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Energy Management Systems and Challenges in Transportation and Power Generation – A Case Study of Sri Lanka

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Abstract The rapid growth of global energy demand implies a significant need for sustainable energy practices. In response to this scenario many countries adopt Energy Management Systems (EnMS) to optimize their energy consumption and to reduce environmental impact. Sri Lanka, like many other developing nations, faces to significant challenges in managing its energy needs as the significant portion of energy requirement of the country depends on the imported fossil fuels. This raises questions about the energy security of the country. Moreover, the energy crisis faced by Sri Lanka in 2022 has highlighted the importance of efficient and sustainable energy management practices for the country. The research uses a qualitative approach and a case study method to gain a deep understanding of the topic and to explore real-world complexities. Primary data for the research is collected through expert surveys and interviews while secondary data is gathered through a literature review, including documents from relevant sectors, peer reviewed academic journals, and research papers. The collected data is reviewed to identify key challenges for energy management and ISO 50001 EnMS. The relevancy of those challenges is reviewed with energy experts and industry professionals. Based on the identified challenges, this research project provides recommendations to address these challenges and enhance the energy management and EnMS in the transportation and power generation sectors of Sri Lanka. Lack of awareness, financial barriers, lack of technology, lack of knowledgeable employees and poor initiatives from the government for energy management are found as mostly affecting factors for these challenges. Since this research objectives are lined up to address the key areas of energy sector in Sri Lanka, those areas very important as a developing country to improve the energy sector. The research findings and recommendations can assist policymakers, energy managers, and industry practitioners in overcoming barriers and promoting sustainable energy management practices in Sri Lanka and similar developing countries.

Keywords Energy Management Systems (EnMS), ISO 50001, Sri Lanka, Energy Crisis, Transportation Sector, Power Generation Sector

1. Introduction

Sri Lanka's energy demand is currently being catered by several energy sources consisting of both indigenous non-fossil fuels and imported fossil fuels. Most of the country's energy needs are met through imported fossil fuels, such as petroleum and coal and in rural areas biomass is extensively used. The rest is made up of other indigenous sources which include large hydro and renewables such as solar, small hydro and wind [1]. In this context the supply, distribution and the utilization of fossil fuels are vital aspects which significantly impact to the energy security of Sri Lanka.

In the year 2020, petroleum products contributed to the major share of Sri Lanka's energy mix as 40%. Another significant energy source is biomass, which is accounted for 34% of total share. The imported coal also has 14% from the energy mix. Major hydro and new renewable energy sources constituted 7.8% and 4.2% of the energy mix in Sri Lanka, respectively [2].

Sri Lanka has experienced significant economic growth in recent years. Following a 30-year civil war, Sri Lanka's economy has grown at an average rate of 6.4 percent between 2010 and 2015, with GDP per capita rising from US$2,014 in 2008 to US$3,837 in 2015 [3]. However, the entire economy of the country was faced to severe challenges with the Covid-19 pandemic, and it hits to the island badly resulting to reduce the state owns foreign currency reservoirs drastically. The consequences of this became evident at the

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beginning of 2022, resulting long ques on the fuel stations for petrol, diesel and kerosene, long ques on the LP gas stations due to the shortage of the LP gas for household cooking utilization, and planned daily power cuts throughout the island. This implies to give a consideration about the energy management of the country. Hence, this research is focused to evaluate energy management systems and the energy management challenges faced by Sri Lanka.

The energy demand of Sri Lanka is divided into three main sectors, industry, transport, and household and commercial sectors [2]. The transport sector and household and commercial sector are having large portion from the total energy demand (Table 1). But in the case of consumers (household and commercial), they tend to control their energy usage as it directly affects the monthly energy bill. So, it can be assumed that there is a self-regulation or energy management in the household and commercial sector. The transportation sector is chosen for research because of its importance and being the next highest energy demand sector. Similarly, the industry sector can also be assumed to have energy management regulations in place, resembling the case of the household and commercial sector. The power generation sector is also chosen for the research due to its vital role for the country to perform its day-to-day operations without interruptions.

