

Article

Mapping the Green Skills Signals in Online Job Vacancies in Four Selected African Countries: An Exploratory and Comparative Analysis

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Abstract

This study aims to map and compare the demand for green skills across four selected African countries by analyzing online job vacancies. Accordingly, the study addresses four research questions: (RQ1) how green skills demand has evolved over time; (RQ2) which sectors exhibit the highest demand for green skills; (RQ3) which occupations are most associated with green skills; and (RQ4) which green competencies are most frequently requested by employers. A Big Data and Labour Market Intelligence approach is employed based on secondary data provided by the online job vacancies (OJV). The results reveal a general upward trend in green skills demand, although with significant cross-country variation. Sectorally, sustainable energy dominates across all countries, followed by more context-specific areas such as agriculture, tourism, and production. At the occupational level, environmental engineers and other technical professions are most strongly associated with green skills. The thematic analysis highlights renewable energy, energy efficiency, and environmental sustainability as the most prominent skill domains, alongside emerging competencies in sustainable mobility, circular economy, and green digital skills. The study contributes to the literature by providing empirical evidence from an underexplored African context and demonstrating the value of online job vacancy data for monitoring labour market transformations.



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Keywords: green skills; labour market intelligence; big data analytics; green transition; sustainable development; skills demand analysis

1. Introduction

The green economy has emerged as a new paradigm in addressing the interconnected challenges of climate change, resource depletion, and socio-economic inequality [1–3]. It represents a shift from traditional growth models toward an approach that integrates environmental sustainability with economic development and social inclusion. Green skills refer to the knowledge, competencies, values, attitudes, and behaviours that enable

individuals and organizations to support the transition toward environmentally sustainable and resource-efficient economies. They encompass both occupation-specific technical skills (e.g., renewable energy management, energy efficiency, sustainable resource use, waste reduction, and environmental monitoring) and transversal competencies (e.g., systems thinking, problem-solving, innovation, adaptability, collaboration, and environmental awareness) [4,5]. These skills enable individuals and organizations to implement environmentally responsible practices across sectors. In the current business landscape, green skills are increasingly critical as firms face regulatory pressures and stakeholder expectations toward sustainability. Organizations are integrating environmental, social, and governance (ESG) criteria into their strategies, requiring employees who can design sustainable products and ensure compliance with environmental standards. Moreover, Kóczyás & Demirel [6] note that green skills support innovation by enabling companies to develop cleaner technologies and circular business models, enhancing competitiveness and long-term resilience. As sustainability becomes a strategic priority, the demand for such skills continues to grow across industries.

Green skills are particularly important for African countries because the continent faces acute environmental and socio-economic challenges while also holding significant potential for sustainable growth. Many economies depend heavily on climate-sensitive sectors such as agriculture, fisheries, and natural resources, making them highly vulnerable to climate change [7,8]. Developing green skills enables the workforce to adopt sustainable practices. These skills are even more critical in the African context due to rapid population growth, urbanization, and the need for job creation. Calanter et al. [9] highlight that circular activities associated with the green sector offer opportunities to generate employment while addressing infrastructure and energy access gaps. Accordingly, African countries can leapfrog traditional, carbon-intensive development pathways and move directly toward more sustainable models. This not only enhances competitiveness in emerging global markets but also supports inclusive development.

This study aims to address a critical gap in the literature by mapping green skill signals in online job vacancies across four African countries, to provide comparative and empirically grounded insights into workforce requirements for the green transition. While global evidence shows that green skills are becoming a key driver of employment growth and economic transformation [10], existing research still lacks clarity on how these skills translate into concrete occupational demands in different regional contexts. This limits the ability of policymakers and educators to design targeted interventions. Prior studies also highlight that, although research on green jobs is expanding, it remains fragmented, with inconsistent definitions and limited alignment between conceptual frameworks and practical workforce needs [11]. Furthermore, the persistence of a green skills gap underscores the mismatch between labour market requirements and existing education and training systems [12]. In the African context, while green technologies and sectors are recognized as important opportunities for youth employment and sustainable development [13], and evidence from countries such as South Africa shows sector-specific employment effects of greening [14], there is still a lack of comparative, multi-country analysis. Against this backdrop, this study aims to systematically identify and compare green skills needs across four African countries, contributing to a more actionable understanding of workforce gaps and informing policy, and capacity-building strategies for the green economy transition.

This study is guided by four research questions:

The first research question (RQ1) is: How has the demand for green skills evolved over time? It aims to assess the growth and temporal dynamics of green skills in online job vacancies.

The second research question (RQ2) is: In which sectors of activity are green skills most frequently demanded? It focuses on identifying the industries driving the demand for sustainability-related competencies.

The third research question (RQ3) is: Which occupations are most associated with green skills? It seeks to map the professional profiles most linked to the green transition.

The fourth research question (RQ4) is: What are the most in-demand green skills? It aims to identify and classify the specific technical and transversal competencies most requested by employers in the green economy context.

2. Literature Review

2.1. Green Economy and Sustainability Transitions

The green economy has become a central analytical framework for understanding how economies can pursue growth while reducing environmental harm and improving social well-being [15]. In the literature, it is generally presented as a transition from carbon-intensive development toward models based on resource efficiency, low emissions, circularity, and social inclusion [16,17]. This transition is not limited to environmental policy; it also reshapes industrial organization, labour-market structures, and the competencies required of workers and managers.

A major implication of this transition is that labour markets must adapt. OECD [18] argues that the green transition changes both the number and the nature of jobs, creating new occupational profiles while transforming existing ones. Studies on renewable energy and green employment in Europe, for example, show that the expansion of clean energy can generate substantial job opportunities, but also requires parallel investments in skills and training systems to avoid bottlenecks [19]. As a result, the green economy is increasingly linked to the broader sustainability transition agenda, which seeks to align economic activity with ecological limits and social objectives. In this perspective, the availability and quality of green skills become key conditions for the pace, inclusiveness, and distributive outcomes of decarbonisation.

