documentation, limited metering and equipment procurement based mainly on initial cost rather than lifecycle energy cost [6]. Similar Small and Medium-sized Enterprises (SME) studies show that technology adoption is affected by barriers in management, finance, information, energy-audit communication and policy support [7].

The Tanzanian building-energy discussion has recently expanded through green building studies, including evidence on stakeholder knowledge, energy performance of green and non-green buildings in Dar es Salaam, and barriers to green building adoption [8], [9]. These studies confirm that sustainable building uptake is affected by technical knowledge, awareness, policy implementation, financing and local capacity [10], [11]. Nevertheless, there remains limited integrated review evidence focused specifically on small-scale industrial buildings, where process energy, building energy, electrical safety, regulation, finance and enterprise behaviour intersect [12].

The central problem addressed in this paper is that existing literature often treats building EE, industrial energy management, green building practice and energy policy as separate subjects [13]. In practice, small industrial buildings require an integrated approach because energy losses can occur simultaneously in machines, electrical networks, thermal processes, building envelopes and user behaviour [14]. A publishable review therefore needs to synthesize technology, regulation, institutional readiness, barriers and implementation pathways rather than merely listing energy-saving devices [15].

The objective of this paper is to critically review EE infrastructure, regulatory readiness, implementation barriers and future pathways for improving energy performance in small-scale industrial buildings in Tanzania. The specific objectives are to identify energy-consuming systems, review appropriate technologies, examine regulatory and policy readiness, compare international lessons, identify research gaps, and propose a practical implementation framework suitable for Tanzania.

2|Review Methodology

A systematic literature-based review method was adopted to ensure transparency, reproducibility, and relevance [13], [16]. The review focused on peer-reviewed journal articles published between 2016 and 2026, with some in other years for more supporting evidence and emphasis on industrial EE, SME energy management, building energy performance, energy audits, green buildings, digital monitoring, policy design, and developing-country implementation barriers [16]. Selected Tanzanian policy and institutional documents were used for contextual interpretation, but the evidence base of the review was anchored mainly in journal literature [7].

The databases considered were ScienceDirect and Google Scholar. Search terms included were: "industrial EE" AND (SME OR SMEs OR "small and medium enterprises"), "small-scale industrial buildings" AND "EE", "energy audit" AND (SME OR SMEs OR "small and medium enterprises"), "Energy Management System (EMS)" AND (SME OR SMEs OR "small and medium enterprises"), "EMS" AND (SME OR SMEs OR "small and medium enterprises"), "building energy performance" AND "industrial buildings", "green building" AND Tanzania, "EE policy" AND (SME OR SMEs OR "developing countries"), "smart metering" AND "EE" AND (SME OR SMEs OR buildings)" AND "Energy saving, "smart metering" AND "EE" AND (SME OR SMEs OR buildings) "AND "energy saving "AND " (energy Regulation " OR " Energy policy "OR " energy framework), "EE barriers" AND (SME OR SMEs OR "small and medium enterprises"), "EE" AND Tanzania AND (industry OR buildings OR SMEs.

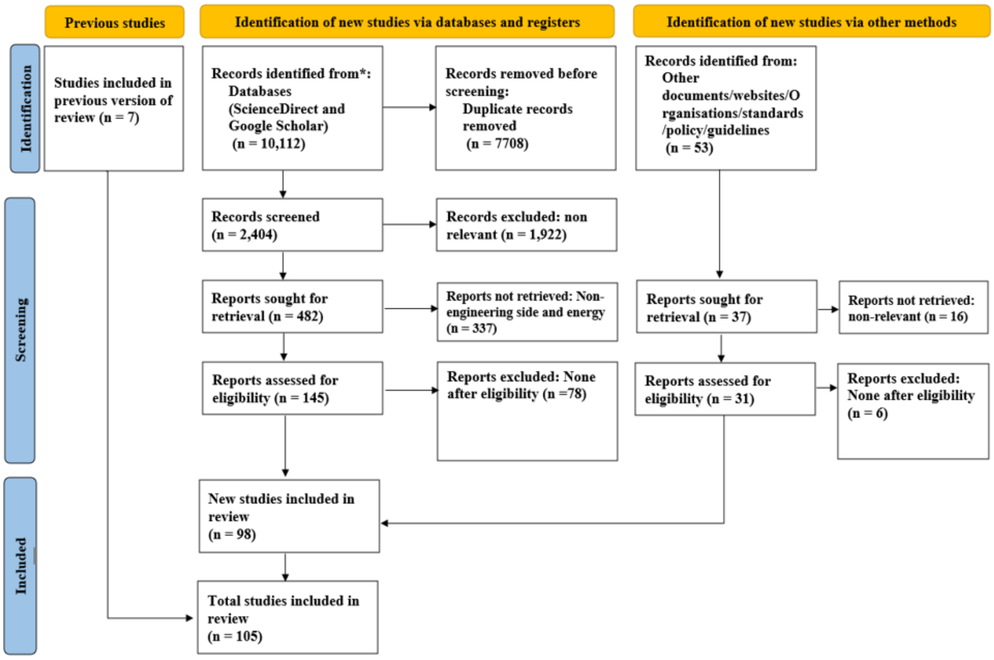

Fig. 1. PRISMA flow diagram for source selection.

The search results from the search terms were as shown in *Fig. 1*, which started with 7 previous studies and 10,112 new records from 3214 ScienceDirect results and 6898 Google Scholar results. After screening, 7,708 duplicate records were removed, leaving 2,404 records for screening. From these, 1,922 non-relevant records were excluded, and 482 reports were sought for retrieval. After removing 337 non-engineering or non-energy-related reports, 145 reports were assessed for eligibility. Finally, 98 new studies were included from databases.