Table 1. Total Energy Demand by Sector [2]

PJ	2017	2018	2019	2020
Industry	103.2	108.8	111.7	111.7
Transport	143.0	135.8	139.3	121.3
Household, Commercial & Other	139.5	141.3	144.6	145.3
Total	385.7	385.9	395.6	378.3

2. Methodology

To narrow down the broad area, the scope was carefully chosen to focus on the transportation and power generation sectors of Sri Lanka. According to the nature of the objectives of the research, a qualitative research approach is chosen. The qualitative research method used to understand the non-numerical data such as opinions, experiences, attitudes, interactions or to understand the concepts [4]. The source of information includes conference proceedings, peer reviewed academic journals, technical reports, research papers, web sites and discussions held with experts from the energy management sector.

A methodological methodical review of literature was conducted to study academia in these sectors to determine the work that needs to be carried out. The identified challenges were evaluated by a survey through experts to verify the relevancies of the challenges quantitatively. The findings of the study direct to give the recommendations to overcome the energy management challenges for the selected sectors of the country.

3. Research

3.1. Background for Energy Management

United Nations developed a set of 17 goals named United Nations Sustainable Development Goals (SDGs) providing a shared blueprint for peace and prosperity for people and the planet for now and into the future [5]. Each SDG has specific targets and indicators to measure the progress toward achieving them and total number of targets are 169. The 7th SDG represents the topic "affordable and clean energy", ensure access to affordable, reliable, sustainable, and modern energy for all [6]. These are an urgent call for action by all developed and developing countries in a global partnership [7].

The formulation of Sri Lanka's energy policy was gone back to early 1980s in the form of a 'National Energy Strategy'. Subsequently, Sri Lanka developed a documented energy policy in a form of a 'Report of the national committee to formulate the national energy policy of Sri Lanka in 1997' [8]. In 2006, the policy formulation was completed, resulting in a stated energy policy for the country from 2008 to 2010. This policy was gazette on 10th of May 2008 as an extra ordinary gazette by the Ministry of Power and Energy [9]. In 2019, the national energy policy was revised and gazette again as an extraordinary gazette aligning with the future goals of Sri Lanka, current global trends in energy and the goal 7 of the SDG. The main objective of the national energy policy and strategies declared in the gazette is to ensure that convenient and affordable energy service are available for the equitable development of Sri Lanka [10].

3.2. Energy Management & Energy Management System (EnMS)

Energy management is a way of systematic monitoring, control, and optimization of energy consumption to decrease the energy cost [11]. This helps to improve energy efficiency and to minimize the environmental impact as reduction of carbon footprint while improving sustainability [12]. Energy management is governed by the EnMS, and EnMS is a framework for energy consumers to manage the use of energy. According to the International Organization for Standardization (ISO), "an energy management system involves developing and implementing an energy policy, setting achievable targets for energy use, and designing action plans to reach them and measure progress. This might include implementing new energy-efficient technologies, reducing energy waste, or improving current processes to cut energy costs" [13].

3.3. Globally Recognized EnMS (ISO 50001)

The International Organization for Standardization (ISO) published their first standard named ISO 50001 for energy management system in 2011 and it is the EnMS which is used widely in the world [14]. Later some amendments were introduced to the standard ISO 50001:2011 and continued it as ISO 50001:2018. As interesting part, the ISO 50001

allows users to fix their targets according to the capacity and budget of the user [15]. The implementation of EnMS required a complete plan and policy. The process of energy management system is based on the Plan-Do-Check-Act (PDCA) continual improvement framework (Figure 1) which is called as the energy management cycle [16].

