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From Green Skills to Sustainable Livelihoods: Repositioning TVET in India's Informal Green Economy

Abstract

Transition to low-carbon, resource-efficient, and climate-resilient economies has centrally positioned Technical and Vocational Education and Training (TVET) in workforce transformation. However, expansion of green skills has not translated into employment opportunities in labour markets characterised by informality, subcontracted employment, labour mobility, and socio-economic inequalities. This paper analyses TVET–labour market mismatch through policy transfer literature, examining TVET through the lens of just transition, employment quality and political economy of informal labour markets. This integrative analytical positioning engages with policy frameworks, industry–TVET alignment, reskilling, and equity in green skills. This study adopts a multi-sectoral approach on four key sectors: renewable energy (solar), electric mobility, e-waste management, and green construction drawing on Indian datasets and reports. Employment across these sectors is found to be predominantly temporary, project-based, and fragmented, reflecting the episodic nature of labour demand. There is persistent gap between training outputs and labour absorption capacity, and access to green skills and employment remains uneven with barriers for women, migrants, and marginalised groups. The paper thus critically examines the *green skills–employment paradox,* in which training systems expand in response to sustainability imperatives, but capacity to generate stable inclusive employment remains constrained.

Keywords: *TVET, green jobs, green skills, decent work, informal livelihoods*

1 Introduction

Increasing global impetus on low-carbon, resource-efficient and climate-resilient economies is positioning Technical and Vocational Education and Training (TVET) at the core of workforce transformation. Within this paradigm, greening of TVET assumes significance beyond inclusion of environmental discussions into curricula, towards systemic reorientation of skill ecosystems to support sustainable production processes, green economies, and inclusive and resilient societies (ILO 2025; Maclean et al. 2018; Kizu et al. 2018). Green TVET is thus gaining importance as a critical lever for balancing sustainable environmental and employment pathways.

In India, this vision is institutionalized through the Skill Council for Green Jobs (SCGJ) alongside broader skilling architecture under the Skill India Mission. These initiatives primarily facilitate and scale training across green sectors including renewable energy, sustainable construction, electric mobility, waste and resource management among others

(Varghese et al. 2018; Bishnoi & Rai 2022). The emerging policy emphasis is clearly on strengthening frameworks for green TVET, reskilling and upskilling for emerging green occupations, and aligning industry-training linkages supporting green transitions.

However, this policy trajectory relies on the assumption that expansion of green skills will translate into corresponding employment opportunities. This assumption of linear skills-to-jobs narrative becomes problematic in contexts like India (NCAER 2018) where labour markets are characterised by persistent informality, subcontracted employment, labour migration amidst seasonal work, and deep-rooted socio-economic inequalities. In such a context, pathways linking skill formation and employment outcomes are influenced by structural conditions that constrain translation of training into stable jobs, without addressing equity concerns in green skilling.

Amidst structural barriers are also institutional challenges in the Indian case. These include expansion of capacity building as part of national missions such as the National Solar Mission through multi-stakeholder participation, assessment of additional skills required, identifying pathways of integrating green skills into programs, restructuring syllabi, training of professionals, certification systems, and so on (Kumar et al. 2010). Additionally, new programs integrating green skills within TVET may not be developed until a regulatory order is set up (Maclean et al. 2017). There are also gaps in integrating education and skill policies with employment policies, which is paramount as the economy moves further towards a green transition trajectory.

The connection between green skills-employment is thus neither automatic nor uniform. It raises a fundamental question of how labour and skill ecosystems align amidst emerging green economies, particularly in context of informality and precarity. The challenge of skill-job mismatch in supply and demand of skilled workers has been found to persist in India (ILO 2018). While green transitions are expected to create some new green jobs, they will also require reskilling/ upskilling of existing jobs as per industry needs. However, green jobs must also result in decent work, whether in traditional sectors like manufacturing or construction, or in emerging sectors like renewable energy and waste management, contributing to protecting the environment while providing secure jobs with adequate wages, safe working conditions, and social inclusion.

1.1 Objectives

While emerging literature on greening of TVET provides valuable insights into identification of sector-specific skill needs, institutional design, curriculum reform and training expansion, most of it remains largely anchored in a supply-side understanding. Much of this work assumes a linear alignment between training provision and employment generation, that green skilling would match evolving labour markets. This assumption needs a deeper investigation in contexts of informal labour markets, fragmented production systems, uneven development and weak industry-training alignment. There is limited discussion on how project-based

employment, subcontracting arrangements, labour mobility, employment absorption capacity, and equity in access to green skills influence the skill-job dynamics.