2.2. Green Skills, Sustainability Competences and Green Competencies

Green skills are commonly defined as the knowledge, abilities, values, and attitudes needed to support environmentally sustainable practices in economic and social life [20]. This definition is deliberately broad, because sustainability-related competencies cut across occupations and sectors. Green skills include technical abilities such as renewable energy management, energy efficiency, waste reduction, sustainable design, waste and pollution control, but also transversal competencies such as systems thinking, innovation, problem-solving, collaboration, and environmental awareness [21,22].

The literature often distinguishes between two related but different ideas: green skills and sustainability competences [23,24]. The first is more closely linked to the practical requirements of jobs in the green economy, while the second refers to broader capabilities for acting responsibly in relation to environmental and social sustainability across life contexts. This distinction matters for curriculum design, because education systems may need to prepare learners both for specific green occupations and for the wider competences required to act sustainably in any profession.

Recent conceptual work further refines this picture by proposing multi-level models of green competences. Wegenberger & Ponocny [25] distinguish between general sustainability competences, intermediate cross-sectional competences, and specific green skills, delineated by their degree of specificity and proximity to concrete work tasks. At the most general level, sustainability competences include systems thinking, anticipatory and normative competences, and interpersonal skills needed to deal with complex sustainability

challenges. At an intermediate level, cross-sectional competences such as project management, stakeholder engagement, and process management are required to implement sustainability strategies across sectors and organizational functions. Finally, specific green skills refer to technical and operational abilities directly linked to low-carbon technologies, resource-efficient processes, and environmental management in particular jobs.

Parallel research on “green competencies” emphasizes that green human capital is inherently multidimensional, integrating knowledge, skills, abilities, attitudes, behaviours, and awareness related to environmental sustainability [26,27]. Company-level studies show that firms often interpret green competencies through the lens of pro-environmental awareness and knowledge, followed by concrete behaviours such as responsible resource use and compliance with environmental standards [28,29]. In practice, green skills in firms tend to intersect with other skill domains: they involve not only technical and regulatory skills (for instance, the ability to work with environmental norms and energy-efficiency standards), but also social and personality-enhancing skills such as teamwork, communication, responsibility, and environmental motivation [30].

From a labour-market and policy perspective, green skills are increasingly conceptualized as “any skills supporting the transition to a sustainable society”, encompassing both new occupations created by the green economy and the transformation of existing jobs [31,32]. Institutional analyses of skill-formation regimes underline that the volume and type of green skills produced in an economy depend on how vocational education and training (VET) systems are organized, how strongly employers are involved, and how public policy supports reskilling and upskilling for the green transition. This institutional angle is particularly relevant for the present study because it suggests that green skills in Africa will be shaped by the specific configuration of education systems, labour markets, and governance arrangements in each country, rather than by a single universal model.

2.3. Firm Performance and Organizational Adaptation

Recent empirical studies suggest that green skills and green capabilities are not only socially desirable but also economically valuable. Kóczyás & Demirel [33] find that green skills and capabilities can positively influence firms’ financial performance by enabling cleaner technologies, sustainability-oriented innovation, and more effective adaptation to the net-zero transition. This result is important because it challenges the idea that environmental competencies are merely a compliance cost; instead, they can function as strategic resources that improve competitiveness and resilience [34]. The organizational literature also indicates that firms are under increasing pressure from regulations, investors, consumers, and supply-chain partners to demonstrate environmental responsibility. In this context, workers with green skills can help organizations meet ESG requirements, improve operational efficiency, and redesign processes to reduce waste and emissions [35,36]. Evidence from emerging economies shows that green entrepreneurial orientation, green innovation and green intellectual capital jointly contribute to sustainable firm performance across economic, environmental, and social dimensions [37,38]. These studies suggest that green knowledge, skills and competences embedded in human, structural and relational capital can become dynamic capabilities that support eco-innovation and help firms derive a “green competitive advantage” in resource-constrained contexts. From a labour market perspective, this strategic importance is increasingly reflected in employers’ recruitment practices, as evidenced by the growing number of job postings seeking competencies in sustainable development. The inclusion of such requirements in job advertisements indicates that organizations are not only responding to regulatory and sustainability pressures but are also actively investing in the capabilities needed to implement green business models and improve environmental performance.

In higher education and public-sector organizations, similar mechanisms can be observed. Studies on green competence building, green passion, and green empowerment indicate that strengthening environmental knowledge and skills among employees can enhance environmental performance by fostering pro-environmental behaviours and enabling staff to participate in sustainability initiatives [39,40]. Together, this body of work reinforces the idea that green skills and competences are strategic assets that enable organizations to respond proactively to regulatory, technological, and market pressures associated with the net-zero transition.

2.4. The Green Skills Gap

Although the demand for green skills is increasing, the literature consistently identifies a gap between labour-market needs and the supply of relevant competencies. Cook & Elliott [12] describe this mismatch as a “green skills gap”, emphasizing that education and training systems in the UK and EU often lag behind the pace of environmental and technological change, particularly in renewable energy and allied fields. They argue that closing this gap requires not only training new entrants but also upskilling the existing workforce through apprenticeships, in-house training, and strategic public support.

Similar concerns are reflected in international policy documents. The OECD [18] notes that the green transition requires anticipatory skills policies, because occupations are evolving faster than many training systems can respond. UNESCO and the ILO likewise stress that without systematic planning for green skill development, the expansion of clean technologies, green infrastructure, and circular economy models may be slowed by shortages of appropriately trained workers [41–43]. The European Skills, Competences, Qualifications and Occupations (ESCO) framework, for instance, identifies hundreds of “green” skills and knowledge items, but highlights that many are not yet fully integrated into national curricula and qualification systems [44].

The green skills gap has several causes. First, curricula in many education systems remain only partially aligned with sustainability and labour-market trends. Second, co-operation between employers and education providers is often weak, limiting the ability to identify future skill requirements and to update programmes accordingly [45]. Third, labour-market intelligence systems may not be detailed enough to track emerging job profiles and to anticipate new skill demands, especially in fast-changing sectors such as renewable energy, building automation, and green infrastructure [46,47]. As a result, the transition toward greener production can be slowed by a shortage of appropriately trained workers, creating a risk that green industrial strategies will be constrained by human-capital bottlenecks.

