PARTNERSHIP FOR LEARNING & SKILLS
TO ADVANCE SAFER ENGINEERING IN EAST AFRICA

REPORT OF SKILLS NEEDS ASSESSMENT FOR DIGITAL & GREEN TRANSITIONS IN THE MARITIME & ENERGY SECTORS IN EAST AFRICA

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List of Abbreviations

FKE	Federation of Kenya Employers
IEA	International Energy Agency
IMO	International Maritime Organization
IRENA	International Renewable Energy Agency
KICD	Kenya Institute of Curriculum Development
MEPC	Marine Environment Protection Committee
SGI	Skills Gap Index
UNCTAD	United Nations Trade and Development

Executive Summary

The energy and maritime sectors are central to sustainable economic growth in East Africa, and are undergoing transformation driven by digitalization, automation, and the shift toward low-carbon energy sources. While these transitions are beneficial, they also introduce technical, operational, and safety challenges that require a skilled and adaptable engineering workforce.

This skills-needs assessment was undertaken to evaluate current competencies and identify critical skills gaps with the aim of informing the development of targeted capacity-building programs aligned with emerging industry demands. The study adopted a mixed-methods approach, combining quantitative data from a structured survey with qualitative insights from a stakeholder validation workshop. The assessment explored awareness and application of emerging technologies, existing and anticipated skills gaps, training preferences, and systemic barriers to skills development. The data was analyzed using both descriptive and inferential statistics.

The findings indicate a high level of awareness of key emerging technologies such as artificial intelligence, smart energy systems, automation, and alternative fuels, but low competency levels, highlighting a significant skills gap. High skills gaps were identified in the area of offshore and marine energy systems, cybersecurity, artificial intelligence, machine learning applications, and alternative fuels. In addition, limited familiarity with advanced digital tools such as digital twins and virtual reality points to a substantial digital capability deficit.

A multi-criteria prioritization approach was applied to rank the identified skills gaps based on their impact on safety, relevance to maritime/energy sector operations, alignment with digitalization and decarbonization goals, and feasibility of training interventions. The prioritized gaps were then mapped to specific learning outcomes for two target groups: engineering students and industry professionals undertaking. This mapping provides a clear framework for the design of the training programs.

With regard to training format, there is a strong preference for short-courses and on-site workshops. However, limited training budgets were identified as the most significant barrier to skills development. The findings of the survey were validated through a stakeholder workshop, which confirmed the relevance of the identified skills gaps.

In conclusion, the study highlights an urgent need for targeted capacity-building actions to bridge critical skills gaps in the energy and maritime sectors, and support the safe and effective adoption of emerging technologies. Based on the findings of this assessment, the following are the recommended actions:

1) To design and implement specialized training programs that directly address the high-priority skills gaps identified, particularly in offshore and marine energy systems, cybersecurity, artificial intelligence, and alternative fuels.
2) To establish partnerships between academic institutions and industry to support curriculum co-development, applied research, and knowledge transfer.
3) To promote international collaboration and benchmarking with countries advanced in offshore and marine energy technologies
4) To integrate emerging digital technologies and tool (e.g., simulation, digital twins, AI) and green technologies (e.g. alternative fuels) into engineering curricula and professional training programs to build advanced, future-ready competencies.
5) To incorporate cybersecurity as a core component of engineering education and professional development

1. Introduction

1.1 Background

Energy and maritime sectors hold the key to resilient and sustainable economic development in East Africa. These sectors are undergoing transitions driven by technological change, increasing digitalization and climate actions. While these transitions present significant opportunities for sustainable development, they also introduce complex operational and safety challenges that demand highly skilled and adaptable engineering workforce. Again, these changes are occurring alongside expanding infrastructure investments further amplifying the need for robust technical capacity.

However, the engineering skills are evolving slowly compared to the pace of technological advancement in East Africa. Indeed, there is growing concern that the current workforce may not possess the full range of competencies required to safely and effectively manage emerging technologies and complex systems. Against this backdrop, building local engineering skills capacity is essential to ensure safe integration and management of these emerging digital and green technologies. Moreover, aligning engineering education and professional training with evolving industry needs is necessary to support a future-ready workforce. But, without assessment of the sector skills requirements, training and upskilling programs may fail to adequately prepare engineering graduates and practitioners for emerging roles within the maritime and energy sectors.

1.2 Overview of the Global Maritime Sector

The maritime sector is a cornerstone of the global economy, facilitating international trade, energy transportation, and global supply chains. It is estimated that more than 80% of global trade by volume is transported by sea, making maritime transport the most cost-effective and efficient mode for moving large quantities of goods across continents. The sector encompasses shipping operations, port infrastructure, maritime logistics, offshore energy systems, and marine engineering services.

Currently, the maritime industry is undergoing significant transformation driven by technological advancement and the increasing demand for sustainable transportation systems. Modern ports are evolving into integrated logistics hubs supported by digital technologies, automation, and advanced cargo handling systems. Simultaneously, global regulatory frameworks are becoming more stringent in relation to environmental protection, emissions reduction, and operational safety. The sector is currently facing two major transitions: decarbonization to address climate change and digitalization to enhance operational efficiency and safety. These transitions are reshaping the nature of maritime operations and consequently altering the skills required by engineers, technicians, and maritime professionals. The demand for competencies related to advanced fuels, digital systems, automation, and safety management is rapidly increasing worldwide.

1.3 Overview of the East African Maritime Sector

The maritime sector plays a critical role in the economic development and regional integration of East Africa. Major ports such as Mombasa, Dar es Salaam, and Djibouti serve as vital gateways for international trade. These ports handle large volumes of imports and exports, including agricultural products, manufactured goods, fuel, and industrial equipment.

East Africa is currently experiencing rapid growth in maritime and energy-related infrastructure. Investments in port expansion and automation are transforming maritime landscape in the region. However, the rapid expansion of infrastructure is occurring alongside a growing demand for skilled engineering professionals. While infrastructure is expanding rapidly, the supply of engineers and technical professionals with specialized maritime and emerging technology skills has not kept pace. This gap presents challenges related to operational efficiency, environmental sustainability, and safety in maritime operations.

1.4 Green Energy Transitions in the Maritime Sector

The global maritime industry is undergoing a major transition toward low-carbon and environmentally sustainable operations. International efforts to reduce greenhouse gas emissions from shipping are driving the adoption of cleaner energy sources and alternative fuels. These include liquefied natural gas (LNG), hydrogen, ammonia, methanol, and other emerging low-carbon fuels. In addition to alternative fuels, the maritime sector is increasingly adopting energy-efficient ship designs, electrification technologies, hybrid propulsion systems, and renewable energy integration within port operations. Ports are also introducing green port initiatives, such as shore-to-ship power systems, electrified cargo handling equipment, and improved energy management systems.

For East Africa, green energy transitions present both opportunities and challenges. While they provide pathways for sustainable maritime development and environmental protection, they also require new competencies related to fuel safety, energy systems integration, environmental management, and risk assessment. Engineers and maritime professionals must therefore acquire specialized knowledge and practical skills to safely handle, store, and operate systems associated with future fuels and low-carbon technologies.

1.5 Digital Transitions in the Maritime Sector

Digitalization is another major transformation shaping the maritime industry. Technologies such as automation, artificial intelligence, digital monitoring systems, Internet of Things (IoT), and cyber-physical systems are increasingly being integrated into ships and ports.

Smart ports are now deploying automated cargo handling systems, predictive maintenance technologies, and real-time vessel tracking to enhance operational efficiency and reduce downtime. Similarly, vessels are being equipped with advanced navigation systems, integrated control systems, and data-driven decision-support tools. These technologies enable improved safety, efficiency, and sustainability in maritime operations.