This paper seeks to address this gap by examining the interface between green TVET systems and labour market realities in key sectors of India's emerging green economy. It seeks to move beyond narratives of green job creation and focuses on the nature, quality, stability and inclusiveness of employment outcomes. In doing so, it contributes to the discourse on policy frameworks, TVET-industry alignment and inclusive green skilling.

This overarching objective is supported by five analytical sub-objectives: *First*, to assess the extent to which current policy frameworks for greening TVET are aligned with sectoral employment structures and industry demand; *Second*, to examine the dynamics of industry–TVET collaboration and skill absorption across select green sectors; *Third*, to evaluate how reskilling and upskilling for emerging green occupations translate into employment; *Fourth*, to analyse equity and inclusion in access to green skills and jobs, particularly for women, migrants, and marginalised groups; and *Fifth*, to explore the relationship between formal skilling systems and informal livelihood frameworks.

The analysis is guided by the central hypothesis that in labour markets characterised by structural challenges of informality, contractual labour, small enterprises and so on, expansion of formal green TVET may not inherently lead to stable, decent and inclusive employment outcomes in green economies, but may rather produce structural misalignment between skills and labour realities.

This hypothesis rests on three underlying propositions: *First, the Institutional Proposition*, that TVET systems are designed assuming formal sector growth, standardised occupations and stable industry linkages, which may not reflect realities of green sectors in developing economies; *Second, the Labour Market Proposition*, that employment generation in green sectors is often mediated by informal, subcontracted and transitional forms of work, limiting labour absorption; and *Third, the Equity Proposition*, that without policy intervention, green skilling risks reproducing inequalities in terms of uneven access to training and employment across gender, migration status, socio-economic groups and so on.

Taken together, the paper reframes the challenge of greening TVET from that of *skill deficits* to that of alignment between training systems, labour markets, and social structures. It engages with the discourse on industry-training alignment, inclusive green skilling, and effective policy towards greening TVET.

2 Methodology

This paper adopts a multi-sectoral political economy approach to examine the interface between green TVET systems and labour market outcomes in India, not as discrete domains but through their interaction within broader institutional structures. Such an approach is

suited to capture complexities in greening TVET in contexts of structural challenges such as informality, fragmented employment and uneven sectoral development.

The study is structured as a comparative sectoral analysis focused on *4 key sectors* central to India's green transition: *renewable energy (solar), electric mobility, e-waste management and green construction*. These sectors represent distinct configurations of technology-driven industry, circular economy practices and infrastructure-linked growth in a broader context of labour organization, skill requirements, industry-training linkages and employment pathways.

Evidence selection: Documentary evidence was purposively selected drawing on multiple secondary data sources for triangulation and strengthening empirical reliability: *First,* SCGJ training and certification data were analysed to understand the scale and spread of green skilling; *Second,* Skill India portal was perused for information on program coverage and training outputs; *Third,* sector-specific reports were examined to glean insights into labour and skill demands and employment trends in greening sectors; *Fourth,* policy documents on skill development and green transition strategies were evaluated; and *Fifth,* academic literature on TVET systems, labour markets, and green sector transitions were reviewed. The selection was guided by relevance to skills and employment and importance of the selected sectors to India's green transition.

This triangulated approach allows for cross-validation and situation of evidence within broader institutional and policy contexts. It enables systematic examination of how green skilling translates into employment outcomes across *5 inter-related analytical dimensions: first,* employment generation and absorption capacity assessing the extent to which trained workers are absorbed into green sectors; *second,* skill utilization and occupational pathways analysing how acquired skills are deployed in greener work processes; *third,* labour regimes and employment quality in terms of formal, stable and inclusive work conditions; and *fourth,* industry-TVET linkages and institutional coordination between training systems, employers and sectoral value-chains, and *fifth,* equity and inclusion in green skills and employment.

Inclusion criteria: Sources were considered relevant where they provided evidence on these analytical dimensions. Programme-level evidence was used to assess selected programmes and sectors in terms of implementation, skilling processes and employment outcomes. Academic literature was included for conceptual and analytical foundations. Official and institutional sources were prioritised for establishing evidence on training, certification, policy and programme developments. Inclusion of different source types enabled examination of green skills expansion, training, employment and institutional context.

Exclusion criteria: Exclusion criteria distinguished between programmes containing green activities and those *designed* as green-skilling or employment interventions. This distinction was important as several programmes in India such as Viksit Bharat–Guarantee for Rozgar and Aajeevika Mission-Gramin include environmentally beneficial activities or elements of skill development, but their primary objectives are rural employment, livelihood security, poverty reduction or welfare. The paper includes sources examining how green TVET and

sector-specific skill formation connect with employment in India's green economy; it does not evaluate public programmes contributing indirectly to green transition.