2.5. Education, Training, and Lifelong Learning

Education and training systems are widely recognized as essential for closing the green skills gap. Higher education, vocational education and training, and workplace learning all have a role to play in preparing learners for sustainability-oriented work [48]. Recent research on green vocational education and training shows that this field is expanding rapidly, with increasing attention to the integration of sustainability into curricula, teaching methods, and institutional strategies [49,50]. At the same time, company-based training and in-formal learning are indispensable for updating workers’ competencies in response to changing regulations, digitalisation, and new low-carbon technologies [51].

The European sustainability competence framework, GreenComp, reflects this broader perspective by identifying a set of knowledge, skills, and attitudes needed to act sustainably in everyday life and professional settings [52]. It emphasizes values such as valuing sustainability, promoting nature and supporting fairness, cognitive competences such as

systems thinking and futures literacy, and action-oriented competences such as political agency and collective action. These ideas resonate with the growing literature on education for sustainable development and green education, which conceptualizes green education as an instructional approach focused on cultivating sustainability literacy, participatory learning, and behavioural change in support of the Sustainable Development Goals [53]. Reviews of green education show that pedagogies such as critical re-flection, experiential learning, project-based learning, and nature-based learning are particularly important for developing the higher-order competences required for sustainability transitions.

Recent work also stresses that the development of green skills depends not only on curricula and pedagogy, but also on how VET and higher education systems are embedded in broader institutional and economic contexts [54]. Comparative analyses of skill-formation regimes show that collectivist and statist systems, with strong public commitment to VET and significant employer involvement, may be better positioned to generate mid- and high-level green skills for sectors such as renewable energy, construction, and transport, provided that coordination mechanisms allow new stakeholders from the green economy to participate. For low- and middle-income countries, including many in Africa, the challenge is compounded by more limited resources, higher informality, and a stronger dependence on international co-operation, which makes locally adapted strategies for TVET greening and capacity building particularly important [55]. From this perspective, African higher education and TVET institutions are not only sites for transmitting technical green skills, but also key arenas for developing sustainability competences, fostering green passion and empowerment, and building the green intellectual capital needed for long-term innovation and inclusive growth. This role is becoming increasingly important as labour market data reveal a growing demand for green skills. The increasing presence of these competencies in online job vacancies suggests that employers are seeking graduates who possess not only technical expertise but also the capacity to apply sustainability principles and contribute to organizational innovation. Consequently, educational institutions play a critical role in aligning curricula and training programmes with emerging labour market needs. The idea is to ensure that learners acquire the knowledge, skills, and attitudes required to support the green transition. This justifies the present study's focus on how education and training systems, together with labour-market actors, can better anticipate and respond to green skills needs in selected African countries.

2.6. Africa and the Green Transition

The African context gives the green skills agenda particular urgency. Many African economies rely heavily on climate-sensitive sectors such as agriculture, forestry, fisheries, mining, and natural-resource extraction, which makes them vulnerable to climate shocks and environmental degradation [56]. At the same time, the continent faces rapid population growth, urbanization, energy poverty, and youth unemployment: around 600 million Africans still lack access to electricity, and every year millions of young people enter labour markets that create far fewer formal jobs [57,58]. These overlapping pressures make green skills especially relevant because they can support both adaptation and employment creation, for example through renewable energy, sustainable agriculture, waste management, and climate-resilient infrastructure [59].

Policy-oriented literature suggests that Africa's green transition could generate substantial opportunities in renewable energy, sustainable agriculture, waste management, green mobility, and green infrastructure, but only if the workforce is adequately prepared [60]. Continental frameworks such as the Continental Education Strategy for Africa, the African Continental TVET Strategy 2025–34, and the Africa Environmental Education and Training Action Plan 2015–2024 explicitly call for greening education and training

systems, improving labour-market alignment, and strengthening environmental literacy. However, empirical studies and policy reports point to persistent skills mismatches: trained graduates in some fields struggle to find jobs, while employers in emerging green sectors report difficulties in recruiting workers with appropriate technical and transversal green skills [61,62].

International partners play an increasingly visible role in this area. The European Union supports green skills development through initiatives linked to the European Green Deal, GreenComp, and programmes that promote peer learning and curriculum reform in African TVET institutions. China's investments in renewable energy, critical raw materials, and green technologies also create demand for local technical capabilities and are accompanied by training initiatives such as Luban Workshops and project-based short courses. While these initiatives can strengthen green skills supply, they also raise questions about coordination, ownership, and the extent to which external training offers are aligned with African countries' own industrialization and just transition strategies.

2.7. Comparative Evidence and Research Gap

Although the literature on green skills has expanded, it remains fragmented in both conceptual and empirical terms. Many studies focus on conceptual definitions and competence frameworks, sectoral applications (for example in energy, construction, or higher education), or single-country case studies, but fewer provide comparative evidence across multiple African countries. This is a limitation because labour-market structures, institutional settings, and education systems vary substantially across contexts, which may affect both the nature of green skills demand and the capacity of training systems to respond.

Recent bibliometric and review work confirms that the field is still developing and that stronger connections are needed between research on green skills, vocational education, and sustainability transitions [63,64]. Likewise, reviews of green jobs research highlight definitional inconsistency and a limited connection between academic debates and practical workforce planning, particularly in relation to skills needs in specific sectors and regions [11,19]. Policy analyses focusing on Africa underscore that skills are now strategically linked to green investments and industrial strategies, but that systematic, empirically grounded mappings of concrete skill needs across countries and sectors are still scarce [60].

These limitations justify comparative studies that map green skills needs in a systematic and context-sensitive way. Building on this literature, the present study contributes by identifying and analyzing green skills needs across four African countries, linking labour-market information, employer perspectives, and education-system characteristics. In doing so, it aims to provide a more actionable evidence base for policymakers, educators, and employers seeking to design anticipatory skills policies and curriculum reforms that support a just and inclusive green transition in Africa.