However, digital transformation also introduces new technical and operational challenges. The integration of complex digital systems requires engineers and operators with strong competencies in data systems, automation technologies, cybersecurity, and system integration. In East Africa, there remains a significant gap between the skills available in the workforce and the competencies required to support these advanced maritime technologies

1.6 Justification of the Skills Needs Survey

The maritime industry in East Africa is transitioning toward greener and digital operations, requiring new technical competencies that were previously not part of conventional engineering training. Despite this transformation, there remains a significant gap between the skills required in the maritime industry and the competencies currently possessed by engineering graduates and practicing professionals. Many engineers have limited exposure to emerging technologies such as cyber-physical infrastructure, advanced maritime monitoring systems, and alternative fuels. As maritime systems become more technologically complex, inadequate technical capacity may lead to increased operational failures, safety incidents, and environmental hazards. Strengthening local engineering capacity is therefore critical to ensure that the region can effectively manage the transition to green and digital maritime systems. Furthermore, engineering curricula often evolve more slowly than technological developments within industry. Without systematic assessment of industry skill requirements, training programs may fail to adequately prepare graduates for emerging roles within the maritime and energy sectors.

This skills-needs assessment is therefore necessary to provide evidence-based insights into the competencies required by industry and the existing gaps within the current workforce and training systems. The findings will support the development of targeted skilling courses for engineering students and practitioners. By identifying priority competencies in digital systems, automation and green energy technologies, the study will contribute to strengthening the region’s engineering capacity and promoting safer, more sustainable maritime operations.

1.7 Objectives

The primary objective of this study is to identify the skills and competencies required to support safe, and sustainable digital and green transitions in the maritime and energy sectors in East Africa. Specifically, the study aimed to:

- Assess the level of familiarity among engineering students, early-career professionals, and industry practitioners with emerging technologies in the maritime and energy sectors.
- Identify the new technical, digital, safety, and sustainability-related competencies required due to automation, digitalization, and the adoption of alternative fuels.
- Identify gaps between existing skills in the workforce and the competencies required by industry/sector.
- Generate evidence to guide the development of targeted skilling courses for engineering education and professional training.

1.8 Scope of the Study

This skill needs assessment focuses on the maritime and energy sectors within the East African region, with particular attention to the competencies required to support green energy systems and digital transitions. The study targets five key stakeholder groups: engineering students, early-career graduates, government/policy makers, regulatory bodies and practicing engineering professionals working within the maritime and energy industries.

2. Desk Review and Industry Context

2.1 Skills Requirements for Green Maritime Technologies

The decarbonization drive in the maritime sector has introduced new skills demands associated with green technologies. The IMO targets net-zero emissions by 2050 with interim reductions by 2030–2040 (MEPC, 2023). The adoption of alternative fuels such as liquefied natural gas (LNG), hydrogen, ammonia, and biofuels require specialized knowledge in fuel handling, storage systems, and safety protocols. Engineers and technicians must be equipped with competencies in energy systems integration, emissions reduction technologies, and lifecycle assessment. Furthermore, there is an increasing need for expertise in renewable energy applications within maritime contexts, including offshore wind, wave, and tidal energy systems. Skills in installation, maintenance, and decommissioning of offshore infrastructure are critical

According to 2026 UN project powering smart, sustainable ports in Africa by UNCTAD, less than 20% of African ports can currently handle hydrogen/ammonia fuels safely. The ports are being upgraded to produce, store, and bunker green fuels. Figure 1 a heat map representation of green port readiness across Africa, based on the following five indicators:

1. Renewable energy potential
2. Port infrastructure
3. Policy activity
4. Green fuel (hydrogen/ammonia) potential
5. Human resource capacity (skills)

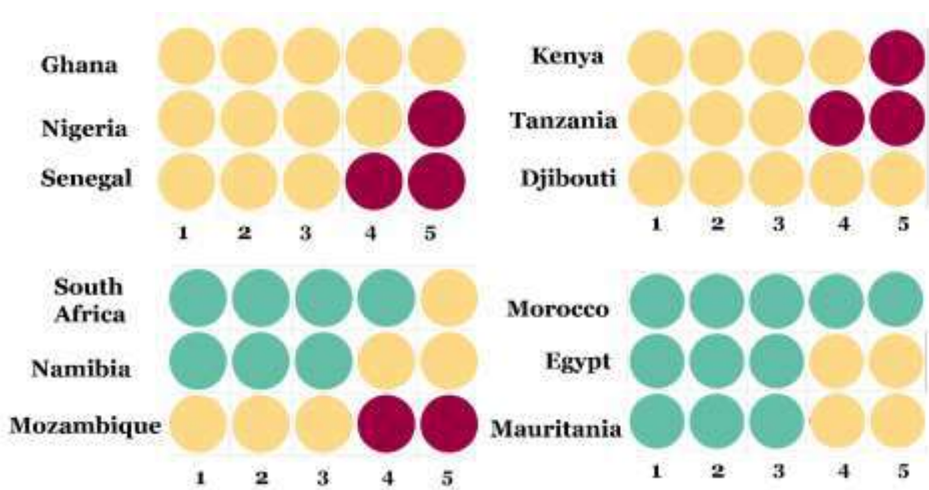

***Figure 1**:Readiness of ports in Africa for green and sustainable fuels*

Environmental sustainability also requires proficiency in energy efficiency measures, including hull design optimization, propulsion systems, and energy management systems. Professionals must be capable of applying data-driven approaches to monitor and optimize vessel performance, thereby reducing fuel consumption and emissions.

A report by the Federation of Kenya Employers (2022) on skills profile in the energy sector in Kenya provides recommendations and intervention measures, specifically the need to strengthen linkages between industry and training institutions. The report further points to lack of local human capital for specialized engineering operations in the energy sector. This is reinforced by the findings by IRENA & ILO (2024), which pointed to a slow pace of workforce development, formal training, and gender inclusion in African markets. There is little existing training on handling alternative marine fuels (ammonia, hydrogen derivatives, biofuels), safety protocols Without investment in training, the region risks deploying clean infrastructure but failing to develop a skilled local workforce. According to the Tanzanian national renewable energy strategy 2024-2034, there are few engineers with hands-on experience in protection relays, grid code compliance, micro-grid/grid interfacing, and systems planning for variable renewables.

2.2 Digital Competencies in Maritime Operations

Digital transformation is a central driver of change in maritime operations. The integration of information and communication technologies (ICT), big data analytics, artificial intelligence (AI), and the Internet of Things (IoT) has enhanced operational efficiency, safety, and decision-making processes. Key digital competencies include data analysis, cybersecurity, systems integration, and software proficiency. Maritime professionals must be able to interpret large datasets generated by onboard sensors and digital platforms to support predictive maintenance and operational optimization. Additionally, the increasing reliance on interconnected systems has heightened the importance of cybersecurity skills to protect critical infrastructure from cyber threats.

Automation and autonomous systems further require expertise in control systems, robotics, and human-machine interaction. Training programs must therefore incorporate digital literacy and advanced technical skills to prepare the workforce for evolving engineering work environments.

According to FKE (2022), there is lack of trained operators for port automation equipment, digital logistics planning, and port cybersecurity awareness, and that the ongoing modernization plans assume capability that training systems are not yet delivering. A World Bank study on demand for digital skills in Sub-Saharan Africa shows that there will be four levels of these skills: foundational digital skills, intermediate non-ICT skills, intermediate ICT skills, and advanced and highly specialized skills.

2.3 Safety and Environmental Management in Maritime Systems

Safety remains a fundamental priority in maritime operations, particularly in the context of new technologies and alternative fuels. The introduction of automated systems and digital platforms necessitates updated safety management practices that address both technical and human factors. Skills in risk assessment, safety auditing, and emergency response are essential for ensuring safe operations. Professionals must also be trained in the safe handling of hazardous materials, particularly in relation to alternative fuels such as hydrogen and ammonia, which present unique safety challenges.