Search strategy: The search did not follow a systematic literature-review but was organised around the central analytical questions of the study: (i) scale and nature of green skill formation; (ii) skill needs and employment potential associated with emerging green sectors; (iii) extent to which trained workers are absorbed into employment; (iv) nature, stability and quality of employment; (v) relationship between training institutions and industry; and (vi) inequalities and structural barriers affecting access to green skills and employment. The search and identification of evidence was iterative, with information obtained from one source category used to identify programmes, reports, institutions or studies in others.

Time period covered: The study does not attempt to construct a continuous series where comparable government data are not available. It analyses the most recent evidence to assess current capacity of green sectors to translate skills into employment pathways. Available SCGJ training and certification data provide evidence on development of green skilling through 2022–23. This is complemented by more recent evidence, including the Periodic Labour Force Survey for January–December 2025 and recent programme, sectoral and institutional evidence, to provide a robust basis for assessing the contemporary skills and employment context.

How data were coded and themes were identified: Within the 5 analytical dimensions, themes were identified through an iterative examination of evidence across the 4 sectors. Evidence was coded based on dimensions that could be meaningfully examined from available sector-specific material, like programme-level evidence for solar; reskilling and occupational restructuring for electric mobility; informality and occupational safety for e-waste; and subcontracting and migrant precarity in green construction. The coding process did not seek to generate identical indicators across sectors, but to provide a common structure for interpreting heterogeneous evidence while retaining sector-specific characteristics. Identification of themes followed 3 steps: (i) examining sectoral evidence by employment, skills and institutional relationships; (ii) comparing sectoral findings for similar patterns, even where their specific manifestations differed; and (iii) grouping recurring issues into broader themes capturing the structural relationship between green skill formation and employment.

How conclusions were derived: Conclusions were derived through a progressive process of sectoral interpretation, cross-sector comparison and synthesis of evidence. Across 5 analytical dimensions and 4 sectors, 5 recurring concerns emerged: temporary/contractual employment; informality and weak institutional regulation; gaps between training outputs and labour-market absorption; the possibility that reskilling and upskilling may not translate into stable employment; and unequal access to green skills and employment. The central conclusion concerning the green skills–employment paradox arises from convergence of these findings. The conclusions were also assessed in terms of their implications for green transition. The

longer-term relevance of the conclusions lies in the possibility that, without such alignment, green transition could reproduce existing labour-market inequalities and precarious work.

The paper employs an interpretive and political economy-oriented analytical framework focusing on structural challenges, labour markets, and institutional dynamics vis-à-vis greening of TVET. The emphasis is on: *first*, understanding how labour markets in green sectors are organised; *second*, examining how skill formation works within sector-specific institutional, economic and employment structures; and *third*, analysing the conditions under which training translates, or fails to translate into meaningful employment. This approach enables deeper engagement with questions of systemic alignment to assess how policy frameworks for greening TVET operate within real-world labour market conditions, and how industry–training alignment or lack thereof impact the effectiveness of reskilling and upskilling strategies in generating inclusive employment outcomes in green sectors.

2.1 Conceptual Framework

The green skills–employment paradox is positioned within existing debates on skill mismatch, employability and labour precarity, but in an integrative analytical approach. Skill-mismatch debates discuss (mis)alignment between skill-supply through training and skill-demand in labour markets (ILO 2018; Schneider & Pilz 2024); employability debates focus on workers possessing capabilities and skills to obtain and retain employment; while labour precarity focuses on nature and quality of employment, especially informal, temporary, subcontracted work lacking social protection (Breman 2020; Srivastava 2022). The green skills–employment paradox consolidates these related but distinct dimensions in context of green skill formation. The central question is whether green skill formation corresponds with labour-market capacity to absorb trained workers into stable, decent and inclusive jobs.

In India, green sectors often operate via informality, subcontracting, project-based work and labour mobility. Going beyond conventional skill-mismatch, individual employability or labour precarity issues, the paper examines why institutional expansion of green training does not produce corresponding improvements in labour-market absorption and employment quality. A trained solar technician may possess requisite skills for emerging green jobs and may get employed, but if the work is limited to short-term installation projects, the issue extends beyond whether the worker is skilled or employable but concerns the capacity of the sector to absorb the skills into sustained employment. Employment in e-waste management does not by itself indicate successful transition when work remains informal and weakly protected. The policy question is whether ‘green’ translates to decent or reinforces precarity.

The analysis presented in the paper is therefore situated at the intersection of three inter-related strands of scholarship, brought together to enable a grounded and contextual systemic-level understanding of greening TVET in a developing country context like India with structural constraints in the labour market.