Figure 1. PDCA Cycle of ISO 50001 [16]

3.4. EnMS and Sri Lanka

EnMS are used in Sri Lankan industries, and these can be their own EnMS or globally recognized systems. For instance, Lanka Electricity Private Limited (LECO) using a their own EnMS and they give their effort to shift to ISO 50001 [17]. Researchers D.D. Piyadasa and M. Siriwardhana [18] have identified that tire manufacturers of the Sri Lanka following the international and national standards including ISO 50001 EnMS. According to the findings of a study conducted by L.G.O. Buddhika and P.A.D. Rajini [19], the ISO 50001 is the only globally accepted EnMS practiced within the country due to its broad benefits. Furthermore, research done by Sashika Abeydeera [20] shows that Aitken Spence, Brandix Lanka Limited and Aitken Spence Hotel Holdings are also following ISO 50001. Another research conducted by S.K.A. Fernando, I.S. Somarathne and A.S. Asmone [21] confirms that the Brandix's Green Factory located at Seeduwa is the first manufacturing location which got the standard ISO 50001. Additionally, research conducted by T.C.B. Rajapakse and B. Rajapakse [22] confirms that the INSEE is having ISO 50001, and they are practicing it actively.

3.5. Power Generation Sector

The Sri Lankan government set a goal of achieving 70% renewable energy generation by 2030 and to becoming carbon neutral by 2050 [23]. Ceylon electricity board (CEB) developed a Long-Term Generation Expansion Plan (LTGEP) for the years 2023 to 2042 based on achieving 70% of electricity generation from renewable energy by 2030, achieve carbon neutrality in power generation by 2050, cease building of new coal fired power plants and new addition of firm capacity from clean energy [24].

3.5.1. Renewable Energy Possibilities in Sri Lanka

The fossil fuel sources of the world are predicted to be depleted in the upcoming few decades. This may be dragging the world towards an energy crisis [25]. Hence, the world is now moving to renewable energy sources, which they continuously replenished by natural processes [26]. Sri Lanka has a significant potential for develop renewable energy due to the abundant availability of hydro, wind, biomass, and solar resources. However, challenges such as lack of new technology, expert knowledge, and financial availability, are the main hurdles for the adaptation and development of renewables [27].

3.5.2. Wind

The most influential factors for wind generation and movement are uneven solar heating, Coriolis effect due to the earth's self-rotation and local geological condition [28]. The electricity generation through wind could save billions of barrels of the oil and reduce the million tons of carbon and other emissions [29]. Sri Lanka having good wind energy resources concentrated in the northwestern coastal area and the central highlands [30] wich enable to have a wind potential of 5653 MW [31]. At the end of the September 2022, the available installed capacity of the wind is 248 MW including CEB and independent power producers (IPPs) [32].

3.5.3. Solar

Solar energy is identified as the most abundant energy resource on the earth [33]. Substantial amount of solar energy resources exists to Sri Lanka throughout the year as the country is located withing the equator belt [34]. The daily solar irradiation of Sri Lanka is about 4.43 kW/m^2 – 5.64 kW/m^2 per day [35]. The government promotes the rooftop solar PV through a project named "Soorya Bala Sangramaya" [36]. However, the high costs and relatively low efficiency associated with solar power technologies present significant challenges to their widespread adoption for energy generation [37].

3.5.4. Hydro

Sri Lanka's topography presents a remarkable opportunity for energy utilization, particularly through the harnessing of energy from rivers that flow from the central hills to the Indian ocean. Hence, hydro power is currently the most favourable renewable energy source with promising potential [38]. The country has made significant strides in the development of hydropower, with the Laxapana and Mahaweli complexes serving as the major hydropower facilities. Besides these, there are major stations such as Samanalawewa and Kukule Ganga along with other mini hydro plants [39].

3.5.5. Biomass

Biomass is a renewable energy source that derived from plants and vegetation that regrows naturally and has a long

history with human [40]. The biomass is called as carbon neutral energy because, the carbon released during the combustion or conversion process is reabsorbed by regrowing biomass through the process of photosynthesis [41]. The biomass utilization is not limited to direct combustion, it can be applied to advanced conversion technologies like chemical, thermal and biological conversion process to produce high grade energy sources such as biofuel, biogas, syngas, char etc. [42]. The technical potential for biomass in the country is estimated at 8000 MW per year. However, after considering social and environmental constraints, the feasible capacity for utilization is limited to 1000 MW [27]. Sri Lanka having 11 of biomass-based power plants (Table 2) in operation to the year 2020 and the total capacity is 39.52MW [2].