Environmental management competencies are equally important, including knowledge of pollution prevention, waste management, and compliance with international environmental standards. The integration of safety and environmental considerations into operational planning is critical for achieving sustainable maritime systems.

2.4 Policy and Regulatory Frameworks for Skills Development

Policy and regulatory frameworks play a crucial role in shaping skills development in the maritime sector. International conventions and standards provide guidelines for training, certification, and operational practices. These frameworks are increasingly evolving to address emerging technologies and environmental requirements. Governments and industry stakeholders are prioritizing policies that support workforce upskilling and reskilling to align with digital and green transitions. This includes the development of competency-based training models, accreditation systems, and partnerships between academia and industry.

2.5 Conclusive Remark

The desk review highlights a rapidly evolving maritime and energy landscape characterized by technological innovation, environmental imperatives, and shifting workforce dynamics. The transition towards digitalization and decarbonization is driving demand for new and hybrid skill sets, particularly in areas such as automation, artificial intelligence, alternative fuels, and safety management. Addressing these skills needs requires a coordinated approach involving policymakers, industry stakeholders, and educational institutions. Emphasis should be placed on developing flexible, forward-looking training programs that integrate technical, digital, and environmental competencies. Such efforts will be essential for building a resilient and future-ready workforce capable of supporting safer and more sustainable maritime and energy systems.

3. Methodology

3.1 Study Design

This study adopted a mixed-methods approach combining quantitative and qualitative data collection techniques to assess the current skills landscape and identify emerging competency requirements in the maritime and energy sectors. The approach allows for the collection of both measurable data on existing skills levels and contextual insights into industry expectations and training needs.

3.2 Target Population

The study targeted key stakeholders involved in the maritime and energy sectors in East Africa. These included:

- Engineering students pursuing undergraduate or postgraduate programs relevant to maritime and energy systems
- Early-career engineering graduates entering the marine industry
- Practicing engineers and technical professionals working in ports, shipping companies, energy companies, regulatory institutions, and digital technology firms
- Training institutions and universities involved in engineering education and professional development

These stakeholder groups provide diverse perspectives on both the availability of engineering skills and the competencies demanded within the industry.

A stratified purposive sampling approach was adopted. We targeted a population of 130 respondents drawn from the energy, maritime, and education sectors. Based on Cochran's formula (Ahmed, 2024), a sample size of 97 respondents was required to realize representativeness. However, a total of 102 respondents participated in the survey.

3.3 Data Collection Methods

3.3.1 Survey Questionnaire

A structured survey questionnaire was developed to systematically capture information from stakeholders. It was carefully developed through a review of relevant literature on emerging technologies, digitalization, and green energy transitions, as well as insights from preliminary consultations with sector experts.

The questionnaire sought to collect data on respondents' level of awareness, familiarity, and practical engagement with emerging technologies, including digital systems, automation, and green energy solutions relevant to the engineering and maritime sectors. In addition, it captured respondents' perceptions of existing and anticipated skills gaps, priority capacity development areas, and the extent to which current training provisions meet industry needs. The questionnaire further explored preferences for training delivery formats, such as short courses, workshops, online learning, and blended approaches, to inform the design of responsive and accessible capacity-building programs.

Data collection was conducted over a one-month period between January and February 2026 using the Google Forms platform. The online format enabled efficient distribution, and real-time monitoring of responses, while also ensuring convenience and flexibility for participants. The survey link was disseminated via email lists, professional networks, and institutional partnerships to targeted respondents. Ethical considerations were strictly adhered to throughout the data collection process. Participation in the survey was entirely voluntary, and respondents were provided with a clear introduction outlining the purpose of the study, how the data would be used, and assurances of confidentiality.

The questionnaire was organized into four key thematic areas to ensure comprehensive coverage of the study objectives:

- Respondent Profile**:** It captured demographic and professional information such as sector affiliation, years of experience, job role, and area of specialization.
- Skills Gaps, Capacity Needs, and Emerging Technologies**:** It examined respondents' awareness and application of emerging technologies, identified skills gaps, and assessed future competency requirements in the context of digitalization and green transitions.
- Program Design: It explored preferred modes of delivery, training duration, certification needs, and barriers to participation, which provided insights for the development of tailored training interventions.
- Institutional and Systemic Enablers**:** It assessed organizational support mechanisms, policy frameworks, and partnerships necessary to facilitate effective skills development and technology adoption.

3.3.2 Stakeholders' Consultation Workshop

A stakeholder validation workshop was convened, bringing together industry experts, engineering professionals, and academic staff to obtain qualitative insights into emerging technological trends and skill requirements in the maritime sector. During the workshop, panel discussions and guided open floor feedback were used to explore key themes emerging from the survey. Inputs from stakeholders were compared with survey findings to confirm consistency, explain discrepancies, and refine interpretations. These discussions helped to contextualize and validate survey findings, and identify priority areas for capacity building.

A total of 30 participants (28 in-person and 2 online) drawn from various stakeholder categories (shown in Table 1) participated in the workshop, held in Nairobi on 19th March 2026. Experts and stakeholders were invited based on their professional background in the energy and maritime sectors. The workshop was organized around three facilitated sessions that included a general session for keynote speakers, a session for panel discussions and a final session for plenary discussion.

Table 1:Institutuins represented at the workshop and number of participants

S.No	Organization	Number of Participants
1	Moi University	7
2	Kenya Ports Authority	4
3	Engineers Board of Kenya	2
4	Kenya Education Network	1
5	Ocean Centers -Kenya	1
6	National Industrial Training Authority	2
7	Lloyd’s Register Foundation (Online)	1
8	University of Wolverhampton (Online)	1
9	Technical University of Kenya	3
10	Bandari Maritime Academy	2
11	Kenya Institute of Curriculum Development	1
12	Murang’a University of Technology	3
13	Multimedia University of Kenya	1
14	University of Eldoret	1
	Total	**30**

3.4 Data Analysis Methods

Quantitative data collected from the surveys was analyzed using both inferential and descriptive statistical methods. The focus of the analysis was on identifying priority areas where training is required. Qualitative insights from stakeholder workshop were analyzed thematically to capture industry perspectives on emerging technologies, integration challenges, and skills gaps.

A standardized engineering skills taxonomy was established prior to analysis to avoid bias in analysis, and the skills were grouped into three domains

1. Digitalization Skills
   - Automation and Autonomous systems
   - AI, data analytics, cybersecurity
2. Decarbonization & Sustainability Skills
   - Renewable energy systems
   - Alternative fuels (e.g., hydrogen, ammonia)

3. Transversal Skills
    - Safety leadership & Systems thinking

The Skills Gap Index (SGI) was computed to quantify the disparity between the proficiency levels required by industry and the current proficiency levels reported by respondents across a defined set of skills. Data were collected using a five-point Likert scale (1–5), where 1 represents very low proficiency and 5 represents very high proficiency. For each skill, two values were established:

- Required proficiency level (R_i): This was determined based on the domain and criticality of the skill. Highly complex skills were assigned a required proficiency level of 5, while moderately complex skills were assigned a required proficiency level of 4.
- Current proficiency level (C_i): This was obtained from respondents' scores using the Likert scale.

The overall Skills Gap Index (SGI) was computed as the average of the skills gaps across the total number of skills surveyed, as presented in equation 1.

$$SGI = (\Sigma (R_i - C_i)) / R_i \quad (1)$$

where:

$\Sigma (R_i - C_i)$ is the sum of the gaps across all skills

Higher SGI values indicate larger aggregate skills gaps, while lower values suggest closer alignment between current competencies and industry requirements.