In addition, 53 records were identified through other methods such as websites, organizational documents, standards, policies, and guidelines. After retrieval and eligibility screening, 31 documents were retained. Overall, the review included 105 total studies/documents, made up of 7 previous studies, 98 new database studies, and supporting documents from other methods

3 | Definition and Scope of Small-Scale Industrial Buildings in Tanzania

In this paper, small-scale industrial buildings refer to physical premises used by micro, small and medium industrial enterprises for production, repair, processing, storage or value addition [4]. Examples include welding workshops, carpentry workshops, garages, milling facilities, bakeries, textile units, food-processing premises, cold rooms and agro-processing plants [17]. These buildings differ from ordinary commercial buildings because process equipment may dominate energy demand, but they differ from large factories because they normally have lower capital capacity, limited formal energy management and fewer specialized technical staff [18].

The energy systems of small industrial buildings should be understood as mixed systems [19]. A single building may include electrical process loads, thermal process loads, refrigeration, ventilation, lighting, Information and Communication Technology (ICT) loads, and sometimes rooftop solar Photovoltaic (PV) or backup generators [20]. Consequently, EE requires both engineering measures and organizational measures such as staff training, energy data recording, maintenance planning, and management commitment [21]. *Table 1* shows the classification of small-scale industrial buildings and energy-saving opportunities.

Table 1. Classification of small-scale industrial buildings and energy-saving opportunities.

Type of Facility	Typical Energy-Consuming Systems	Main Efficiency Opportunities	References
Food-processing unit	Motors, mixers, ovens, boilers, dryers, refrigeration, lighting	Efficient motors, insulation, heat recovery, efficient refrigeration, production scheduling	[4], [22], [23], [24]
Welding and metal workshop	Welding machines, compressors, grinders, lighting, ventilation fans	Efficient welding machines, power-factor correction, leak management, and Light-Emitting Diode (LED) lighting	[4], [20], [25]
Carpentry and wood workshop	Saws, planers, dust extraction, motors, lighting	Efficient motors, dust-extraction control, maintenance, daylighting and Variable Speed Drive (VSDs)	[26], [27], [28]
Agro-processing/milling	Mills, conveyors, motors, dryers, pumps, packaging equipment	High-efficiency motors, load management, dryer insulation and preventive maintenance	[4], [17], [24]
Cold room or storage	Compressors, evaporators, fans, lighting, door heaters	Insulation, door sealing, efficient compressors, temperature control and monitoring	[13], [29], [30]
Garage/repair workshop	Compressors, lighting, welding, pumps, hand tools	Compressed-air leak control, LED lighting, power management and safer wiring	[4], [6], [7]
Small manufacturing premise	Mixed process equipment, motors, lighting, ventilation, ICT	Sub-metering, energy audit, motor upgrade, process scheduling and EMS	[3], [19], [31]

4|Energy-Consuming Systems and Efficiency Infrastructure

EE infrastructure includes the physical, electrical, thermal and digital systems that reduce energy waste while maintaining output quality [27]. In small industrial buildings, the largest opportunities are usually found in motors, compressed air, refrigeration, process heating, lighting, ventilation, power quality and operational control [28]. Evidence from industrial energy-efficiency literature shows that barriers and drivers vary by sector and technology; therefore, recommendations must be adapted to the facility type and managerial capacity [32].

4.1|Electrical Systems

Electrical efficiency measures include high-efficiency motors, variable-speed drives, LED lighting, proper cable sizing, phase balancing, capacitor banks, efficient transformers, protection devices, and preventive maintenance [25]. Motors are central because many industrial processes use pumps, fans, compressors, mills, saws, and conveyors [33]. Oversized motors, worn bearings, poor alignment, poor maintenance, and continuous operation under partial load can waste energy and reduce equipment life [26]. Power-factor correction is particularly relevant where inductive loads such as motors, transformers, and welding equipment are common [20]. A low power factor increases current, raises distribution losses, and may reduce voltage quality [19]. Automatic capacitor banks, load balancing, and routine electrical inspection can therefore improve EE and reliability at the same time. For small enterprises, these measures should be packaged with simple payback calculations so owners can see the business benefit.

4.2 | Thermal and Process Systems

Process efficiency depends on the industrial activity [22]. Bakeries, dryers, boilers, food-processing units and agro-processing plants can reduce losses through insulation, heat recovery, improved burners, steam leak control and better temperature control [34]. Cold rooms can reduce energy demand through insulation, door sealing, efficient compressors, correct refrigerant charging and disciplined operating practice [24]. Compressed-air systems can save energy by leak detection, pressure optimization and avoiding compressed air for cleaning where lower-energy alternatives exist.

4.3 | Building Envelope and Passive Design

Building-level measures are important because industrial productivity and equipment performance are affected by indoor heat, lighting and ventilation [13], [35]. Relevant passive strategies for Tanzania include reflective roofing, roof insulation, natural ventilation, daylighting, external shading, controlled openings, improved roof ventilation and climate-responsive layout [14]. Building energy literature shows that technology selection should be integrated with building physics and user behaviour instead of being treated as isolated equipment replacement [36]. For small-scale industrial buildings, passive design has practical value because it can reduce the need for mechanical cooling and lighting while improving worker comfort [12]. However, passive measures must be aligned with safety and industrial hygiene. For example, natural ventilation should not spread dust, welding fumes or process contaminants; daylighting should reduce lighting demand without causing glare; and thermal insulation should be selected according to local material availability and fire safety [37]. Digital monitoring is increasingly important because energy cannot be effectively managed without data [38], [39]. Smart meters, sub-metering, low-cost data loggers, energy dashboards and Internet of Things sensors can help small enterprises identify which machines consume the most energy, when peak demand occurs and whether savings have been achieved after intervention [40], [41]. Advanced artificial intelligence can support prediction and optimization, but small enterprises first need affordable measurement, understandable dashboards, and trained users, as shown in *Fig. 2* [30].