Table 2. Biomass Based Power Plants Operational in Sri Lanka [2]

Name of the Power Plant	Year Commisioned	Capacity (MW)	Generation (GWH)
Badalgama (Biomass)	2005	1.00	0.4
Tokyo	2008	10.00	2.8
Embilipitiya (Dendro)	2013	1.50	0.12
Bathalayaya (Dendro)	2014	5.00	38.3
Ninthaur	2014	2.00	5.3
Batugammana (Dendro)	2015	0.02	-
Loluwagoda DPP	2016	4.00	20.1
Laggal Oya DPP	2017	2.00	11.6
Panamure DPP	2018	0.99	0.2
Kalawa Aragama DPP	2018	10.00	-
Dehiattakandiya DPP	2019	3.00	19.8
Total		39.52	97.62

3.6. Transportation Sector

Transportation sector plays a major role in the economic activity of a country, and it has a significant impact on various aspects such as employment growth, market reach, resource accessibility and mobility behaviour [43]. The transport sector consuming about 29% of the global energy consumption [44]. Sri Lanka consume 29% for the transport sector in the aspect of road and rail transport [2].

3.6.1. Vehicle Population of Sri Lanka

According to the statistical data of the department of motor traffic, Sri Lanka vehicle population of the 2020, 2021 and May-2022 is mentioned in the Table 3 [45].

The portion of busses is very low (about 1%) and this is a sign of worsening public transport services in the country. The energy consumption of the transportation sector has a positive impact from the vehicle energy usage, vehicle intensity, GDP and population scale [43]. Electrification of the transport system is a solution to decarbonize the transport sector [46]. Hence, with the poor public transport services, the fossil fuel usage of the transportation sector is possible to intensify with the increment of the consumers.

Table 3. Vehicle Population of Sri Lanka – May 2022 [45]

Class of Vehicle	2020	2021	May - 2022
Motor Cars	896,885	900,380	901,070
Motor Tricycles	1,182,227	1,184,320	1,184,337
Busses	112,583	112,864	113,074
Dual Purpose Vehicles	448,552	449,323	449,707
Motor Lorries	346,409	349,002	349,605
Prime Movers	6,696	7,055	7,127
Lorry Trailers	9,248	9.547	9,675
Lorry Others	13,134	14,227	14,562
Ambulances	3,464	3,552	3,566
Hearses	490	490	491
L.V. Tractors	380,668	391,088	393,782
N.A. Tractors	958	958	958
L.V. Trailers	74,385	78,729	80,382
Quadricycle	2,442	2,442	2,442
Moto Home	3	6	6
Total	8,297,852	8,331,702	8,341,861

3.6.2. Electric Vehicles

Many factors are influencing the adoption of electrical vehicles (EV) for a country, such as technological factors, economic factors, environmental factors, social factors, infrastructure factors and policy/regulatory factors [47]. Understanding these factors can help policymakers, manufacturers, and stakeholders to develop strategies to promote adoption of electric vehicles effectively [48]. Sri Lanka has been making efforts to promote the adoption of EVs as part of its sustainable transportation initiatives. To encourage the adoption of EVs, the Sri Lankan government has implemented various policies and incentives. These include tax concessions, duty exemptions, and reduced import taxes on EVs. Additionally, the government has been working on expanding the charging infrastructure across the country to support the growing number of EVs.

4. Findings

The research findings describe the current energy management challenges for the power generation sector including both public and private power producers and transportation sector including rail and road transport which is governed by public and private service providers of the country. 12 challenges for the power generation sector, 7 challenges for the road transportation sector and 5 challenges for the rail transportation sector were identified through the research as follows.

4.1. Power Generation Sector

1. Lack of awareness and understanding
2. Difficulties on capital allocation
3. Shortage of knowledgeable persons
4. Resources limitations of time and technology

5. Negative attitudes of employees and resistance to change
6. Practices prevailing in organizations
7. Inadequate data management and monitoring practices
8. Challenge of regulatory and policy framework
9. Shortage of technical expertise and training
10. High dependence on non-renewable energy sources
11. Insufficient investment on renewable energy
12. Limited grid infrastructure and transmission capacity