3. Materials and Methods

This study adopted an exploratory and comparative approach to map green skill signals in online job vacancies in four African countries, using big data techniques applied to labour market intelligence (LMI), which refers to the set of data, analyses, and information on the functioning of the labour market, including skills demand, employment trends, wages, occupations, and employer needs [65,66]. The research was based on secondary data provided by the online job vacancies (OJV), using as a methodological reference the models developed by the European Training Foundation (ETF, Turin, Italy) and the African Continental Qualifications Framework (ACQF, Addis Ababa, Ethiopia), particularly within the scope of the "Green Dashboard Africa". The location of those four African countries is presented in the map of Figure 1, which was generated by artificial intelligence using

Microsoft CoPilot v.2026.6.1 with the following command: “Create a simple, clean map of the African continent in a minimalist info-graphic style, with the outline of Africa clearly visible against a light background. Highlight the countries Egypt, Kenya, Morocco, and Tunisia with contrasting colours and small markers, keeping the names legible and well-positioned. The map should be educational, without excessive detail, and have a professional appearance suitable for academic use, in a 16:9 landscape format.”

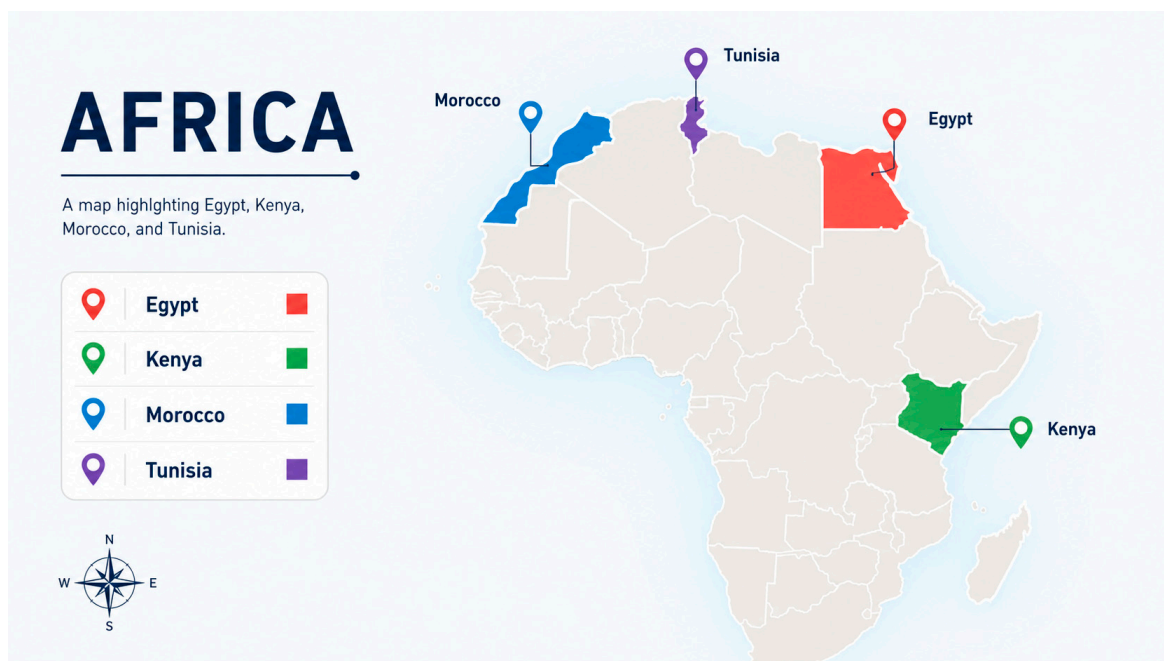


Figure 1. Geographic location of the four African countries.

The choice of this methodological approach is based on the growing recognition that traditional methods of labour market analysis, such as surveys and official statistics, have limitations in terms of timeliness, granularity, and the ability to monitor in real time the changes in the skills required by employers. In contrast, data from online job postings allow for the identification of emerging trends in skills, occupations, and economic sectors more quickly and in greater detail [67,68]. The study focused on four African countries participating in the ACQF and ETF skills monitoring initiatives: Egypt, Kenya, Morocco, and Tunisia. These countries were selected due to the availability of structured databases of online job advertisements and the existence of harmonized dashboards that enable comparative analyses across different national contexts.

The analysis focused specifically on green skills, defined as knowledge, technical abilities, and soft skills related to environmental sustainability, energy efficiency, the circular economy, and the green transition. Accordingly, this study captures both technical green skills and transversal sustainability competences. To ensure analytical consistency, the taxonomy of green skills adopted by the ETF and the ACQF was used, based on international classifications such as the European Skills, Competences, Qualifications and Occupations (ESCO), International Standard Classification of Occupations (ISCO), and International Standard Classification of Education (ISCED). The time period analyzed covered the years 2022 through 2025, allowing for the observation of recent trends in the demand for green skills across different economic sectors.

In the first phase, a quantitative analysis of the data is conducted. Indicators related to the frequency of green skills in job postings, sectoral distribution, occupations most associated with the green transition, and the temporal evolution of demand for environmental

skills were examined. In the context of this study, demand is characterized as the share of all online vacancies containing at least one green skill.

The second phase involved a thematic analysis aimed at grouping the competency categories identified through the Green Dashboard Africa, enabling the coding, organization, and interpretation of the most frequent terms within conceptually homogeneous themes. This process followed an inductive approach to qualitative analysis, in which first-order codes (specific competencies) were aggregated into second-order codes (thematic categories of green competencies) based on their semantic and functional proximity, making it possible to identify the key competency domains required for the transition to a sustainable economy. It is also important to note that the process related to text-mining and linguistic processing analysis was not performed by the authors but by the Green Dashboard Africa.

The comparative component of the study was developed through a cross-analysis of the four countries. Variables such as the intensity of demand for green skills, key economic sectors associated with sustainability, emerging occupations, and the most valued transferable skills were compared. This strategy made it possible to identify convergences and divergences among different African national contexts, contributing to an understanding of how the green transition is influencing labour markets in different ways.