The *first* strand of analysis draws on scholarship around limits of policy transfer in the context of green TVET and labour market outcomes. For instance, Pilz's work revolves around issues of formal training systems vis-à-vis informal labour markets in India, the failure of policy transfers due to differing social, economic and cultural contexts, mismatches in labour supply and demand leading to issues of employability, and challenges of green TVET to ensure decent jobs (Pilz 2017; Regel & Pilz 2019; Schneider & Pilz 2024; Albertz & Pilz 2025; Rajagopalan et al. 2026). In particular, policy transfer literature for TVET stems from comparative studies in education to understand case studies for policy replicability and design (Phillips 2006), of which the most diffused are the National Skills Qualification Framework (NSQF) and Dual-VET, the latter not diffused at large-scale as effectiveness of transfer depends on governance, industry and labour market institutions (Maurer & Gonon 2014), which renders such formal systems unsuitable to informal economy contexts. Building on these insights, the paper examines how policy transfer/ learning in formal green TVET interacts with structurally informal labour markets such as India to examine industry–TVET alignment in the context of green economies.

The *second* strand engages with narratives around just transition at the intersection of green economies, digital innovations and decent work amidst growing labour precarities. Stemming from ILO's work and critically examined by scholarship at the intersection of labour and climate policy, narratives of just transitions emphasize revamping skill systems to ensure socially inclusive employment outcomes (Rosemberg 2010; Maclean et al. 2018; Bianchi et al. 2024; Steer et al. 2025). In the context of TVET, reskilling and upskilling for employment in green sectors should then not be evaluated only in terms of quantity and certification numbers, but also in terms of quality, security and accessibility. This becomes relevant for green sectors like waste management, construction etc. where employment generated could be temporary, informal or unsafe. The analysis also foregrounds implications and concerns on equity in green skilling for marginalised groups including women and migrants often excluded from formal training and employment pathways.

The *third* strand draws on political economy approaches to understand labour markets through scholarship around persistence of informality, labour migration, and precarious work in India and the Global South (Brown et al. 2024; Srivastava 2022; Breman 2020). These discussions caution against assuming that modernization leads to formalization, and showcase how informality and precarity of labour are structurally embedded in growth processes, and do not disappear on their own in the context of green transition trajectories. Labour markets steeped in subcontracting, circular migration, segmentation of work by caste, gender etc., and weak social protection influence the nature of employment and hence the outcomes of skill development. Through this lens, the paper argues that emerging green sectors in India may reproduce existing informal labour regimes.

Bringing these strands together, the paper advances an integrative conceptual positioning to understand the greening of TVET. It goes beyond viewing green TVET as curriculum reform and capacity development alone, and conceptualizes it as an overarching challenge of systemic alignment between: institutional systems (TVET providers, certification frameworks

and so on); labour market structures (formal, informal and differing by sectoral dynamics); and industrial needs in transitioning economies. This highlights that the success of greening TVET is not reflected by skill supply, but structural conditions that shape demand, quality and absorption capacity of employment. Through the three-strand conceptual framing, the paper contributes to the discourse on policy framework and learning for greening TVET, industry–training alignment in green sectors, and equity and inclusion in green skilling.

3 Key Findings

Discussions in the literature document growing green sectors such as renewable energy, green construction, water and waste management, green mobility, sustainable textiles and so on (Burkart 2009; Reddy et al. 2023). Clean energy investments in particular are projected to have increased employment outcomes (Azad & Chakraborty 2018). Within this sector, many roles in installation, operation and maintenance are expected to engage semi-skilled workers, with relatively low educational attainment levels (Jairaj et al. 2017). In India, since SCGJ's establishment in 2015, over half a million individuals have been trained and certified (Figure 1) across green sectors including renewable energy, waste and water management, e-mobility, sustainable agriculture, and so on.