EMS institutionalize energy responsibility by assigning roles, collecting data, setting targets, implementing measures, and verifying results [18], [42]. Full International Organization for Standardization (ISO) 50001 implementation may be demanding for very small enterprises, but simplified energy management routines can be applied: Monthly energy review, equipment inventory, maintenance logs, energy-saving targets, and management accountability [6], [31]. Studies on SMEs indicate that communication, trust, and actionable advice are necessary for audit recommendations to become real investments [21]. *Table 2* shows Energy-consuming systems, common inefficiencies, and recommended infrastructure in SMEs.

4.4 | Digital Monitoring and Energy Management

Table 2. Energy-consuming systems, common inefficiencies and recommended infrastructure.

Energy System	Common Inefficiency	Infrastructure/Measure	Expected Implementation Level	References
Motors and drives	Oversizing, poor maintenance, fixed-speed operation	High-efficiency motors, VSDs, alignment, bearing maintenance	Short to medium term; prioritize high-use motors	[4], [26], [27]
Lighting	Old lamps, poor daylighting, unnecessary operation	LED lighting, daylight controls, occupancy switching	Short term; low complexity and visible savings	[13], [14], [29]

Table 2. Continued.

Energy System	Common Inefficiency	Infrastructure/Measure	Expected Implementation Level	References
Compressed air	Leaks, high pressure, misuse for cleaning	Leak repair, pressure optimization, efficient compressors	Short to medium term; requires routine maintenance	[22], [24], [25]
Refrigeration	Poor insulation, leaking doors, old compressors	Door sealing, insulation, efficient compressors, monitoring	Medium term; important for cold rooms and food storage	[13], [29], [30]
Process heat	Uninsulated boilers, dryers, steam leaks	Insulation, heat recovery, burner tuning, steam management	Medium term; depends on thermal process type	[22], [24], [34], [43], [44]
Power quality	Low power factor, unbalanced phases	Capacitor banks, phase balancing, electrical inspection	Short term; improves reliability and may reduce penalties	[19], [20], [42]
Building envelope	Heat gain, poor ventilation, low daylight	Reflective roof, insulation, shading, natural ventilation	Medium term; best during new construction or renovation	[36], [37], [45]
Monitoring	No sub-metering, no baseline data	Smart meters, loggers, dashboards, energy audits	Immediate foundation for all future measures	[30], [31], [46]

Fig 2 shows how primary energy sources such as crude oil, coal, natural gas, renewables, hydropower, nuclear power, and biomass are transformed into useful energy services. The diagram shows that energy passes through conversion stages such as refining, electricity and heat generation, transportation, industry, and residential/commercial use. A major message of the figure is that large amounts of energy are lost during conversion and final use, especially in transportation, electricity generation, and residential/commercial sectors. Therefore, EE and energy management are important for reducing losses and improving useful energy output. These findings show that there are many points where energy is lost that need to be identified and improved [17]. The values in *Fig. 2* are expressed in EJ, which means exajoules, and 1 EJ = 10^{18} joules.

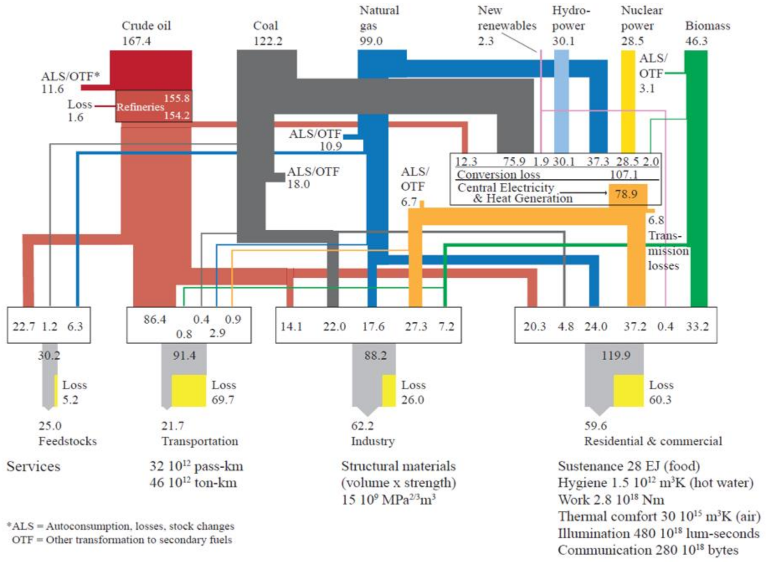

Fig. 2. Energy flows from the source to useful energy, and the energy loss during conversion from one form of energy to another is expressed in EJ [17].

5 | Regulatory and Policy Readiness

Regulatory readiness is the capacity of the policy system to convert energy-efficiency goals into measurable action at the facility level [15]. It includes standards, enforcement, incentives, audits, labels, procurement rules, financing mechanisms, inspection capacity and monitoring systems [47]. In small industrial buildings, regulation should not be limited to general policy statements; it must create practical pathways for equipment standards, electrical safety, efficient building design, energy audits, technology financing and compliance verification [48].