The study acknowledges some methodological limitations. Data obtained from the Green Dashboard Africa dashboard do not represent the entire labour market, and there may be biases related to more digitized sectors, formal jobs, or urban areas with greater internet access. Furthermore, certain occupational groups that do not typically appear in online job posts may be underrepresented in the sample. To mitigate these limitations, the results were interpreted from an exploratory and contextualized perspective, prioritizing the identification of emerging trends and patterns rather than absolute estimates of the labour market. Additionally, the use of international taxonomies and harmonized methodologies contributed to increasing the comparability and analytical robustness of the data.

4. Results

4.1. RQ1. How Has the Demand for Green Skills Evolved over Time?

Figure 2 shows the % share of jobs containing at least one green skills. The evolution of green skills demand across the four African countries shows both heterogeneous trajectories and an overall upward trend over the observed period. At the aggregate level (“All”), demand remains relatively stable between 2022 and 2024, fluctuating slightly around 1.6%, before increasing more markedly in 2025. This suggests a recent acceleration in the integration of sustainability-related competencies in online job postings. Furthermore, country-level dynamics reveal substantial differences. Kenya (KE) consistently exhibits the highest and most sustained growth in green skills demand, rising steadily from 2.25% in 2022 to 3.68% in 2025. This indicates a strong and continuous consolidation of green labour market requirements in KE. Morocco (MA) shows a more volatile pattern, with an initial increase in 2023, a decline in 2024, and recovery thereafter, suggesting a less linear but gradually strengthening demand. Egypt (EG) follows a similar but more moderate trajectory, with a dip in 2023 followed by steady growth up to 2025. Tunisia (TN) presents the most striking change, with relatively low and stable values until 2025. In “all” category is represented the average in percentage for the four countries.

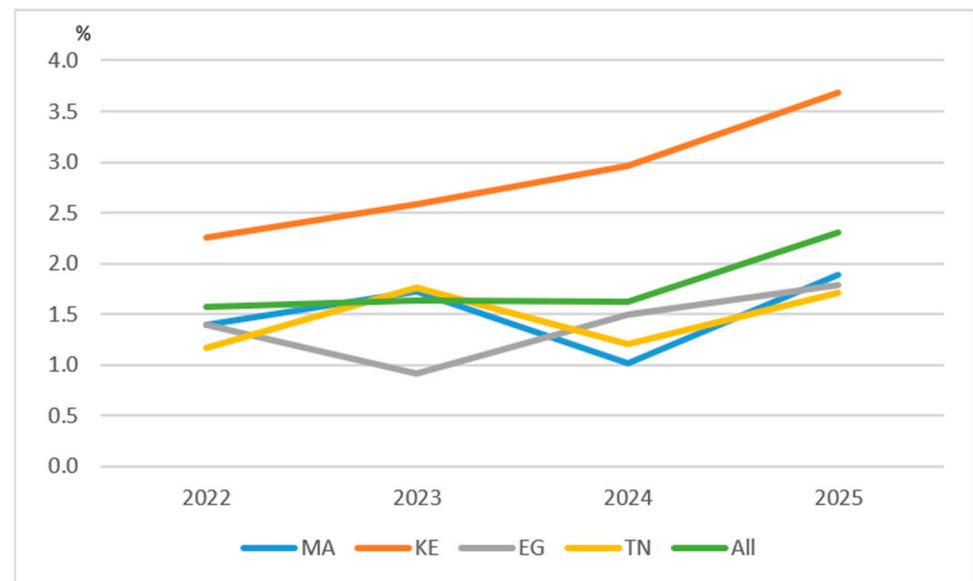


Figure 2. Evolution of the demand for green skills.

4.2. RQ2. In Which Sectors of Activity Are Green Skills Most Frequently Demanded?

Figure 3 reveals that green-skill demand is highly concentrated in sustainable energy, which clearly dominates across the four countries with an aggregate value of 4.25%. Kenya stands out with 1.63%, substantially above the other sectors in the country, while Morocco and Tunisia also display relatively stronger demand in energy-related activities. This pattern suggests that the green transition is currently driven primarily by energy-related occupations rather than by a broad-based transformation across all sectors. In contrast, other sectors show more fragmented and country-specific demand. Sustainable transport, although the second-largest category, remains comparatively small overall (0.26%), with Morocco recording the highest value (0.42%). Sustainable agriculture (0.55%) and sustainable tourism (0.46%) are mainly concentrated in Kenya, indicating that green-skill demand may be shaped by national economic specializations such as agribusiness and tourism. Egypt and Tunisia show relatively moderate levels in sustainable production, while sustainable construction remains marginal across all countries (0.05%).

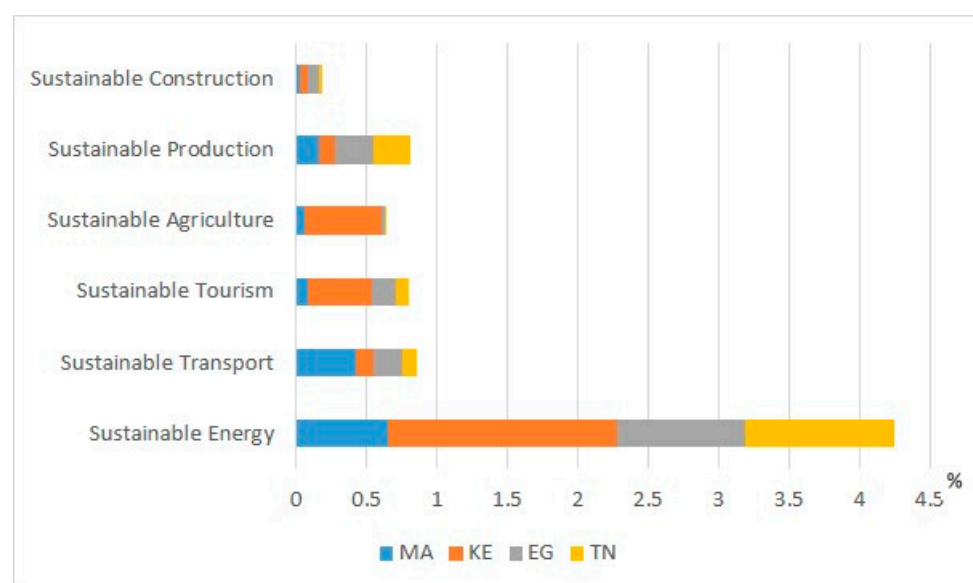


Figure 3. Sectors of activity that demand green skills more.