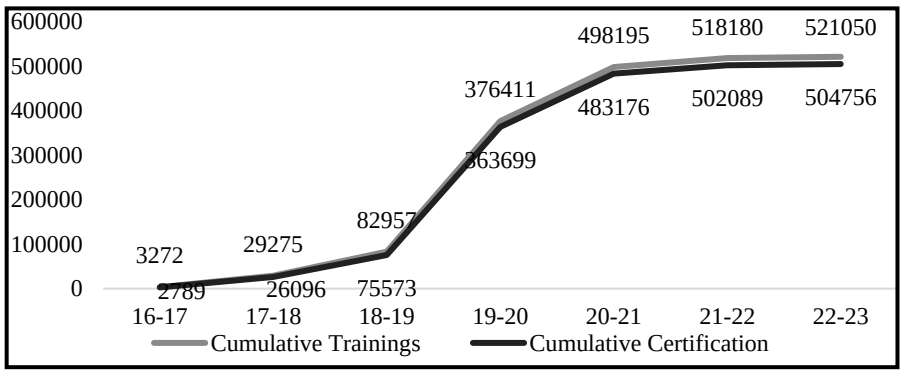


Figure 1: Training status of SCGJ as per Skill India Portal

From an economic perspective, while short-duration training and certifications boost numbers and are preferred by trainees (PAGE 2023), its conversion to durable and stable employment has been limited, with trainees often engaged in informal short-term roles. Additionally, green skilling is male-dominated; for instance, in the solar energy sector, 85% trainees were male, and over 90% women faced barriers such as social norms, inadequate affirmative action for their inclusion in training and industry roles etc. (Reddy et al. 2023). Such factors perpetuate labour-market segmentation; women continue in sectors such as textiles (96% female dominated in terms of training, and 60% women trained in this sector are employed), beauty and wellness (96% female dominated in terms of training, and 56% women trained in this sector are employed), while men dominate sectors such as construction (91% male-dominated in terms of training, and 86% men trained in this sector are employed), infrastructure (96% male-dominated in terms of training, and 96% men trained in this sector

are employed), and manufacturing sectors set to lead the green transition as per data from India's Periodic Labour Force Survey (PLFS) conducted during January- December 2025.

Table 1: **Percentage distribution of persons aged 15-59 years by vocational/technical training received/receiving (All-India as per data from PLFS Jan-Dec 2025)**

Type of Vocational/Technical Training	**Male**	**Female**	**Persons**
Formal vocational/Technical training	**5**	**4**	**4**
Informal vocational/Technical training			
Hereditary	13	10	12
Self-learning	12	7	9
Learning on the job	**21**	**5**	**13**
Other informal sources	4	3	4
Subtotal: Informal vocational/Technical training	**50**	**25**	**37**
Total received vocational/Technical training (Formal + Informal)	54	28	41
Did not receive any vocational/Technical training	**46**	**72**	**59**
Total	**100**	**100**	**100**

Table 1 reveals three important patterns in India's skilling landscape: *First*, dominance of informal skill acquisition; *Second*, significant gender gaps in training access; and *Third*, the different pathways through which men and women acquire vocational training. The broad overview is that India's TVET ecosystem continues to bank on informal mechanisms of skill formation. Meanwhile, gender gaps in access and modes of skill acquisition are substantial; while men benefit to a large extent from workplace-based learning, women remain dependent on family-based, informal forms of training and are much less likely to receive any training. Such patterns underscore the need for a green TVET paradigm that constantly reconciles with economic imperatives, social equity and effective governance.

3.1 Sectoral Analysis

The analysis is anchored in 4 key sectors central to India's green transition: renewable energy (solar), electric mobility (Electric Vehicles- EVs), e-waste management, and green construction. These sectors have been selected not just as illustrations, but with an analytical purpose. Each sector represents a distinct configuration of technological change, labour organisation, and institutional engagement with TVET systems. They provide an empirical basis to examine the interface between green skilling and sector-specific labour-market structures, employment outcomes in terms of absorption and quality, and TVET-industry alignment.

3.1.1 Renewable Energy (Solar). Expansion without Employment Stability

Within renewable energy, the solar sector is emerging as an important domain of green skilling in India, supported by large-scale initiatives such as the Suryamitra programme. To meet India's target of 300GW solar capacity by 2030 and projections of 3.26 million jobs by 2050, over 100000 individuals have been trained as solar PV technicians under this initiative, accounting for 90% of trainings for solar sector jobs (Reddy et al. 2023). However, much of these jobs are concentrated in installation activities, inherently project-based and time-bound.

Despite creating periodic spikes in demand for skilled labour, it does not ensure sustained employment. This *episodic* employment moves workers across sites and projects with no guarantee of continuity or stability. Inter-state mismatches in supply and demand have led to hiring of technicians from states producing large Suryamitra candidates to states with higher solar installed capacity, adding to the precarity of such workers (Tyagi et al. 2022). This results in a situation where training outputs exceed stable labour absorption capacity, raising concerns about industry-TVET alignment.

From a labour market standpoint, a more rigorous and representative methodology to track employment in the sector would be to disaggregate projected employment into short-term project-specific roles versus long-term operational and maintenance roles where skill gaps are visible (PAGE 2023). Within all projected roles in the solar sector, installation roles are temporary in nature, and manufacturing segment is projected to create 0.175 million roles by 2050 expected to be longer-term roles (Reddy et al. 2023). However, spread over 3 decades, this amounts to just around 6000 annual positions, which cannot be expected to absorb large labour surpluses or establish robust domestic value-chains to reduce import-dependence. Without distinguishing between the nature of jobs created therefore, cumulative projections risk over-estimation by counting the same worker over successive short engagements. As India grapples with structural under-employment, the challenge is not just quantum of aggregate jobs created, but whether these lead to decent work offering job stability, social protection and sustained incomes. There is a need for a deliberate strategy to expand manufacturing capacity through state and industry incentives along with stronger integration with training programmes.