The establish the priority skills, each of the identified skills gaps were scored against four criteria items, namely:

- The impact on engineering safety and risk i.e. how critical the skill is in preventing accidents, system failures, environmental harm, or operational risks. This criterion was assigned a weight of 30%)
- The scale of application in energy and/ or maritime industry, that is, how widely the skill is required across the energy and/or maritime sectors. This criterion was assigned a weight of 25%)
- The alignment with digitalization/decarbonization trend i.e. how well the skill supports emerging trends such as automation, AI, smart systems, and low-carbon technologies. This criterion was assigned a weight of 25%
- The feasibility of addressing the skill gap through training i.e. how practical it is to address the gap through training (availability of trainers, cost, time, infrastructure). This criterion was assigned a weight of 20%.

4. Findings of the Skills Needs Assessment

4.1 Introduction

This chapter presents the results of the survey and stakeholder consultations. It analyses the current level of familiarity and application of emerging digital and green technologies, identifies skill gaps, and highlights priority competencies required to support safer engineering practice in the maritime and energy sectors.

4.2 Data from Questionnaire Survey

The structured questionnaire survey was conducted to identify priority technical, safety, digital, and sustainability-related competencies required to support safe, resilient, and green transitions in the maritime industry, driven by automation, digitalization, and future fuels. The survey provided valuable insights into the current skills landscape and emerging competencies required in the energy and maritime sectors in East Africa. The findings highlight critical gaps in technical expertise, digital capabilities and green skills. The results are presented in thematic sections to ensure clarity, logical progression, and ease of comparison across key skill areas.

4.2.1 Profile of the Respondent

The characteristics of the respondent including gender, work designation, sector of employment and years of experience in the sector were profiled. Figure 2 shows the distribution of respondents in terms of work designation/role and gender. The respondents were predominantly male (74.5%), which reflects a persistent structural trend in engineering and technical sectors in East Africa. With regard to designation, the respondents were largely composed of engineers (including apprentices) at 59%, researchers/trainers (20%), government/policy and regulatory officers (15%), and students at 6%.

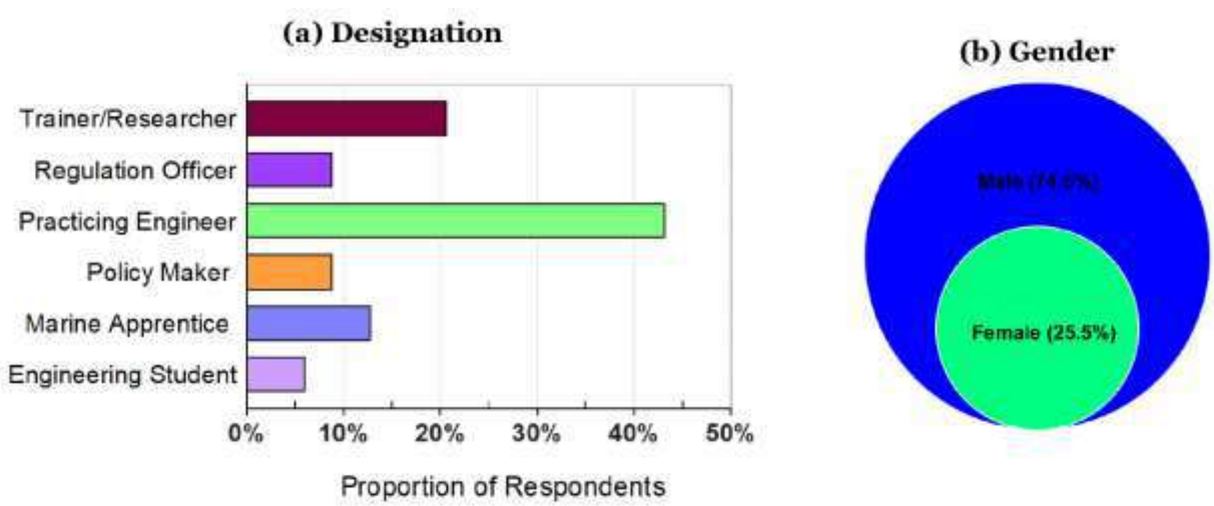

***Figure 2** (a-b): Gender and work designation*

This distribution demonstrates a strong industry orientation, with majority of respondents directly involved in technical services at their workplaces. The inclusion of researchers and policymakers provides a multi-stakeholder perspective, which is consistent with best practices.

Table 2 presents the distribution of professional disciplines among the engineering respondents. Electrical engineers were majority (33.6%), followed by Mechanical engineers (15.4%), and Energy systems engineers (14.4%). The decision to include more electrical engineers in the survey aligns with global energy transition trends, where electrification, grid modernization, and renewable integration are key focus areas. The proportion of marine engineers, though smaller (10.6%), is significant and appropriate for maritime sector representation.

Table 2: Professional category of the respondent

Professional Discipline	# Respondents	%
Chemical Engineering	8	7.7
Electrical Engineering	35	33.6
Energy Systems	15	14.4
Environmental Engineering	6	5.8
IT / Computer Engineering	9	8.7
Marine Engineering	11	10.6
Mechanical Engineering	16	15.4
Mechatronics Engineering	4	3.8
Grand Total	**104**	**100.00**

The respondents were distributed across sectors as shown in Figure 3a. The distribution has a higher representation from the energy sector to align with the interconnected role of the energy sector with other sectors linked to the maritime industry.

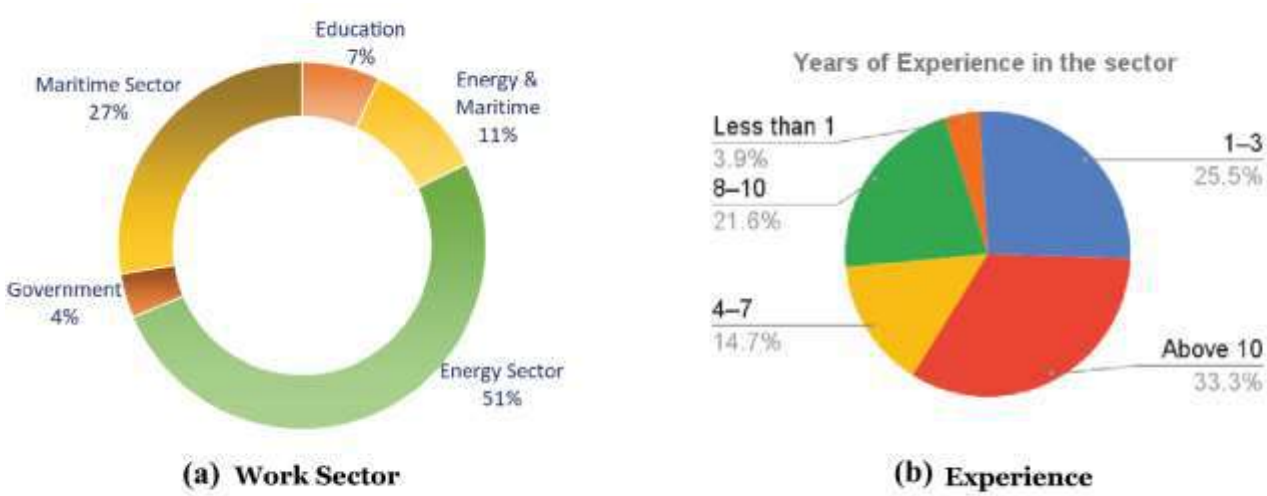

Figure 3(a-b): *Sector of engagement and years of working experience in the sector*

Majority of the respondents (33.3%) had a high level of experience as depicted in Figure 3b, having worked in their respective sectors for over 10 years. Only 3.9% of the responds had less than 1 year of experience. This indicates that the dataset is largely informed by mid- to senior-level professionals, enhancing the credibility and reliability of insights

Overall, the respondent profile is broadly representative of the technical workforce in the energy and maritime sectors, which suggest that the findings are industry driven and reflect the current status of skills needs and capacity

4.2.2 Awareness of Impact of Emerging Technologies

The survey also sought to understand the respondent's familiarity with emerging technologies and those that are likely to have the greatest impact. The respondents consistently identified a cluster of emerging technologies as likely to have the greatest impact on the energy and maritime sectors over the next 5 to 10 years. These include artificial intelligence, smart energy systems, offshore renewable energy, robotics and automation, alternative fuels, and autonomous vessels as depicted by the results in Figure 4.