4.3. RQ3. Which Occupations Are Most Associated with Green Skills?

Figure 4 indicates that green-skill demand is concentrated primarily in technical, engineering, and environmental occupations, suggesting that the green transition in the analyzed countries is being driven largely by the need for specialized expertise rather than by widespread adoption of green competencies across the labour market. Among the occupations identified, environmental engineers emerge as the most prominent (21.45%), with particularly high values in Egypt (31.99%) and Kenya (21.47%), highlighting the importance of environmental management and sustainability-related technical capabilities. The results also reveal distinct sectoral pathways through which green skills are being integrated into national economies. The prominence of ships engineers (20.52%) points to the relevance of maritime and transport-related activities, particularly in Morocco and Egypt, while the high demand for medicine associate professionals (20.01%), especially in Morocco, suggests that sustainability-related competencies are extending beyond traditionally environmental sectors. Similarly, the importance of aquaculture workers (17.39%) in Morocco and Kenya reflects the role of blue-economy activities in shaping green labour-market demand. Finally, the presence of metal production process controllers (16.83%), environmental protection professionals (16.38%), and insulation workers (15.79%) further indicates that green skills are increasingly associated with resource efficiency, environmental governance, and industrial decarbonisation.

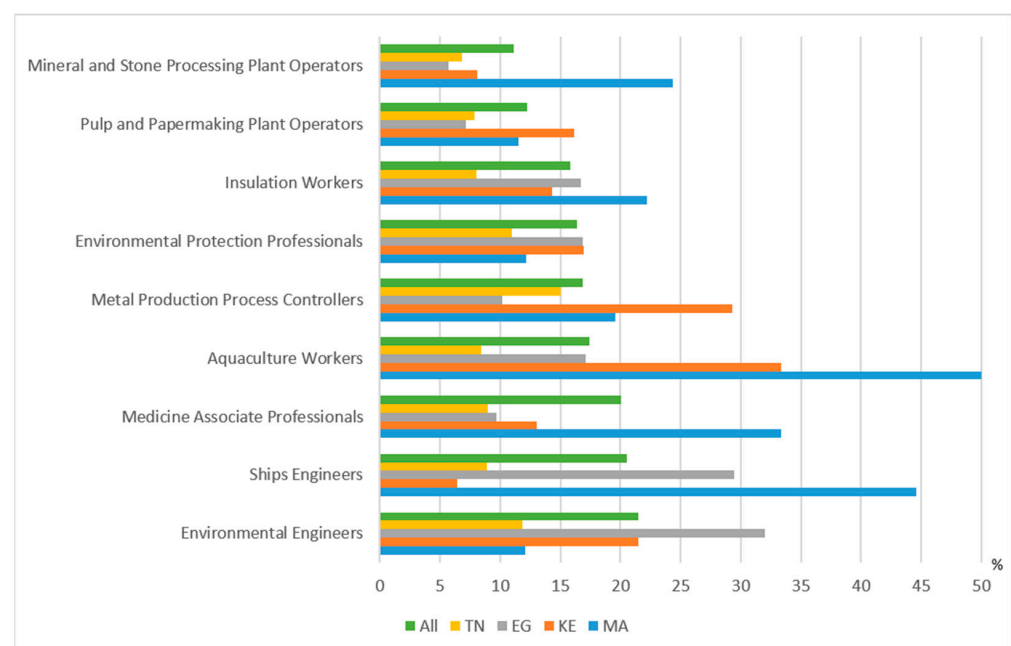


Figure 4. Occupations that are most associated with green skills.

The comparative analysis presented in Table 1 reveals that, although all four countries show increasing demand for green skills, they are following distinct transition pathways. Kenya emerges as the clear leader, exhibiting the highest and most sustained growth in green-skills demand. Its strong concentration in sustainable energy, agriculture, tourism, and environmental engineering suggests a broad-based integration of sustainability into the labour market. Morocco displays the most diversified profile. In addition to sustainable energy, demand is evident in sustainable transport, maritime occupations, healthcare-related professions, and aquaculture, indicating that green skills are spreading across multiple sectors of the economy. Egypt follows a more specialized pathway, characterized by a strong concentration of environmental engineers and other technical occupations. This pattern suggests that the green transition is primarily driven by infrastructure development,

environmental management, and industrial modernization. In turn, Tunisia records the lowest overall demand and the slowest growth, despite signs of acceleration in 2025. This suggests that the integration of green skills into the labour market remains at an earlier stage.

Table 1. Key comparative insights.

Country	Distinctive Characteristic
Kenya	Leader in green skills demand growth and intensity, with strong links to renewable energy, agriculture, tourism, and environmental engineering.
Marocco	Most diversified sectoral and occupational profile, with notable roles for sustainable transport, maritime activities, healthcare, and aquaculture.
Egypt	Strong specialization in environmental engineering and technical sustainability-related occupations, supported by steady recent growth.
Tunisia	Least developed green skills market among the four countries, although showing signs of acceleration in 2025.

4.4. RQ4. What Are the Most In-Demand Green Skills?

The thematic analysis of green job vacancies presented in Table 2 was conducted by systematically organizing the green skills competency categories provided by the Green Dashboard Africa into higher-order thematic domains. Accordingly, the reported frequencies correspond to the number of database records classified under each thematic category, rather than to the frequency of individual keywords, phrases, or skill terms extracted directly from the job vacancy texts. Therefore, the absolute frequency values reflect the distribution of competency categories within the Green Dashboard Africa dataset, rather than the occurrence of specific lexical items in the advertisements themselves.