4.2. Transportation Sector – Road Transport

1. High dependence on fossil fuels in transport sector
2. Inefficient vehicle fleet in Sri Lanka
3. Inadequate public transportation and higher private vehicle usage
4. Limited infrastructure for electric vehicles (EV)
5. Poor traffic management in road transportation
6. Lack of awareness and incentives on energy efficient practices
7. Limited research and development

4.3. Transportation Sector – Rail Transport

1. Diesel powered locomotives
2. High energy consumption
3. Inadequate maintenance and outdated technology
4. Limited use of renewable energy
5. Insufficient capacity and frequency

An expert survey was conducted with 28 professionals from the energy management sector of the Sri Lanka. Most of them are corporate members of the Sri Lanka Energy Managers Association (SLEMA) who have deep understanding on the energy management and ISO 50001. Also, they are practicing the energy management and auditing over the country through SLEMA and through their private organizations.

5. Evaluation of the Relevance of Challenges

According to the responds received from experts to the survey, each challenge allocated a score ranging from the 0 to 5 scale. These are the mean values from the responses received for each of challenge. It represents the relevancy of the considered challenge. Figure 2, Figure 3, and Figure 4 shows the respective score for each of the challenge for the considered sectors.

5.1. Power Generation Sector

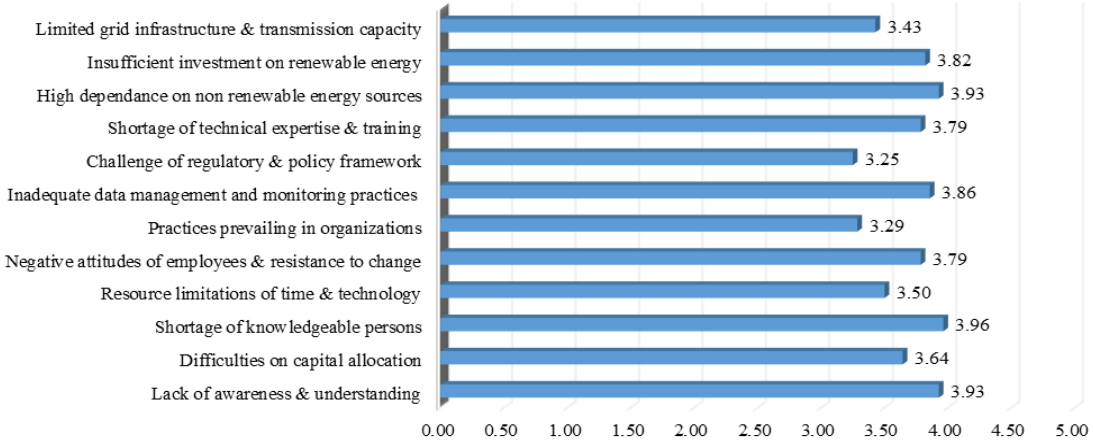

Figure 2. Relevancy of power generation sector challenges

5.2. Transportation Sector – Road Transport

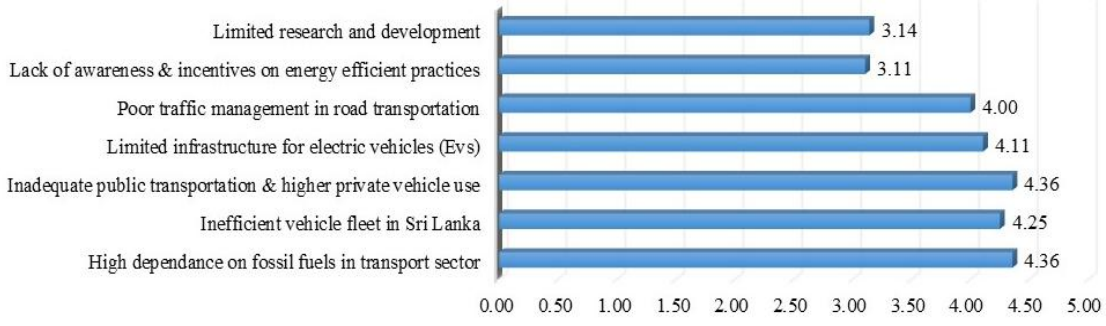

Figure 3. Relevancy of road transport sector challenges

5.3. Transportation Sector – Rail Transport

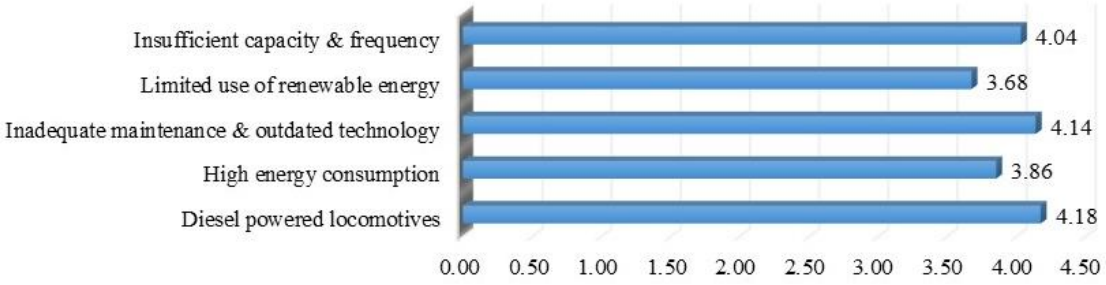

Figure 4. Relevancy of the rail transport sector challenges

The benchmark for the relevance was 3 and all the 24 challenges are higher than the 3 from the scale, resulting in all of them are identified as relevant challenges through the expert review. This implies the addressing of these 24 challenges to overcome them can impact positively to the energy management of the country.

6. Solutions

Addressing the challenges requires a comprehensive approach to improve energy management in Sri Lanka's power generation and transportation sector. The recommendations were given to analysed challenges to overcome them.

6.1. Power Generation Sector

1. Lack of awareness and understanding
   - Promote ISO 50001 through awareness sessions, campaigns, industry training, and prepare informative materials for widespread adoption and understanding.
2. Difficulties on capital allocation
   - Provide government backing for ISO 50001, find funds with low-interest financing, and set aside a budget for ISO 50001 implementation, emphasizing potential cost savings from energy management.