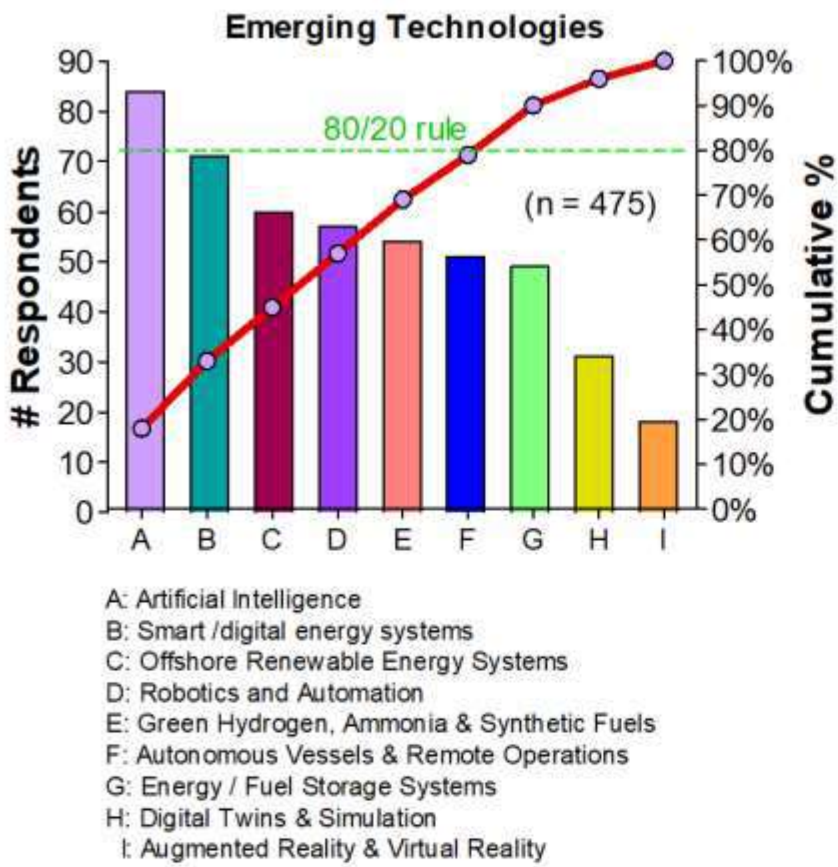

Figure 4*: Familiarity with emerging technologies that are likely to have greatest impact on the energy & maritime sectors in the next 5-10 years*

Artificial Intelligence (AI) was perceived as a revolutionary technology due to its cross-cutting applications in predictive maintenance, route optimization, and operational efficiency, while robotics and automation were recognized for their ability to improve efficiency, safety, and precision in both sectors. Autonomous vessels were also ranked highly, reflecting expectations of increased automation in maritime transport. Respondents appear aware of the long-term potential for reduced human intervention, improved safety, and optimized logistics.

Smart energy systems were rated high due to their role in integrating renewable energy systems, improving energy management, enhancing grid stability, and enabling real-time monitoring. Respondents' strong recognition of this technology suggests familiarity with ongoing energy transition efforts, particularly in grid modernization. Offshore renewable energy systems were also considered highly impactful. This reflects the trends in clean energy expansion, particularly in maritime infrastructure.

Alternative fuels such as green hydrogen and ammonia were identified as critical for decarbonization. This awareness strongly aligns with global trends where shipping and heavy industry are transitioning toward low-carbon fuel alternatives.

Despite being a critical enabler of renewable energy systems, energy and fuel storage technologies were rated as less impactful compared to the technologies above. This may indicate a perception that storage is a supporting rather than transformative technology. However, global evidence (IEA, 2024) suggests that energy storage (including batteries and hydrogen storage) is fundamental to energy transition, highlighting a potential knowledge gap in energy systems thinking among respondents.

A significant finding from the survey is that most respondents reported low familiarity with digital twins, simulation technologies, and virtual reality (VR)**.** The low familiarity indicates a significant digital capability gap. The current education and training systems may not be adequately covering emerging digital engineering tools. These tools are essential for system design and optimization, predictive maintenance, and experimentation. Their limited recognition suggests that respondents are more exposed to operational technologies than to analytical and modeling tools. Indeed, advanced digital tools often lag in adoption in developing economies due to high implementation costs, limited technical capacity, and lack of exposure in education and training systems.

Overall, the results on familiarity and perceived impact of emerging technologies reveal important insights into how professionals in the energy and maritime sectors understand, prioritize, and engage with technological change. These insights have direct implications for skills development, policy, and industry readiness.

4.2.3 Sector Preparedness in Skills & Capacity

The survey results provide important insights into areas of emerging technologies where the energy and maritime sectors are least prepared in terms of skills and capacity. The results are presented in Figure 5. The results reflect the degree of unpreparedness across key emerging technologies. In this context**,** higher percentages indicate greater skills and capacity gaps, and therefore lower levels of preparedness. Digital monitoring and diagnostics exhibit the highest skill gap, with 62% of respondents indicating unpreparedness, which indicates low digital transformation capabilities.

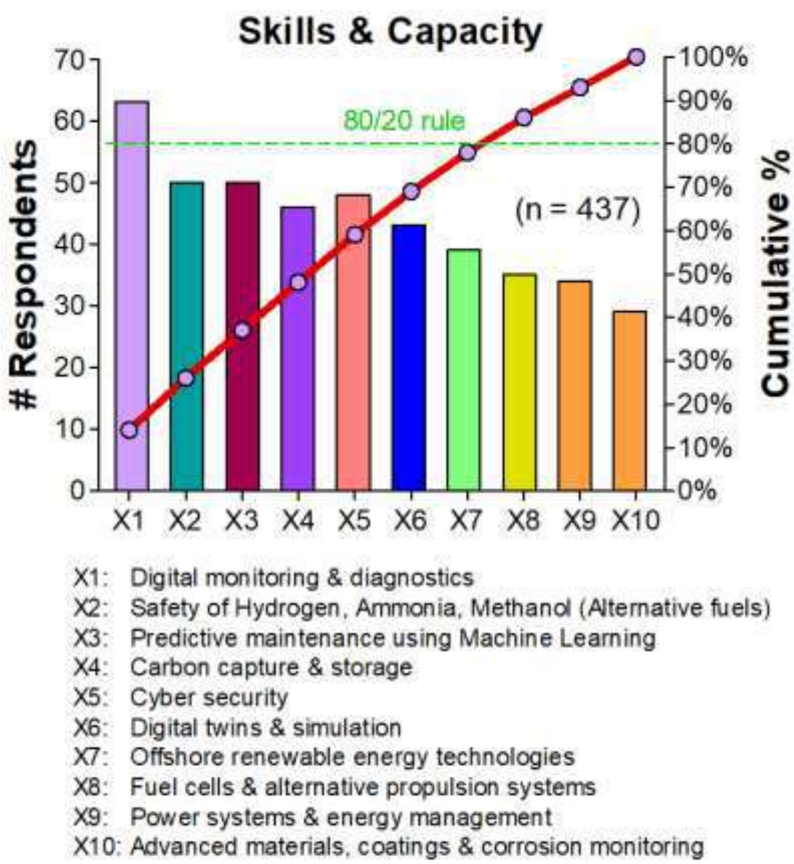

Figure 5*:Preparedness in skills and capacity in the areas of emerging technologies*

The low capability in safety of hydrogen, ammonia and methanol (49% of respondents indicate unpreparedness) highlights a significant gap in competencies related to alternative fuels, particularly in safety protocols and operational handling, areas that are critical for the transition to low-carbon energy systems.