Tanzania has begun to strengthen the policy environment for EE and green building uptake, but journal evidence indicates that implementation is slowed by low awareness, limited technical skills, weak incentives, fragmented responsibilities and insufficient mandatory frameworks [8], [11]. Green building literature from Tanzania is particularly useful because it shows that energy-efficient technologies must be supported by knowledge, regulation and local capacity [12]. The same logic applies to small industrial buildings [9].

International evidence suggests that energy audits, financial support, voluntary agreements, information programmes and energy-management assistance can increase SME EE when they are targeted and followed up [7], [46]. However, audits alone do not guarantee implementation [5]. Policy must convert audit findings into investment decisions by providing trusted information, financial products, certified suppliers, monitoring and an enforcement or incentive mechanism [24]. *Table 3* shows Policy, guidelines, regulations and frameworks for EE implementation in SMEs in Tanzania.

Table 3. Policy, guidelines, regulations and frameworks for energy efficiency implementation in SMEs in Tanzania.

Policy, Guideline, Regulation or Framework	Function	Weakness/ Challenge in SMEs	How to Solve Them	References
National EE Strategy 2024–2034	Provides national direction for EE in buildings, manufacturing, mining, transport and electricity supply	Implementation may remain general if small industries are not given sector-specific targets and simple compliance tools.	Develop SME-specific energy-efficiency guidelines, audit templates, incentives and monitoring indicators.	[49]
Energy audit guidelines for SMEs	Identify energy losses in motors, lighting, compressors, refrigeration, process heat and building systems.	Many SMEs lack skilled auditors, baseline data and money to implement audit recommendations.	Use simplified audit checklists, train local auditors, subsidize audits and link audit findings to financing.	[7], [24]
ISO 50001 energy management framework	Provides a structured EMS based on planning, implementation, checking and continual improvement	Full ISO 50001 certification may be too costly and complex for small enterprises.	Apply a simplified ISO 50001-based model using monthly energy review, energy targets, maintenance logs and staff responsibility.	[3], [4], [19], [50]

Table 3. Continued.

Policy, Guideline, Regulation or Framework	Function	Weakness/ Challenge in SMEs	How to Solve Them	References
Minimum energy performance standards for equipment	Prevents inefficient motors, lamps, compressors, appliances and industrial equipment from entering the market	SMEs often buy equipment based on low initial cost rather than lifetime energy cost.	Enforce standards, promote certified efficient equipment and provide tax relief or green loans for efficient technologies.	[46], [51]
Building energy-efficiency guidelines	Guide passive design, daylighting, ventilation, insulation, roof treatment and efficient building services.	Small industrial buildings are often built incrementally without energy-conscious design.	Link energy-efficiency guidance with building permits, industrial estate planning and renovation approval	[8], [13], [51]
Green building framework	Promotes sustainable materials, efficient technologies, water saving, indoor comfort and lower environmental impact	Green building adoption in Tanzania is limited by awareness, cost, technical capacity and weak mandatory requirements.	Provide local green building guidelines, training, demonstration projects and incentives for efficient industrial premises.	[8], [9]
Financial incentive policy	Reduces upfront cost of efficient motors, VSDs, LED lighting, insulation, refrigeration and smart meters	SMEs may reject energy-efficiency measures because of high initial cost and short payback expectations.	Introduce green credit lines, tax incentives, equipment leasing and results-based financing.	[52–54]
Energy-efficiency awareness and training framework	Builds knowledge among owners, electricians, technicians, building inspectors and facility operators	Low awareness and poor communication reduce adoption of energy-saving measures.	Use sector-based training, local language materials, peer learning and certified energy-auditor programmes.	[6], [55], [56]

Table 3. Continued.

Policy, Guideline, Regulation or Framework	Function	Weakness/ Challenge in SMEs	How to Solve Them	References
Smart metering and energy data reporting guideline	Provides data for benchmarking, monitoring, verification and energy-saving decisions	Many SMEs do not have sub-metering or machine-level energy data	Install affordable smart meters, create simple dashboards and develop national SME energy-use benchmarks	[30], [57], [58]
Inspection and compliance regulation	Ensures that energy-efficiency, electrical safety, power quality and building-performance requirements are followed	Enforcement may be weak because responsibilities are spread across different institutions.	Create clear compliance workflow involving energy regulators, standards bodies, local authorities and building inspectors.	[15], [59]
Energy service company/performance contracting framework	Allows SMEs to implement efficiency measures with payment linked to verified savings	SMEs may not trust savings estimates and may lack contractual knowledge	Use standardized contracts, measurement and verification protocols, certified suppliers and pilot projects	[25], [60]
Efficiency-first renewable-energy framework	Ensures solar PV and backup systems are sized after reducing demand through efficiency measures	SMEs may install oversized PV or batteries without first reducing inefficient loads.	Conduct energy audit first, reduce demand, then size rooftop PV and storage based on optimized load.	[61–63]

6 | International Lessons for Tanzania

International SME energy-efficiency studies provide several lessons for Tanzania [28]. First, EE programmes should segment enterprises by size, sector, energy intensity and decision-making capacity rather than using one message for all SMEs [6]. Second, audit recommendations must be converted into practical business cases [27]. Third, trusted intermediaries, peer learning and sector associations can improve communication [5]. Fourth, programmes require follow-up because many enterprises accept energy-saving advice but delay implementation. European and other international policy experience shows that energy-efficiency measures work better when audits, subsidies, standards, capacity building and monitoring are combined [7], [19]. Industrial energy management research also shows that organizational practice matters: the presence of a responsible person, management review, maintenance culture, staff training and performance indicators increases the chance of sustained savings [3], [20]. For Tanzania, these lessons suggest that small industrial buildings should be approached through a stepwise framework: start with simple audits and low-cost measures; support medium-cost retrofits with financing; introduce sub-metering and benchmarks; and strengthen regulation as market capability improves [46], [64]. This staged approach reduces the risk of designing a policy that is technically correct but difficult for small enterprises to implement [17]. *Table 4* shows international policies and directives promoting EE and a low-carbon economy witch can be a lesson to Tanzania.