The results reveal that demand for green skills is strongly concentrated in energy-related domains, particularly solar energy and photovoltaics ($N = 783$), renewable energy ($N = 652$), and energy efficiency ($N = 633$). This pattern reflects the growing importance of renewable energy infrastructures, energy optimization practices, and the transition toward low-carbon development pathways. Skills associated with clean energy and decarbonisation ($N = 521$) also appear prominently, underscoring the increasing emphasis on reducing carbon emissions and supporting climate mitigation efforts across industries.

Beyond the energy sector, substantial demand is observed for competencies related to the circular economy and resource management ($N = 505$), highlighting the importance of waste reduction, recycling systems, and resource efficiency in advancing sustainability objectives. Similarly, the prominence of sustainable mobility ($N = 439$) indicates that environmental concerns are increasingly shaping transportation and logistics systems. These findings suggest that the green transition is extending beyond traditional environmental occupations and becoming embedded in broader economic and operational activities.

The analysis further identifies emerging areas of demand, including climate change adaptation ($N = 311$), water and resource sustainability ($N = 238$), sustainable construction ($N = 190$), and sustainable agriculture ($N = 184$). Although less frequent, these themes demonstrate that organizations are increasingly seeking capabilities to address climate resilience, resource conservation, sustainable infrastructure, and environmentally responsible food production. Finally, the presence of green digital and analytical skills ($N = 151$) highlights the growing role of digital technologies, environmental data analysis, and sustainability monitoring systems in supporting evidence-based decision-making.

Table 2. Thematic analysis of the demands in green skills.

First-Order Codes	Second-Order Codes	Brief Description
solar panels, photovoltaic systems, panels installation, solar maintenance	Solar Energy and Photovoltaics (N = 783)	Skills related to the installation, operation, and maintenance of solar-based energy systems.
wind turbines, renewable power generation, renewable infrastructure	Renewable Energy (N = 652)	Competencies associated with the production and management of renewable energy sources.
energy-saving systems, energy auditing, efficient equipment, energy optimization	Energy Efficiency (N = 633)	Skills focused on reducing energy consumption and improving operational efficiency.
clean technologies, low-carbon systems, carbon reduction, decarbonisation	Clean Energy and Decarbonisation (N = 521)	Competencies aimed at reducing carbon emissions and supporting low-carbon transitions.
waste reduction, recycling systems, circular economy, resource efficiency	Circular Economy and Resource Management (N = 505)	Competencies focused on minimizing waste and maximizing resource reuse and efficiency.
electric vehicles, green transport, sustainable logistics, smart mobility	Sustainable Mobility (N = 439)	Skills associated with environmentally sustainable transportation and logistics systems.
climate adaptation, climate resilience, climate risk assessment	Climate Change Adaptation (N = 311)	Skills related to managing and responding to climate-related risks and impacts.
water conservation, wastewater treatment, sustainable water management	Water and Resource Sustainability (N = 238)	Competencies associated with efficient water use and environmental resource management.
green construction, sustainable buildings, eco-design, insulation technologies	Sustainable Construction (N = 190)	Skills linked to environmentally sustainable building design and construction practices.
sustainable agriculture, organic farming, precision agriculture, climate-smart farming	Sustainable Agriculture (N = 184)	Skills related to environmentally responsible agricultural production systems.
environmental data analysis, sustainability metrics, environmental monitoring systems	Green Digital and Analytical Skills (N = 151)	Skills involving digital tools and data analysis for sustainability monitoring and decision-making.

5. Discussion and Implications

The findings show that demand for green skills is growing steadily in the African labour markets analyzed, although at varying rates across countries and economic sectors. This pattern confirms trends already discussed in the international literature in studies by Alves et al. [69] and Redman & Wiek [70], according to which the ecological and energy transition is driving structural changes in organizations' skills needs. The strong presence of skills associated with renewable energy, energy efficiency, and environmental sustainability reinforces the idea that the green economy is no longer a peripheral phenomenon but has come to play a central role in economic and industrial development strategies.

One of the most well-established findings in the literature is the growing importance of the energy sector as a central driver of the green transition [71–73]. The results obtained broadly support this perspective, particularly in the case of Kenya, where demand for green skills related to sustainable energy is significantly higher than in the other countries.

This pattern may reflect differences in national energy transition trajectories, including varying levels of investment in renewable energy infrastructure and distinct dependencies on traditional energy systems. In contrast, the more moderate representation of energy-related green skills in Morocco, Egypt, and Tunisia suggests that the transition may be more sectorally diversified or at earlier stages of consolidation in these contexts. Similarly, the high demand for environmental engineers and environmental protection professionals across countries confirms previous studies such as Alhassani et al. [74] and Ortiz-Marcos et al. [75], which identify technical and scientific occupations as foundational to sustainability transitions. However, the strength of this pattern varies cross-nationally, with Egypt and Kenya showing comparatively higher concentrations, which may indicate more advanced institutional or industrial integration of environmental expertise, while Morocco and Tunisia display a more distributed occupational profile.

Beyond these established patterns, the study also reveals emerging dimensions that are unevenly distributed across countries and have received less attention in the literature. One example is the expansion of green skills into cross-cutting occupational domains such as management, logistics, sustainable mobility, and environmental data analysis. These developments appear more pronounced in Morocco and Tunisia, suggesting a gradual integration of sustainability principles into organizational and operational functions beyond strictly environmental sectors. In contrast, Kenya's profile remains more strongly oriented toward technical and energy-related occupations, indicating a potentially different pathway of green specialization. This heterogeneity suggests that green skills are not diffusing uniformly across labour markets but are instead shaped by country-specific economic structures, sectoral priorities, and stages of transition. Sustainability is therefore increasingly emerging as a systemic organizational competency; however, its institutionalization appears to follow distinct national trajectories rather than a single convergent pattern. Another relevant emerging aspect is the growing interconnection between green and digital skills. The presence of competencies related to environmental monitoring, data analysis, and smart systems suggests that the dual green and digital transition is influencing African labour markets, but again with variation across countries. This convergence appears more visible in Morocco and Egypt, where digital-intensive occupational profiles are more prominent, while Kenya shows stronger alignment with energy-focused technical pathways. This reinforces recent discussions by de Oliveira [76] and Shaddick et al. [77] on the need for hybrid professionals combining environmental and technological competencies, while also highlighting that the intensity and form of this convergence differ across national contexts.