3. Shortage of knowledgeable persons
   - Create a strong focused workforce by training experts, collaborating with other organizations to share the skills, organizing skill enhancing programs, and promoting a culture of learning and growth.
4. Resources limitations of time and technology
   - Allocate enough time and funds for a successful energy management system setup and operation, including both implementation and technology investments.
5. Negative attitudes of employees and resistance to change
   - Establish a supportive learning environment to learn about energy management, involve employees at all levels to actively participate in ISO 50001 implementation, while acknowledging and valuing their contributions.
6. Practices prevailing in organizations
   - Gain the commitment of top management with ISO 50001 and energy management, tweak the energy policy to match ISO 50001, and shift the sector's management approach to follow the PDCA cycle.
7. Inadequate data management and monitoring practices
   - Create easy to use systems for managing energy data, guarantee data accuracy through quality checks, and establish real time data capture for automated metering and monitoring.
8. Challenge of regulatory and policy framework
   - Advocate for ISO 50001 by showcasing its advantages and collaborating with regulators to create custom policies. Collaborate with regulators to establish clear implementation guidelines and standards for ISO 50001.
9. Shortage of technical expertise and training
   - In collaboration with expert bodies, offer training programs for ISO 50001 and energy management to enhance expertise. Implement internal training sessions led by experienced individuals to share ISO 50001 insights.
10. High dependence on non-renewable energy sources
    - Simplify CEB processes for faster solar project implementation, promote invest in renewable energy sources, and support research in energy storage and advanced conversion technologies for alternative energy.
11. Insufficient investment in renewable energy
    - Make it easier for investors to support renewable energy by simplifying regulations, offering stable power purchase agreements, financial rewards, and educating them about the lasting advantages of such investments.
12. Limited grid infrastructure and transmission capacity
    - Improve the power grid for clean energy by enhancing infrastructure and creating a smart grid that can manage and balance renewable sources effectively.

6.2. Transportation Sector – Road Transport

1. High dependence on fossil fuels in transport sector
   - Encouraging the use of alternative fuels, electrifying vehicles, setting fuel efficiency standards, improving public transportation, and promoting carpooling to reduce fossil fuel dependence.