Table 4. International policies and directives promoting energy efficiency and a low-carbon economy.

Policy	Contextualization	Lesson to Tanzania	References
Paris Agreement	A worldwide agreement intended to limit global warming to well below 2 °C and pursue efforts toward 1.5 °C. Countries are required to submit national climate action plans, although the agreement does not itself prescribe all specific technical measures for energy-system decarbonization.	Should align industrial-building EE with national climate action plans by reducing energy waste, improving efficient technologies, and lowering emissions from SMEs	[65]
2012 EE Directive and 2018 Amendment	Establishes rules and obligations for European Union (EU) Member States to achieve EE targets. It promotes energy savings, public-sector energy reduction, consumer protection, technical assistance, one-stop shops, and financial advice for consumers.	Can introduce clear energy-efficiency obligations, energy audits, technical assistance, consumer protection, and financial advice for SMEs and small industrial buildings	[66], [67]
2030 Climate and Energy Framework	Establishes EU targets for the 2021–2030 period, including greenhouse gas emission reduction, renewable-energy share increase, and energy-efficiency improvement	Should set measurable national targets for EE, renewable-energy adoption, and greenhouse-gas reduction in buildings and industries	[68]
European Green Deal	A roadmap for achieving the EU long-term 2050 strategy, with emphasis on near-zero greenhouse gas emissions, clean energy transition, EE, renewable-energy integration, modern infrastructure, product eco-design, gas-sector decarbonization, smart integration, and offshore wind development	Can use EE as part of a wider green-industrial transition by promoting clean energy, efficient infrastructure, eco-design, and low-carbon technologies	[69]
Fit for 55 Package	A set of policy proposals intended to reduce EU emissions by at least 55% by 2030. It includes reform of the EU Emissions Trading System, stronger targets for non-ETS sectors, transport decarbonization, methane reduction, aviation and maritime emission measures, increased renewable-energy share, higher energy-efficiency targets, and transformation of buildings toward zero-emission performance	Strengthen sector-specific policies for transport, buildings, industries, and energy systems, with clear targets for emission reduction and efficient energy use.	[70]

Table 4. Continued.

Policy	Contextualization	Lesson to Tanzania	References
REPowerEU	An EU strategy designed to reduce dependence on imported fossil fuels and address the climate crisis. It promotes higher energy-efficiency targets, increased renewable-energy share, and reduced fossil-fuel use in industry and transport.	Reduce dependence on expensive or unreliable energy sources by improving EE, expanding renewable energy, and reducing fossil-fuel use in industries.	[71]
European Industrial Strategy	A policy package supporting the green and digital transition of European industry. It promotes sustainability, digitalization, cooperation among member states, clean-technology research, renewable-energy investment, grid development, and industrial competitiveness.	Connect industrial development with green technology, digitalization, renewable energy, and energy-efficient production to increase competitiveness.	[72]
EU Strategy for Energy System Integration	A strategy combining the aims of the European Green Deal and the EU 2050 long-term strategy. It is built around three pillars: EE and circular economy, renewable-based electrification, and alternative low-carbon fuels such as green hydrogen, carbon capture and storage, and carbon capture and utilization.	Apply the energy-efficiency-first principle, promote waste-heat recovery, renewable-based electrification, energy storage, and integration of clean energy into industrial systems.	[73]
Sweden/Europe Communication and trusted energy-audit advisory framework	Communication, trust and clear explanation strongly influence whether SMEs implement energy-efficiency recommendations	Use local trusted auditors, practical language and sector-based awareness programmes	Framework source: [6], [27], [74]
Lithuania — SME energy-audit database and benchmarking guideline	Audit databases are used to analyse energy-saving opportunities, impacts and sector patterns among SMEs	Build a Tanzania SME audit database for benchmarking, policy design and retrofit prioritization	Guideline source: [24], [75]
Uganda — Industrial energy-efficiency institutionalization framework	Institutional barriers, weak capacity and poor coordination slow industrial energy-efficiency implementation	Strengthen institutional coordination, professional training and national implementation responsibility	[64]
Germany — Workplace energy culture and SME energy-efficiency behaviour framework	Employee behaviour, management culture and internal routines influence energy-efficiency adoption	Promote workplace energy culture, staff responsibility, maintenance routines and simple energy-saving targets	Framework source: [42], [76]
United Kingdom (UK)— SME energy-efficiency policy design framework	SME policy works better when it addresses finance, time, information and organizational-capacity barriers	Design SME policies that reduce upfront cost, simplify audits and provide business-oriented savings evidence	Policy source: [21], [48], [77]

Table 4. Continued.