Low preparedness in predictive maintenance using machine learning indicates limited adoption of AI-driven maintenance strategies, pointing to insufficient skills in data analytics, machine learning, and condition-based monitoring systems. The results also show low capability for carbon storage, which suggest the two sectors are not yet adequately equipped with the technical expertise required to implement carbon mitigation technologies at scale.

A high level of unpreparedness in cybersecurity raises concerns about the vulnerability of increasingly digitalized energy and maritime systems to cyber threats, underscoring the need for stronger digital security skills capabilities. Conversely, the results indicate a notable level of preparedness and capacity in the area of advanced materials, coatings, and corrosion monitoring

Overall, the findings reveal widespread capacity gaps across both digital and green transition technologies, with varying levels of preparedness, which underscore the need for targeted skills development and specialized training programs

4.2.4 Gaps Between Industry Skills Needs and Existing Competencies

The respondent self -assessment of competencies on a scale of 1 (no skill) to 5 (expert), presented in Table 3, provides a clear picture of the current capability distribution across key technical domains relevant to digitalization and green transitions.

Table 3: Existing level of competencies among local engineers

	Competence Area	**Competence Level (1= No skill, 5 = Expert)**
		Mean
X1	Digitalization of engineering systems	3.36
X2	Autonomous, Smart systems	3.10
X3	Offshore and Marine energy systems	2.08
X4	AI/ Machine Learning applications	2.70
X5	Future Fuels/Alternative fuels	2.35
X6	Offshore installation & decommissioning	2.24
X7	Decarbonization & Sustainability	3.10
X8	Engineering design for safety	3.13
X9	Cybersecurity in industrial systems	2.38
X10	Digital safety in engineering applications	2.91
X11	Systems approach to problem solving	3.02

From the results in Table 4.2, the competence ratings range from 2.08 to 3.36, suggesting that most respondents are within the basic to intermediate proficiency level. Digitalization of energy systems (3.36) is the highest-rated competency, indicating that respondents are relatively conversant with basic digital tools, automation in engineering processes and digitally enabled monitoring and control systems. This reflects ongoing digital transformation efforts across industries and suggests that respondents have exposure to digital systems**,** even if not at advanced levels.

The scores in engineering design for safety (3.13) and digital safety (2.91) indicate moderate competencies in safety standards and risk management, integration of safety in engineering design and emerging aspects of digital safety. However, the slightly lower score for digital safety suggests a gap in adapting traditional safety principles to digital environments. The equal score of 3.1 in autonomous and smart systems, and decarbonization and sustainability may suggest that respondents are aware of both digital and green transitions, but their competence remains at a conceptual or intermediate level rather than advanced application.

Systems approach to problem solving is a critical competency for managing modern engineering challenges. The moderate score of 3.02 suggests adequate but improvable systems thinking capability, which is essential for integrating digital and green technologies.

A score of 2.7 in AI and Machine Learning applications reflects basic awareness of AI concepts. Despite AI being identified as a high-impact technology, the relatively low competence level highlights a significant skills gap between awareness and application**.** Also, a score of 2.38 in Cyber security indicates low preparedness for securing digital infrastructure.

The respondents rated their competency in future/alternative fuels at 2.35 suggesting limited technical knowledge of green fuels such as hydrogen and ammonia. Although respondents recognize the importance of alternative fuels, they lack the technical expertise required for implementation, indicating a need for targeted training.

Offshore and marine energy systems, and offshore installation and commissioning recorded the lowest competence scores. These low scores highlight a critical skills gap in offshore and maritime-related engineering domains. This is particularly important given global trends identified by UNCTAD (2023), which emphasize offshore energy as a key component of future energy systems.

Overall, respondents are aware of emerging trends but lack technical proficiency. Low scores in offshore systems, alternative fuels, and cybersecurity highlight limited exposure to rapidly evolving fields and gaps in training. To bridge the gaps, dedicated training programs are required while partnerships with industry and international institutions should be strengthened

4.2.5 Preferred Training Formats

The survey results in Figure 6 indicate a clear preference among respondents for practical and structured, modes of upskilling**.** Majority of respondents **(**82.4%**)** identified on-site training workshops as their most preferred method of upskilling. This overwhelming preference suggests that professionals in energy and maritime sectors place high value on face-to-face learning environments that are closely aligned with their workplace context. On-site seminars typically allow for real-time engagement with trainers, hands-on demonstrations, and immediate application of concepts to operational settings.

Figure 6: Results of questionnaire survey on preferred training format

Similarly, a significant proportion **(**66.7%**)** of respondents expressed a preference for **s**hort courses of not exceeding 2 weeks**.** This reflects a demand for time-efficient training programs that can deliver desired outcomes without requiring long-term commitment.

In contrast, only a small proportion of respondents indicated a preference for online learning or modular programs**.** This comparatively low uptake may reflect several underlying factors, including limited familiarity with digital learning platforms, concerns about the effectiveness of remote training for technical subjects, or infrastructural challenges such as inconsistent internet access in certain operational environments.

Overall, the preference for on-site seminars and short courses indicates a strong inclination toward applied learning, as well as opportunities for peer interaction and knowledge exchange. Some of the important implications of these findings are that in-person training formats should be the primary mode of capacity building and that partnership with industry would be essential to enhance training outcomes. Also, while online learning is less preferred, there is an opportunity to integrate blended learning approaches.

4.2.6 Barriers to Skill Development

Data obtained from the survey (Figure 7) highlight a range of barriers to skills development in energy and maritime sectors, encompassing four dimensions, namely policy, partnerships, expertise and economic, with the latter as predominant. Limited training budget was cited by the majority of respondents as a significant barrier. Less than 20% of respondents identified weak training policies or limited industry partnerships as major constraints**.** Similarly, lack of qualified trainers was reported as the least significant barrier, suggesting that there is some level of access to technical expertise or training personnel within the ecosystem.

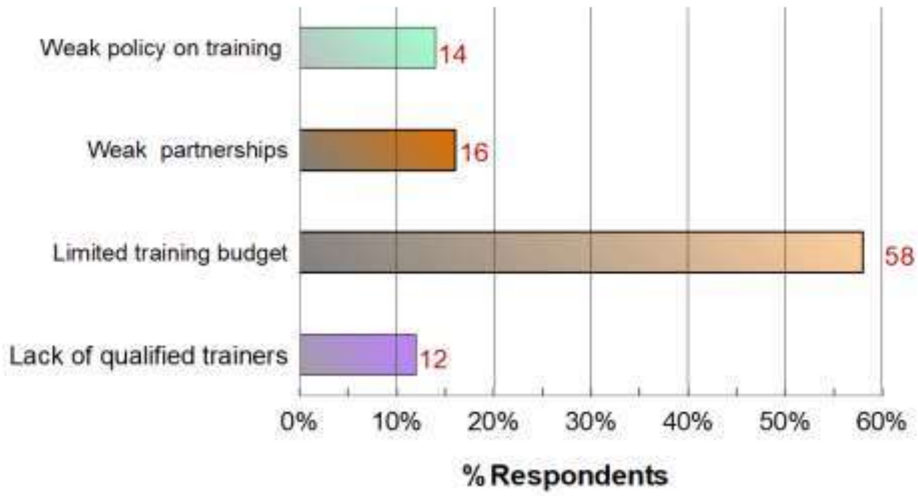

Figure 7: Barriers to skills development in the energy and maritime sectors

These findings point to the need for targeted interventions to increase funding for training. Since policy and partnerships are not viewed as major barriers, there is an opportunity to build on existing policy structures and strengthen partnerships. Also, while lack of trainers is not a major issue, maintaining the quality and relevance of trainers, especially in emerging digital and green technologies is important to ensure effective knowledge transfer. This could be achieved through training of trainers (ToT) programs.