2. Inefficient vehicle fleet in Sri Lanka
   - Enhance vehicle efficiency and reduce emissions by implementing stricter import rules, offering incentives for fuel-efficient cars, introducing vehicle scrappage programs, aiding fleet modernization, and raising public awareness about the advantages of fuel-efficient vehicles.
3. Inadequate public transportation and higher private vehicle usage
   - Improving public transportation through building new terminals, upgrading vehicles, connecting different modes of transport, creating dedicated lanes, and implementing efficient systems like Bus Rapid Transit (BRT), making travel easier, faster, and more comfortable for commuters.
4. Limited infrastructure for electric vehicles (EVs)
   - Create a robust charging network with stations at strategic points, incentivize private investment through benefits, prioritize fast-charging on highways, collaborate with companies for quicker growth, and establish clear safety regulations.
5. Poor traffic management in road transportation
   - Enhance traffic infrastructure with modern systems for efficient flow, real-time monitoring, and optimized signal control. Prioritize public transport via dedicated lanes and improved transit systems to alleviate congestion.
6. Lack of awareness and incentives on energy efficient practices
   - Promote eco-friendly transportation by educating people about its benefits, incorporating it into school curriculum, offering incentives for energy-efficient vehicle purchases, and implementing certification programs for green transportation options.
7. Limited research and development
   - Strengthen road transport research by increasing funding, fostering academic-industry collaboration, facilitating tech transfer with global partners, and implementing targeted policies for R&D promotion.

6.3. Transportation Sector – Rail Transport

1. Diesel powered locomotives
   - Switching to electric trains for rail transportation is vital for energy efficiency and emissions reduction. Invest in the necessary infrastructure, including overhead electrification systems and substation facilities.
2. High energy consumption
   - Upgrade the rolling stock introducing modern and energy efficient trains, electric or hybrid trains to enhance energy efficiency and reduce fuel consumption to improve overall performance while saving maintenance expense.
3. Inadequate maintenance and outdated technology
   - Implement effective maintenance practices to ensure optimal energy efficiency and performance. Upgrade rail infrastructure, signalling systems, and rolling stock to enhance energy management and to minimize energy losses.
4. Limited use of renewable energy
   - Explore opportunities to integrate renewable energy sources into the rail system including the installation of solar panels at railway stations and depots and wind/ solar farms near tracks to power trains and related infrastructure.
5. Insufficient capacity and frequency
   - Expand rail capacity and improve scheduling to eliminate overcrowding and to optimize energy consumption. Increasing the number of trains, enhancing station facilities, and implementing efficient timetables can improve passenger flow, reduce waiting times, and ensure more effective energy utilization.

7. Conclusions

The study highlights the main energy management challenges of the power generation and transportation sector. The identified challenges of the research can be concluded to main 5 areas. They are, lack of awareness about EnMS and energy management, financial barriers, lack of technology, lack of knowledgeable employees and poor initiatives from the government for energy management.

The lack of awareness about energy management and energy management systems (EnMS) has a negative impact on energy management as it implies lack of knowledge about the importance of energy management. Additionally, insufficient financial resources can limit the possibilities for the implementation and operation of energy management systems. Technology is an important aspect when considered about implementation and sustainability of energy management and energy management systems as it needed updated technologies for its proper operations. Moreover, having knowledgeable employees, such as energy managers, experts, and trained personnel, is an essential prerequisite for driving energy management systems and effective energy management. Finally, government involvement and initiatives play a key role in promoting energy management.

These challenges are possible to overcome through proper policy planning and resource development as addressed throughout the research. Since the power generation and transportation sector of the Sri Lanka are in control of the government, a significant changes and improvements to the existing policies are required to improve country's overall energy management. Furthermore, it is crucial to put the national energy policy into practice and closely monitor its implementation. Otherwise, policy formulation will be in vain. By implementing the proposed strategies, the country can undoubtedly make significant progress in its energy management for transportation and power generation.

Furthermore, the research findings can provide support to any developing country considering the implementation of energy management and energy management systems to

enhance their energy security.

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