Policy	Contextualization	Lesson to Tanzania	References
Italy/European manufacturing SMEs — Sector-based SME classification guideline for energy-efficiency programmes	Barriers, drivers and decision-making processes differ across SMEs and technologies.	Avoid one-size-fits-all policy; classify Tanzanian SMEs by sector, energy intensity and investment capacity.	Framework source: [4], [22], [78]
Kenya — Commercial and industrial energy-efficiency regulatory guide	Energy-efficiency projects focus on motors, pumps, compressed air, HVAC, lighting and heat-recovery opportunities	Start with practical high-impact systems such as motors, pumps, compressed air, refrigeration and lighting	Regulatory source: [79], [80]
South Africa — Verified energy-savings incentive and tax-support framework	Financial incentives and tax-based support encourage companies to implement verified energy savings	Develop tax relief, green loans or performance-based incentives for verified SME energy savings	Regulatory source: [7], [81], [82]

7 | Barriers to Implementation in Tanzania

The barriers affecting small-scale industrial building EE can be grouped into financial, technical, informational, regulatory, institutional and behavioural categories [4]. Financial barriers include high upfront cost, limited access to credit, short payback expectations and competition with immediate production needs [2]. Technical barriers include limited energy-audit capacity, poor equipment sizing, weak maintenance and limited access to certified efficient technologies [5].

Informational barriers include weak metering, poor understanding of energy bills, absence of machine-level energy data and uncertainty about savings [1]. Regulatory barriers include weak enforcement, lack of sector-specific benchmarks and limited connection between building approvals, electrical inspections and energy-efficiency requirements [6]. Institutional barriers arise where responsibilities are distributed across energy regulators, standards agencies, local authorities, building inspectors, financial institutions and industrial development bodies [15].

Behavioural and organizational barriers should not be underestimated [36]. Owners may prioritize production output and equipment repair over energy performance [35]. Staff may bypass controls, leave equipment operating during idle periods, or lack maintenance routines [21]. The review literature shows that durable EE requires social, managerial, and behavioural engagement, not only technical replacement. Avoiding or reducing this energy barrier can lead to high energy savings and lower running costs, as shown in *Table 5*.

Table 5 shows the energy-efficiency case studies from different small-scale industries and SMEs, including chemical plants, food and beverage industries, bakeries, breweries, metal manufacturing, construction, glass production, printing, and coffee roasting. It shows that energy savings can be achieved through practical measures such as efficient climate control, LED lighting, natural lighting, solar PV, gas-leakage elimination, waste-heat recovery, Combined Heat and Power (CHP) systems, insulation, improved machinery, efficient process control, and smart sensors. The reported savings range from small cost reductions, such as USD 400 per year in lighting bills, to large savings such as 421 GWh/year in steam processes. The table demonstrates that EE can reduce energy consumption, operating costs, and carbon emissions while improving productivity and business competitiveness. For small-scale industries, the main lesson is to begin with simple, low-cost actions before investing in advanced technologies [17].

Table 5. Energy saving from the selected small-scale industries and SME case studies [17].

Sector	Case Study	Implemented Measures	Savings	References
Chemical industry	SATECMA plant	More efficient climate-control systems; LED lamps; better use of natural light; PV solar-energy generation plant.	20% in total energy	[83]
Chemical industry	Chemical plant in the UK	Elimination of gas leakages associated with boiler supply	30% in total energy	[84]
Chemical industry	Wacker Chemie AG plant	Waste-heat recovery; CHP systems; connection of surplus heat sources to heat sinks through local heating networks	421 GWh/year in steam processes; 44 GWh/year in facility heating and hot-water preparation	[85]
Food and beverage industry	World-leading producer of Scotland's national dish haggis	Efficient cooking methods; staff training; waste-heat recovery from refrigerators; improved control of heating, cooling and lighting; efficient lighting replacement	15% reduction in gas bills from 2006–2008	[84]
Food and beverage industry	Brewery in Aying, Germany	CHP system with 200 kW electrical capacity and 230 kW thermal output; in-house electricity use; excess electricity supplied to public grid	20% in electricity; 100 tons/year reduction in CO_2 emissions	[86]
Food and beverage industry	Krones A brewery	"EquiTherm" process using waste-heat recovery to reduce heating, cooling and freshwater requirements	20% in electricity; 30% in thermal energy	[87]
Food and beverage industry	Rager bakery	Optimized baking processes and oven use; reduced refrigerator use; improved cold-room insulation; refrigeration waste-heat recovery for hot water; LED lighting; shorter dishwasher programme; hybrid vehicle	2.5 k EUR/year	[86]
Food and beverage industry	Bakery in Germany	Maintenance of bake ovens; LED lighting; improved hot-water use; pipe insulation; thermostat recalibration	6.5% energy	[88]
Food and beverage industry	Cupcakes of Westdale Village company	Improvement of lighting equipment	USD 400/year in electricity bills	[89]

Table 5. Continued.

Sector	Case Study	Implemented Measures	Savings	References
Metal manufacturing industry	AMB Alloys Ltd	Energy-efficiency improvement through a completely new production plant	4.3 MWh/year in total energy; 1.7 CO_2 tons/year	[90]
Construction	Lagodekhautogza Ltd	Upgrade of old machinery to more recent and efficient machinery	Production volume increased by 55%; 160 MWh/year in total energy	[90]
Construction	Mshenebeli 2019	Replacement of natural-gas-based heat generator with biomass-based solid-fuel heat generator	USD 126,400/year in fuel bills	[90]
Miscellaneous sectors	Liquid gases company in Denmark	Ozone unit and sand-filter technology to reduce cooling-water temperature	153 MWh/year in total energy; USD 50k, 12k and 20k/year savings in process chemicals, corrosion inhibitors and corrosion, respectively	[91]
Miscellaneous sectors	Firozabad heat-recovery system	Glass-sector SME cluster implemented simple waste-heat recovery system	25–30% in total energy	[92]
Miscellaneous sectors	Druckerei senser	New printing machines; solar-power system; roof thermal insulation; waste-heat recovery from printing process to neighboring rooms	30% in total power; 25% in total electricity; 20% in heating	[93]
Miscellaneous sectors	Reunion Island Coffee Roasters company	LED lighting panels; six motion-activated occupancy sensors; five thermostats; reflective window tint; energy-efficient coffee-roasting machine	25% in electricity bills	[94]

8 | Research Gaps and Future Research Priorities

The main research gap is the absence of measured energy-use intensity benchmarks for Tanzanian small-scale industrial buildings [24]. Without data on kWh per square metre, kWh per unit output, peak demand, load factor and power quality, it is difficult to design targeted policy or evaluate savings [95]. Energy audits should therefore become a research and policy tool, not only an engineering service [34].