4.3 Stakeholders Validation

The stakeholder validation workshop, held on Thursday 19th March 2026 at the KICD Conference Centre, Nairobi, provided a platform for reviewing and strengthening the findings of the skills needs assessment on digital and green transitions in the energy and maritime sectors across East Africa. The workshop brought together representatives from academia, industry, government agencies and regulatory bodies (Figure 8).

During the workshop, participants were presented with the key findings of the assessment, including identified skills gaps, sector capacity, and priority areas in emerging technologies. Stakeholders generally affirmed the validity and relevance of the findings. In particular, there was strong consensus that technologies such as Artificial Intelligence (AI), smart energy systems, alternative and low-carbon fuels, and autonomous systems are high-impact and will significantly shape the future of both the energy and maritime industries. These technologies were therefore confirmed as priority areas for capacity development and curriculum design.

Figure 8: Participants at the stakeholders' validation workshop

A key outcome of the workshop was the validation and identification of priority skills areas. Stakeholders helped to further contextualize these priorities by aligning them with industry needs and global trends in decarbonization and digitalization. The workshop also generated valuable insights on strategies to strengthen collaboration and linkages. Participants proposed the establishment of structured partnerships between academia and industry to support curriculum co-development, applied research and innovation.

Overall, the workshop played a key role in confirming the validity of the assessment findings while improving them with expert insights, which enabled the prioritization of critical skills gaps and informed the identification of targeted capacity building programs.

5. Analysis & Discussion

5.1 Analysis of Critical Skills Gaps

Based on the validated data, a Skills Gap Index (SGI) was constructed to quantify the severity of capacity deficiencies across the identified key competency domains in the maritime and energy sectors. First, the Kruskal-Wallis statistical analysis (Chan and Walmsley, 1997) was performed followed by a post-hoc analysis using Dunn's test to assess if there is a statistically significant difference in rank means between the competence domains (groups) assessed. The rank mean is the average of ranks for each group after ranking all data across groups together. Table 4 shows the results of the analysis.

Table 4: Summary of Kruskal-Wallis statistical analysis

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
N	104	104	104	104	104	104	104	104	104	104	104
Mean	3.3627	3.0981	2.0784	2.6922	2.3529	2.2353	3.0980	3.1275	2.3824	2.9118	3.0247
Variance	1.1839	1.3764	1.5779	1.4437	1.7554	1.6471	1.5150	1.4588	1.3078	1.6258	1.4837
Median	3	3	2	3	2	2	3	3	2	3	3
Rank Sum	71588	65036	38732	50735	45948	42529	64774	65664	46775	60131	69091
Rank Mean	701.84	637.62	379.73	499.64	450.47	416.95	635.04	643.76	458.58	589.52	677.36

Kruskal-Wallis Statistic	
Chi-Square	131.72 *** (P<=0.001)
DF	10
P-Value	2E-023

A significant result from the test would indicate that at least one group's distribution differs from the others. The null hypothesis is that the median ranks of the two compared groups are equal. If the Q-value is higher than Q-critical, the null hypothesis is rejected. The Q-values are p-values that are adjusted for multiple comparisons to control for false positives.

Three competence domains (groups) with the highest mean rank (X1, X2, X8) were subjected to the Dunn's test, yielding the results in Table 5.

Table 5: Results of the Dunn's test

Comparison	Q-Value	Q-Critical	Decision
X1, X2	3.0504	3.3102	Accept H_O
X1, X8	2.6225	3.3102	Accept H_O
X2, X8	1.5965	3.3102	Accept H_O

All the Q-values are less than the critical value, which indicates that all the three groups are not significantly different. A skills gap index was then constructed using equation 1 presented earlier in Chapter 3 for all competence areas identified. The results are presented in Table 6 where C denotes the current competence level and R is the required competence level. The index uses the mean rank to classify the skills gaps hierarchically on a scale of (0–1), where, 0.6–1 represents a critical gap, 0.4–0.59 is a high gap, 0.25–0.39 is a moderate gap, and a value below 0.25 is considered an emerging gap.

Table 6: Severity ranking of the skills gaps

Code	Competence Area	C	R	SGI	Severity
X1	Digitalization of engineering systems	3.36	5	0.33	Moderate
X2	Autonomous, Smart systems	3.10	5	0.38	Moderate
X3	Offshore and Marine energy systems	2.08	5	0.58	High
X4	AI/ Machine Learning applications	2.70	5	0.46	High
X5	Future Fuels/Alternative fuels	2.35	5	0.53	High
X6	Offshore installation & decommissioning	2.24	5	0.55	High
X7	Decarbonization & Sustainability	3.10	5	0.38	Moderate
X8	Engineering design for safety	3.13	5	0.37	Moderate
X9	Cybersecurity in industrial systems	2.38	5	0.52	High
X10	Digital safety in engineering applications	2.91	5	0.42	High
X11	Systems approach to problem solving	3.02	5	0.40	High

The SGI analysis in table 6 provides an assessment of the disparity between current competence levels (C) and required competence levels (R) across key skills domains relevant to digital and green transitions in the energy and maritime sectors. The findings reveal a mix of high and moderate skill gaps, with no areas classified as "critical" (SGI $\geq$ 0.6), but several approaching that threshold, indicating urgent need for intervention.

The highest gaps are concentrated in offshore, digital security, and energy transition technologies, reflecting the limited existing capacity. This gap is particularly significant given the global shift toward offshore renewable energy, suggesting that the local engineers in the energy and maritime sectors are not adequately prepared to support future investments in this area. However, with ongoing regional expansion of marine infrastructure, this gap poses risks to safety, cost efficiency, and environmental sustainability.

The analysis highlights significant skills gaps that could hinder the effective transition to digital and green systems within the energy and maritime sectors. While no area is yet classified as critical, several are approaching that level, particularly in offshore energy and emerging fuel technologies. Without targeted interventions in training (with a strong focus on future-oriented skills development), curriculum reform, and strategic partnerships these gaps will constrain the transition toward safer, greener, and more efficient maritime systems in East Africa.

5.2 Skills Prioritization

The study applied a multi-criteria approach to prioritize the identified skills gaps by ranking them based not only on their severity but also on their strategic importance to the energy and maritime sectors. Each identified skills gap was evaluated against four key criteria listed below:

Criteria 1: Impact on engineering safety & risk
Criteria 2: Scale of application in energy/maritime sector
Criteria 3: Alignment with digitalization/decarbonization
Criteria 4: Feasibility of training intervention

Each criterion was scored on a scale of 1 to 5, then the individual criterion scores (q) were aggregated (with associated weighting) to produce a composite prioritization score**.** To incorporate the severity of the skills gap, this composite score was then multiplied by the Skills Gap Index (SGI) for each skill area to obtain the final prioritization score. This ensured that skills with both high SGI and high strategic importance were ranked on a higher priority level. Based on the final scores, skills gaps were categorized into three priority levels: Level 1 (high priority), Level 2 (medium priority), and Level 3 (low priority) as shown in Table 7