Another layer is the unequal access to solar training by gender, 85% trainees being men. The skew points to systemic barriers limiting women, ranging from social norms to differential educational opportunities and limited mobility, which require concerted affirmative action and enabling pathways, mentorship and engagement from industry and training partners. There are documented gaps highlighting reluctance of industries in hiring women, which trickles to their inclusion by training partners for challenges in meeting placement targets (Reddy et al. 2023). This creates a cycle of exclusion from employment and training, entrenching inequalities. The solar energy sector illustrates a broad pattern of green skills not being matched with stable employment pathways, raising concerns over design of green TVET prioritising training volume over long-term labour market-industry integration.

3.1.2 Electric Mobility (EVs): Transition, Displacement, and Uncertainty in Jobs

The Electric Vehicle (EV) sector within green mobility is projected as a sunrise industry, estimated to generate 10 million direct and 50 million indirect jobs by 2030 linked to manufacturing, servicing and charging infrastructure. These numbers suggest an opportunity to absorb new workforce and reskill the 35 million workers currently employed in the internal combustion engine (ICE) sector (Reddy et al. 2023). Much of the projected jobs may not generate new employment but a translocation of existing workers from ICE to EVs, but many workers may be at risk of displacement due to occupational restructuring. From a TVET

perspective, this requires reskilling/upskilling for emerging green roles, especially in transitioning existing workforce. A study by Ola Mobility Institute in 2022 reports that while there may be overlaps between ICE and EV components/processes, the skill-sets are not easily interchangeable and nearly 65% of new jobs will require new skill-sets. There are also concerns about Artificial Intelligence (AI) and automation replacing repetitive jobs like welding and painting (FICCI et al. 2017).

The literature cites examples of models supporting upskilling of mechanics for EV servicing, Toyota's Technical Education Program (T-TEP), and other inclusive endeavours such as all-women sales and logistics within automotive sector, and Ola's Future Factory Plan to upskill and employ women into EV segments (Reddy et al. 2023). However, these remain exceptions rather than the rule. Upcoming roles in EV, including installation of charging stations, and demand for six million semi-and low-skilled workers for battery manufacturing and charging infrastructure are likely to create project-based temporary jobs. Placement in automotive sectors post the T-TEP was at 70%, which raises concerns regarding industry-led initiatives themselves falling short of full-placement, indicating that risks for public and private training centres would be higher. As per a women's survey (Reddy et al. 2023), 66% candidates were keen on working in the EV sector, but as in the case of solar, were constrained by social stereotyping, inadequate outreach and institutional support. Anticipated employment gains in the EV sector are uneven and uncertain. The challenge for green TVET is to design reskilling pathways that address skill deficits and structural realities to generate net employment gains.

3.1.3 E-waste Management: Circular Economy within Informal Labour Regimes

E-waste sector in India is valued at USD 3 billion, India's high consumption of electronic goods driving a significant two million tons of e-waste annually placing the country as third globally in terms of e-waste generation. This sector is expected to generate 0.5 million new jobs by 2025, adding to 1 million workers already employed (largely informally) in manual recycling (Reddy et al. 2023). Recovery, recycling and refurbishing imply creation of labour-intensive roles within the sector. However, the sector presents the risk of remaining informal, 90% of workers currently working without formal contracts or social protection, facing hazardous conditions, lacking training and exposed to toxic substances from the e-waste.

From a regulatory perspective, E-Waste Management Rules of 2018 mandate Producer Responsibility Organisations (PROs) to ensure safe working conditions for workers. But, missing training and formal skilling and the need for formal-informal partnerships has been highlighted (GIZ 2018). Formalizing collection and segregation, creating a formal-informal interface, and integration of health and safety protocols will be critical steps. The e-waste sector shows a duality between high demand and high informality. Despite regulatory frameworks, and stress on skilling, structured TVET in the sector remains limited. Thus, workers continue relying on informal learning pathways. The sector highlights a fundamental challenge for green TVET; engaging with informal labour markets within formal frameworks.

3.1.4 Green Construction: Sustainability Overlay on Informal Labour Structures

The construction sector is increasingly aligning with sustainability standards, green building practices and energy-efficient design benchmarked through rating systems like IGBC (Indian Green Building Council), GRIHA (Green Rating for Integrated Habitat Assessment) etc. However, 97% of construction workers are engaged informally, characterised by sub-contracting and a large migrant workforce. Greening of this sector is expected to affect 11 million jobs by 2030 (Reddy et al. 2023). From a TVET perspective, despite growing demand for skill-building across the value-chain, employment structure does not facilitate formal or stable jobs. When workers are engaged short-term with limited job and skill progression opportunities, limited returns to training and limited skill utilization emerge as gaps.