A second gap is the limited integration between building energy performance and process energy performance [10]. Many studies examine office buildings, green buildings or industrial energy management separately, but small industrial buildings combine all three [13]. Future research should therefore examine how envelope design, ventilation, lighting, machine efficiency, process heat and renewable-energy systems interact in real facilities [96], [97].

A third gap concerns digital readiness [40], [98]. Smart energy management research is rapidly developing, including AI and predictive control, but small enterprises require affordable and maintainable solutions [38]. Future Tanzanian studies should test low-cost sub-metering, mobile dashboards, simple anomaly detection and maintenance alerts before assuming advanced AI adoption [29].

A fourth gap is policy effectiveness [1], [99]. More work is needed to evaluate whether audits, incentives, equipment standards and building guidelines actually change investment behaviour [48]. Such investigations require interdisciplinary research combining engineering measurement, economics, regulation, behavioural science and institutional analysis [15]. *Table 6* shows research gaps and future research priorities.

Table 6. Research gaps and future research priorities.

Research Gap	Recommended Future Study	Expected Output	References
No national energy-use intensity data for small industrial buildings	Measured audits across food, welding, wood, cold-room and agro-processing buildings	Benchmark database and typical load profiles	[7], [24]
Limited process-building integration	Combined audit of building fabric, electrical network and production equipment	Integrated retrofit packages	[4], [13]
Weak digital monitoring evidence	Pilot sub-metering and simple dashboards in SMEs	Low-cost monitoring model	[30], [31], [38]
Limited financing evaluation	Payback, lifecycle cost and loan-performance studies	Bankable EE investment templates	[6], [7], [48]
Policy enforcement uncertainty	Institutional mapping and compliance case studies	Clear roles and compliance workflow	[7], [15], [47]
Limited renewable-energy integration studies	Efficiency-first PV sizing studies for SMEs	Reduced lifecycle cost and grid demand	[7], [13], [100]

9 | Proposed Implementation Framework for Small-Scale Industrial Buildings in Tanzania

The review indicates that Tanzania's small-scale industrial building sector can benefit from a staged strategy [25]. Immediate actions should focus on low-cost and high-visibility measures such as LED lighting, power-factor correction, leak control, operating schedules and maintenance [33]. Medium-term actions should target motors, VSDs, refrigeration, insulation and process heat recovery [7]. Long-term actions should build national benchmarking, digital monitoring, mandatory minimum standards and structured energy-performance reporting.

A key argument of this review is that EE should precede renewable-energy sizing [100]. Solar PV and battery systems can improve energy security, but they should be designed after demand has been reduced through efficient equipment and improved operation [63]. Efficiency-first planning reduces capital cost, avoids oversizing, and improves reliability of hybrid systems [101].

The review also shows that Tanzania-specific research should move from general advocacy toward measured evidence [13]. Future papers should therefore include real audit data from representative small industrial buildings, techno-economic comparison of retrofits, and policy implementation assessment from Tanzania [102].

The proposed framework translates review findings into a practical pathway for Tanzania [3]. It begins with baseline energy auditing because data are required before investment [19]. It then benchmarks energy use, identifies losses, ranks measures, links actions to finance, integrates compliance, monitors performance, and creates continuous improvement [7]. This sequence is consistent with industrial energy management research and SME policy evidence showing that technical measures must be accompanied by management, financing, and verification [46]. Proposed implementation frameworks are as follows:

Step 1 is a baseline energy audit covering energy bills, equipment inventory, rated power, operating hours, production output, thermal systems, power factor, voltage quality, and building-envelope conditions. The audit improves energy performance by identifying where, when, and how energy is consumed. It helps reveal high-consuming machines, unnecessary running hours, poor maintenance, heat losses, voltage problems, and inefficient building conditions before any retrofit is selected [95].

Step 2 is benchmarking by floor area, operating hours, and product output. The benchmarking process improves EE by comparing actual energy use with production level or building size. It helps determine whether the facility is consuming more energy than expected and identifies whether losses are caused by poor operation, inefficient equipment, or low productivity [24].

Step 3 is loss identification in motors, lighting, compressed air, refrigeration, process heat, wiring and building fabric. The loss-identification process improves energy use by locating avoidable losses such as oversized motors, air leaks, old lamps, poor insulation, steam leakage, inefficient compressors and heat gain through roofs and walls. Once losses are known, energy-saving actions can be targeted instead of applied randomly [27].

Step 4 is technology selection based on energy saving, payback, maintenance requirements and local availability. The technology-selection process improves EE by ensuring that selected technologies are technically suitable and economically practical. Examples include LED lighting, high-efficiency motors, variable-speed drives, efficient compressors, insulation, power-factor correction, efficient refrigeration and smart meters [103].