Table 7: Prioritization matrix of the skills gaps

Skill Code	**Criteria 1** Weight: w 30%		**Criteria 2** Weight: w 25%		**Criteria 3** Weight: w 25%		**Criteria 4** Weight: w 20%		Sum of wt. Score x SGI	**Priority Level**
	Score	w x q	Score	w x q	Score,	w x q	Score	w x q		
X1	3.3	0.99	4.6	1.15	4.7	1.18	4.5	0.90	1.39	**3**
X2	4.3	1.29	4.3	1.08	4.6	1.15	4.8	0.96	1.70	**2**
X3	3.9	1.17	3.7	0.93	4.6	1.15	3.7	0.74	2.31	**1**
X4	4.2	1.26	3.9	0.98	4.8	1.20	4.8	0.96	2.02	**1**
X5	4.5	1.35	3.9	0.98	4.8	1.20	4.8	0.96	2.38	**1**
X6	3.8	1.14	3.2	0.80	4.0	1.00	3.2	0.64	1.97	**2**
X7	3.7	1.11	4.5	1.13	4.6	1.15	4.5	0.90	1.63	**2**
X8	4.0	1.20	4.3	1.08	4.1	1.03	4.8	0.96	1.58	**3**
X9	4.6	1.38	4.4	1.10	4.8	1.20	4.8	0.96	2.41	**1**
X10	4.2	1.26	4.0	1.00	4.6	1.15	4.7	0.94	1.83	**2**
X11	4.5	1.35	3.6	0.90	4.4	1.10	4.8	0.96	1.72	**2**

The application of this prioritization approach helped to identify four areas that require priority skilling intervention. These areas are:

X3: Offshore and Marine energy systems
X5: Future Fuels/Alternative fuels
X9: Cybersecurity in industrial systems
X4: AI/ Machine Learning applications

Systems thinking (X11) was categorized under medium priority but with a score approaching high priority. This indicates that it is a strategically significant cross-cutting skill that calls for close monitoring and consideration in skills development planning. Indeed, beyond technical know-how, there is a critical need for engineers who think in systems, that is., engineers who can assess not just the performance of individual components, but how systems interact with other interconnected components and relationships (i.e. how sub-systems interact within a larger context).

5.3 Skills Gap to Training Mapping

The identified skills gaps reflect the need for targeted capacity building interventions that not only impart technical knowledge but also enhance innovation capacity, and regulatory awareness. Therefore, the expected learning outcomes of the training program have been formulated to correspond to the required competencies for two key target groups: (i) engineering students at undergraduate or early career level, and (ii) industry professionals for upskilling. The mapping process links each high-priority skills gap to one or more learning outcomes as presented in Table 5.5, demonstrating how the proposed training program will close identified competency deficiencies.

Table 8: Mapping of skills gaps to learning outcomes

Skills Gap Area	**Proposed Program Learning Outcomes (PLOs)**	
	Training Level: Engineering Students	Training Level: Industry Professionals (CPD)
Offshore & Marine Energy Systems	1. Design, analyze and optimize offshore and marine renewable energy systems 2. Apply simulation tools to assess marine energy resources 3. Apply systems thinking in integrated marine energy systems	1. Apply advanced risk assessment tools to manage safety risks in complex and evolving energy and maritime systems 2. Oversee safe integration of offshore energy into existing infrastructure
Future Fuels / Alternative Fuels	1. Evaluate and optimize hybrid propulsion systems integrating low-carbon and alternative fuel technologies for efficient, safe, and sustainable applications 2. Assess lifecycle emissions, safety implications, and system integration requirements. 3. Implement safe handling and storage protocols for Hydrogen, LNG, and Ammonia	1. Ensure safe handling, storage, and regulatory compliance of alternative fuels 2. Utilize digital tools and simulation techniques to model and optimize hydrogen-based energy systems configurations 3. Develop decarbonization strategies for the maritime and industry

Cybersecurity in Industrial Systems	1. Apply cybersecurity principles in industrial systems 2. Design secure digital and automation architectures 3. Integrate digital technologies safely into complex engineering systems	1. Manage cyber risks in critical engineering systems 2. Lead the integration of digital and automated systems securely
AI / Machine Learning Applications	1. Develop and apply AI and machine learning solutions in engineering systems 2. Apply predictive analytics for systems optimization and decision-making 3. Implement AI-driven predictive maintenance and structural health monitoring of energy/maritime infrastructure	1. Integrate AI into engineering and automation systems 2. Use data analytics for safety and operational efficiency
Cross-Cutting (Systems Thinking, Innovation)	1. Apply systems thinking in complex engineering environments 2. Demonstrate innovation and teamwork in sustainable engineering solutions	1. Lead safety-critical decision-making in complex systems 2. Foster safety culture and inclusive leadership

For students, the focus is on building foundational technical competencies, analytical capabilities, and systems thinking. For industry professionals, the emphasis shifts toward advanced application, leadership in safety-critical environments, regulatory compliance, and strategic decision-making. Overall, the mapping shows that the proposed training program will bridge existing skills gaps and support the digital and green transitions towards safe and sustainable energy and maritime systems in East Africa.

6. Conclusions & Recommendations

6.1 Summary of Key Findings

The maritime and energy sectors are undergoing rapid transformation driven by global imperatives for decarbonization, digitalization, and climate resilience. Emerging technologies such as autonomous systems, artificial intelligence and low-carbon alternative fuels are reshaping the operations in these sectors. However, these technological shifts present complex engineering, safety and environmental challenges, particularly in developing regions like East Africa where capacity to manage digital and low-carbon technologies is limited. Building local engineering capacity is essential to ensure the safer integration of green and digital technologies in the energy and maritime industries in East Africa.

This study aimed to identify the skills gaps that should be addresses to enable safer transition to digital and low-carbon technologies in the energy and maritime sectors in East Africa. The methodology utilized in the study involved questionnaire survey and stakeholders' workshop. The data obtained from the survey reveals that while there is a growing awareness of emerging digital and green technologies, the prevailing competency levels to integrate and apply these technologies is largely within the basic to intermediate range, particularly in high-impact areas such as offshore marine energy systems, cybersecurity, AI/machine learning applications, and alternative fuels.

The analysis further reveals that maritime and energy sectors are insufficiently prepared to manage the complexities associated with technological advancement. Significant capacity gaps in digital safety, cybersecurity, AI/Machine learning applications and simulation tools underscore the urgent need to strengthen skills capacity in these areas. At the same time, low competence in offshore and marine energy systems and emerging low-carbon fuel technologies points to a clear need for specialized skilling program aligned to green energy transition.

The prioritization of skills gaps using a multi-criteria approach ensures that training programs are focused on areas with the highest impact on safety, scalability, and alignment with digitalization and decarbonization goals. The study also revealed a strong preference by industry professionals for short courses or on-site training formats

Finally, the stakeholder validation workshop reinforces the relevance of the findings, while underscoring the importance of collaboration between academia, industry, and policy makers. Strengthening these partnerships will be essential for enhancing knowledge transfer, and fostering innovation.

Overall, the study provides critical insights that will inform the design, structure, and content of the proposed capacity-building programs. These interventions should be tailored to two distinct training levels: undergraduate students, to develop future workforce capacity, and industry professionals, through Continuous Professional Development (CPD) to support skills enhancement.

6.2 Recommendations

Based on the analysis the following five actions are recommended:

6) Design and implement specialized training programs that directly address the high-priority skills gaps identified, particularly in offshore and marine energy systems, cybersecurity, artificial intelligence, and alternative fuels.
7) Establish partnerships between academic institutions and industry to support curriculum co-development, applied research, and knowledge transfer.
8) Promote international collaboration and benchmarking with countries advanced in offshore and marine energy technologies
9) Integrate emerging digital technologies and tool (e.g., simulation, digital twins, AI) and green technologies (e.g. alternative fuels) into engineering curricula and professional training programs to build advanced, future-ready competencies.
10) Incorporate cybersecurity as a core component of engineering education and professional development

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