From a political economy perspective, the transition risks disproportionate accrual of benefits to large corporate builders while migrant workers remain precarious without much voice as one of the stakeholders in the process. In economic terms, green construction is poised to be a high-growth value-chain creating demand for skilled workers. From a just transition lens, utilizing subcontracted labour on short-term basis allows large firms to externalise risk, but leaves workers without social protection or income security. This demands a rethink of governance architecture; training alone is not the solution if workers remain outside the ambit of labour law. The sector thus underscores the need to rethink TVET interventions when informality shapes skill utilisation and employment outcomes.

3.2 Cross-sector comparison of green skills and employment

The 4 sectoral cases reveal different configurations of green skill formation and employment, but can be compared through the 5 analytical dimensions established in the study. The comparison demonstrates that the 4 sectors do not represent the same employment problem. Solar reflects direct expansion of green training with employment often in short-duration installation work. Electric mobility represents disruptive transition faced with creating new green jobs while reskilling existing workers amid occupational restructuring and displacement. E-waste presents a configuration wherein green economic activity is embedded in informal labour arrangements and safety concerns. Green construction witnesses expanding green skill needs mired in informality, subcontracting and migrant labour. Across these configurations, questions of equity and inclusion take different forms, including gender barriers in solar and electric mobility, limited access to formal training and safer employment for e-waste workers, and precarity of migrant workers in green construction.

The comparative value lies in the differing implications for TVET: solar requires stronger alignment between training volumes and sustained employment pathways; electric mobility requires reskilling within occupational transitions; e-waste requires engagement between formal skill systems and informal labour; and green construction requires green skill development connected with the realities of subcontracted and migrant employment. The comparison also identifies a common underlying issue: conversion of green skill formation into sustainable employment in each sector is mediated by conditions beyond training

systems, leaning on labour-market demand, organisation of production, job duration, informality, technological change, subcontracting, occupational mobility and social inequalities. The sectors thus converge around broader questions of whether expansion of green skills matches institutional and labour-market capacity to absorb and retain workers in stable, decent and inclusive employment. This comparative synthesis provides the basis for the following discussions on green skills–employment paradox. It shows that expansion of green skills and green economic activity does not necessarily translate into employment of comparable scale, stability, quality and inclusiveness. This is the point at which the sector-specific findings converge into the paper's central analytical argument.

Table 2: **Synthesis of green skill formation across 4 sectors within 5 analytical dimensions presented by the authors**

Sector	**Renewable energy (solar)**	**Electric mobility**	**E-waste management**	**Green construction**
Employment generation and labour-market absorption	Training has expanded substantially, but employment is concentrated strongly in installation activities that are project-based and time-bound.	Employment growth is partly associated with restructuring of existing automotive employment rather than net new employment.	Employment potential is significant but informal. The issue is not just job creation but conditions under which existing and new workers can be absorbed into safer and more formalised activities.	Green transition is expected to generate demand for skilled workers, but absorption occurs within informal, subcontracted, migrant-led labour markets.
Skill utilisation and occupational pathways	Suryamitra training creates pathways into solar installation, but employment is concentrated in project-based roles, limiting continuity and longer-term occupational progression.	Existing ICE skills are not fully transferable to EV occupations. Reskilling is required, while automation may alter or eliminate some existing occupations.	Workers rely on informal learning, while structured TVET is limited. The central issue is limited integration of existing skills and informal experience into safer, formally recognised green occupations.	Green building practices create new or changing skill requirements, but short-term and subcontracted employment can limit skill progression and utilisation.
Labour regimes and employment quality	Installation work is temporary and mobile, with workers moving between projects and locations. Gender barriers limit inclusive access to training and work.	Technological restructuring can create new occupations while transforming existing work. Women also face barriers to participation.	Informality is pronounced, with weak contracts and social protection and significant occupational health and safety risks.	Informality, subcontracting and migrant labour are dominant, limiting job security, social protection and returns to training.
Industry–TVET linkages and institutional coordination	The scale of training is not fully matched by stable labour demand,	Reskilling requires closer coordination between training systems and an	Formal TVET has limited penetration into an informally organised sector,	Training needs to be connected to production systems and value chains in

	raising questions about alignment between training provision and longer-term industry requirements.	industry undergoing technological and occupational restructuring.	creating a gap between regulatory ambitions, training and actual work practices.	a sector where employment is organised largely through subcontracting rather than stable direct employment.
Equity and inclusion in green skills and employment	Access to solar training and employment is strongly gendered, with women facing social barriers to participation as jobs are male-dominated.	Women's participation in EV workforce remains limited, while technological and occupational restructuring may create unequal opportunities.	Informal workers have limited access to formal training, certification and safer employment pathways, creating inclusion challenges in formalised e-waste management.	Dependence on migrant labour, and challenges of equal access to training, skill recognition, employment security and social protection, with uneven benefits of green upgrading.