In terms of public policy, the findings have particularly relevant implications. First, they highlight the need to align education and vocational training systems with the new demands of the green economy. African governments should promote curricula more focused on sustainability, renewable energy, energy efficiency, and green digital skills. Furthermore, the results suggest the importance of developing LMI systems based on Big Data, capable of monitoring changes in skills needs in real time and supporting more agile decisions regarding educational planning and employment policies. Furthermore, the differences observed between countries demonstrate that uniform policies may not be appropriate. While some countries show greater dynamism in energy sectors, others exhibit growth in sustainable agriculture, tourism, or environmental management. Consequently, it is essential to adopt context-specific national strategies, considering economic structures, natural resources, and specific development priorities.

Finally, the study underscores the importance of integrating green skills into Africa's sustainable development and industrialization agendas, particularly because the ecological and digital transformation of the global economy is likely to profoundly reshape the landscape of international competitiveness. In this context, African countries face both

a challenge and a strategic opportunity. On the one hand, there is a risk of deepening economic and technological inequalities if African labour markets fail to keep pace with the new skill requirements associated with the green economy. On the other hand, the abundance of natural resources, the high potential for renewable energy, and the youth of the African population create favourable conditions for the development of new sustainable economic sectors.

6. Conclusions

6.1. Final Remarks

This study presented an exploratory and comparative analysis of the demand for green skills across four African countries. The results indicate that the demand for green skills is growing, although with marked heterogeneity across countries and time. These patterns indicate differences in the evolution of green labour-market demand across the four countries; however, the underlying drivers cannot be determined from the present data alone. In particular, Tunisia's recent surge should be interpreted as an empirical pattern that warrants further investigation, as it may reflect a range of factors, including changes in labour-market conditions, sectoral dynamics, policy developments, or data-related effects. Similarly, Kenya's sustained growth suggests a relatively stable demand for green competencies over time, but additional evidence would be required to conclude that this reflects a consolidated or more advanced green labour market. Morocco and Egypt display more moderate and fluctuating trajectories, indicating less stable growth patterns while nonetheless demonstrating a continuing demand for green skills.

At the sectoral level, sustainable energy emerges as the dominant field driving green skills demand, reinforcing its central role in the four selected African countries included in the analysis. Other sectors such as sustainable agriculture, tourism, and production demonstrate more localized and context-specific relevance. In terms of occupations, environmental engineers, ships engineers, and aquaculture workers are among the most strongly associated with green skills, highlighting the importance of both environmental and resource-based economic activities. The thematic analysis further confirms that renewable energy, energy efficiency, and environmental sustainability are the most prominent skill domains, while emerging areas such as sustainable mobility, circular economy, and green digital skills are increasingly relevant.

6.2. Limitations and Future Research Directions

This study presents several limitations that should be acknowledged when interpreting the findings. First, the analysis relies exclusively on secondary data provided by the Green Dashboard Africa dashboard, which does not fully represent the overall labour market in the four African countries. Informal employment, public sector recruitment processes, and offline hiring channels remain highly relevant in many African contexts and are therefore not captured in the dataset. This introduces a structural bias toward formal, urban, and digitally mediated job markets, potentially overestimating the importance of certain sectors such as information-intensive services and underrepresenting rural or informal green activities, particularly in agriculture and small-scale production.

Second, the temporal scope of the dataset is relatively limited and the exact number of job advertisements included in the database is not reported, which constrains the ability to identify long-term structural trends or cyclical variations in green skills demand. In addition, differences in digital maturity and platform penetration across countries may influence the volume and composition of available data, further affecting comparability. Another limitation relates to the nature of the available data. Because the quantitative analysis relies exclusively on percentage values obtained from secondary sources rather

than raw job advertisement records, it is not possible to conduct sensitivity analyses or other robustness checks that would assess the stability of the results under alternative assumptions. Consequently, the findings should be interpreted as indicative patterns of green skills demand rather than precise estimates of labour market dynamics.

Future research should address these limitations in several ways. First, integrating multiple data sources, such as household labour force surveys, enterprise surveys, and administrative employment records, would provide a more comprehensive picture of labour market dynamics and reduce reliance on online vacancies alone. Second, combining quantitative Big Data approaches with qualitative methods, such as expert interviews or case studies of key sectors (e.g., renewable energy, agriculture, and transport), would allow deeper contextual interpretation of emerging green skills trends. Third, future studies should extend the geographical coverage to additional African countries and, where possible, include longitudinal datasets spanning longer time periods to capture structural transformations more robustly.

Finally, future research could more deeply investigate the relationship between green skills demand and policy interventions by moving beyond descriptive analyses toward more explanatory and causal frameworks. One promising direction would be to examine how specific national and regional policy instruments influence the emergence and intensity of green skills in labour markets. Mapping the timing of these policy interventions against shifts in online job vacancy data could allow researchers to identify whether policy changes precede measurable increases in demand for corresponding skills. A further step would involve comparative policy analysis across countries with different levels of green policy maturity. This would make it possible to assess whether countries with more ambitious climate strategies, such as nationally determined contributions under the Paris Agreement, exhibit faster diversification of green skills demand compared to countries with less developed policy frameworks. In this context, quasi-experimental designs such as difference-in-differences approaches or synthetic control methods could be applied to evaluate the impact of specific policy reforms on labour market outcomes.

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Abbreviations

The following abbreviations are used in this manuscript:

ACQF	African Continental Qualifications Framework
ESCO	European Skills, Competences, Qualifications and Occupations
ESG	Environmental, Social, and Governance
ETF	European Training Foundation
ILO	International Labour Organization
ISCED	International Standard Classification of Education
ISCO	International Standard Classification of Occupations
LMI	Labour Market Intelligence
OECD	Organization for Economic Co-operation and Development
OJV	Online Job Vacancies
TVET	Technical and Vocational Education and Training
VET	Vocational Education and Training

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