Step 5 is financing and procurement support through green loans, equipment leasing, tax incentives, aggregated purchase schemes or performance-based models. Such support improves EE by helping SMEs overcome the high initial cost of efficient technologies. With better financing, small industries can replace inefficient equipment earlier and adopt energy-saving measures that reduce long-term operating costs [48].

Step 6 is regulatory compliance through standards, inspections and energy-performance reporting. Such compliance improves energy performance by ensuring that buildings, machines and electrical systems meet minimum efficiency and safety requirements. Standards also discourage the use of inefficient equipment and encourage regular reporting, inspection and accountability [18].

Step 7 is smart monitoring and verification using smart meters or sub-meters. Such monitoring improves EE by allowing real-time tracking of energy use in different machines, rooms, or production lines. It helps detect abnormal consumption, equipment faults, peak demand, idle operation, and energy waste after retrofits have been installed [31].

Step 8 is continuous improvement through periodic audits, staff training, maintenance, and technology upgrading. Such efforts improve EE by making energy management a permanent practice rather than a one-time activity. Regular maintenance keeps equipment efficient, staff training reduces careless energy use, and periodic audits identify new saving opportunities as production conditions change [104], [105].

10 | Conclusion

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-based source selection process demonstrates that the review was conducted using a transparent, systematic and evidence-based approach. The screening process began with previous studies, new database records from ScienceDirect and

Google Scholar, and additional documents obtained through other methods such as websites, organizational reports, standards, policy documents and guidelines. This structure strengthened the review because it allowed both academic literature and policy-relevant documents to be considered. The process showed that although a large number of records were initially identified, many were removed because they were duplicates, outside the required year range, non-relevant to the topic, or not directly connected to EE infrastructure and regulatory readiness for small-scale industrial buildings in Tanzania.

The final included studies provide a focused evidence base for understanding technologies, policy gaps, barriers, and implementation pathways related to EE in small-scale industrial buildings. The diagram confirms that only the most relevant records were retained after screening and eligibility assessment. Therefore, the review is supported by a controlled selection process rather than random literature collection. Such a process improves the reliability, academic quality, and publication readiness of the study. Overall, the PRISMA process confirms that EE in Tanzanian small-scale industrial buildings requires an integrated approach involving technical measures, regulatory readiness, energy audits, smart monitoring, financing mechanisms, standards, policy enforcement, and continuous improvement.

11 | Recommendations

Future studies should maintain the PRISMA-based selection approach because it improves transparency, reduces bias, and clearly shows how sources are included or excluded. The review should prioritize journal articles published between 2016 and 2026, especially those directly related to industrial EE, SMEs, energy audits, EMS, smart metering, green buildings, policy frameworks, and developing-country implementation barriers. Articles outside the year range should be used only when they provide essential background, historical policy context, or technical definitions that cannot be replaced by recent sources.

It is recommended that non-article documents such as standards, policy reports, regulations, guidelines, and organizational documents should not be mixed with peer-reviewed articles without explanation. Instead, they should be used mainly in the regulatory and policy-readiness section. Such an approach will help separate scientific evidence from policy-supporting evidence. Weak sources such as general websites, search-engine pages, unclear institutional repository pages, and non-academic documents should be removed or replaced with official policy documents, government publications, international agency reports, or peer-reviewed journal articles.

For Tanzania, future research should move beyond literature review and collect measured energy data from real small-scale industrial buildings. Important data should include electricity consumption, floor area, production output, operating hours, power factor, lighting load, motor load, refrigeration load, process heat demand, and peak demand. These data can support national benchmarking and help identify cost-effective energy-efficiency interventions. Policymakers should also develop SME-specific energy audit guidelines, minimum energy performance standards, green financing schemes, smart-metering requirements, and compliance mechanisms. Finally, EE should be treated as the first step before renewable-energy system sizing, because reducing demand first lowers investment cost and improves long-term sustainability.

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Author Contribution

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Data Availability

All data are included in the text.

Conflicts of Interest

The authors declare that no conflict of interest.

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Appendix

Table A1. Results of search terms from the database of sciencedirect and google scholar.

Search String/Terms Used	Year Range	Records Found/All Access	Records Selected with Open Access	
		Sciencedirect	Sciencedirect	Google Scholar
"industrial energy efficiency" AND (SME OR SMEs OR "small and medium enterprises")	2016–2026	183	62	222

Table A1. Continued.

Search String/Terms Used	Year Range	Records Found/All Access	Records Selected with Open Access	
		Sciencedirect	Sciencedirect	Google Scholar
"small-scale industrial buildings" AND "energy efficiency"	2016–2026	1	1	0
"energy audit" AND (SME OR SMEs OR "small and medium enterprises")	2016–2026	481	177	222
"energy management system" AND (SME OR SMEs OR "small and medium enterprises")	2016–2026	1015	355	842
"building energy performance" AND "industrial buildings"	2016–2026	327	109	181
"green building" AND Tanzania	2016–2026	143	43	313
"energy efficiency policy" AND (SME OR SMEs OR "developing countries")	2016–2026	1290	362	390
"smart metering" AND "energy efficiency" AND (SME OR SMEs OR buildings)"AND "Energy saving	2016–2026	3398	1,000	1,610
"smart metering" AND "energy efficiency" AND (SME OR SMEs OR buildings) "AND "energy saving "AND " (energy Regulation" OR "energy policy "OR " energy framework)	2016–2026	1637	569	1,190
"energy efficiency barriers" AND (SME OR SMEs OR "small and medium enterprises")	2016–2026	34	15	38
"energy efficiency" AND Tanzania AND (industry OR buildings OR SMEs)	2016–2026	1522	521	1,890
Total			3214	6898