3.3 Discussion: The Green Skills- Employment Paradox

Across all four sectors, five common concerns arise: *First*, employment is predominantly temporary and contractual; *Second*, labour markets are largely informal with weak institutional regulations; *Third*, gaps persist between training outputs and employment outcomes in terms of labour absorption capacity; *Fourth*, reskilling/upskilling may not always translate into stable jobs in green sectors; and *Fifth*, access to green skills and jobs remains uneven across social groups, with barriers for women, migrants and marginalised communities. Collectively, these signify a broader structural challenge of green transition in developing economies, where expansion of green skills is not matched with transformation of labour market institutions. Effectiveness of green TVET must therefore be evaluated in relation to structural, institutional and socio-economic conditions governing inclusion, labour absorption, skill utilization and employment quality. The following discussion unpacks the green skills-employment paradox, its characteristics and implications using the analytical positioning of the paper's conceptual framework.

The four sectors expose a paradox, a consistent pattern of divergence between green skills formation and employment outcomes. While numbers may suggest increase in opportunities, most jobs generated are characterised by informality, precarity and exclusion. Within the solar sector, training initiatives and employment outcomes remain concentrated largely in short-term semi-skilled and low-skilled installation jobs rather than manufacturing. Electric mobility largely reflects reconfiguration of jobs in the automotive sector and reshaping of labour demand and skill requirements in line with technological changes. E-waste sector, though promising, remains mired in informal training systems. Green construction requires upskilling workers, but is faced by a largely informal labour regime and migrant workforce.

The challenge is threefold: moving beyond counting number of green jobs to assessing quality of jobs, using a political economy approach to understanding structural and institutional barriers, and aligning with principles of just transition to ensure secure jobs, fair

wages, equity and social protection. The first step is to understand and acknowledge the gap, and create robust labour market information systems to help document green occupation taxonomies and integration of green training and labour absorption in correspondence with industry demands for such jobs (Granata & Posadas 2024). To ensure equity and inclusion within this process, integration of climate engagement at all levels of education and training across disciplinary areas to make the transition to green TVET smoother (Kwauk & Casey 2022) can help green skilling aligned with socio-economic inclusion. The *green skill-employment paradox* and the challenges identified thus necessitate a mix of approaches.

Table 3: **Synthesis of the Green Skills-Employment Paradox from the sectoral analysis by the authors**

Challenge	**Characteristics**	**Implications**	**Policy Learning Possibility**	**Just Transition Requirements**	**Political Economy Understanding**
Employment Expansion without Stability	Despite expansion in green skilling (90% solar PV technician trainings), employment concentrated in temporary (installation-based) activities.	Structural disconnect between where skills are created (training systems) and where stable value is generated (long-term sector operations).	Not just scalability but stability- Green TVET systems must not be designed around scaling numbers, but must match industry needs for long-term labour absorption.	Stable jobs for income security- short-term employment may not help in livelihood diversification for those trained; stable income guarantees are needed.	Institutional coherence for skill-job match-alignment between training institutions and industry - manufacturing jobs in solar longer-term than installation but certifications are higher for the latter.
Informality as Dominant Labour Regime	Across sectors, green employment is deeply embedded within informal labour structure (90% informal workers in e-waste sector; 97% in construction, in green building segment).	Green transition is layered onto existing informal labour regimes, rather than transforming them.	Challenge assumption underlying policy framing for green TVET- formal training does not lead to formal employment; need to design TVET systems engaging with informal economies.	Ensuring long-term written contracts with social protection- for the green transition to be successful, it must break existing structural barriers, not build over them.	Informality begets precarity-without resolving structural issues of informality, adding more short-term green jobs will lead to different forms of precarity withinemerging green sectors.
Job Creation as Reconfiguration, Not Expansion	Automation, technological change constrain labour demand, and new green jobs may just reconfigure old	Challenges dominant assumptions of large-scale green job creation.	Rethinking of training models within broader employment strategies- For green TVET, reskilling is not simply about	Who is trained, who is left out in the transition- In this reconfiguration, are existing workers	Track nature and quality of jobs upcoming-green transitions are not purely additive but involve

	jobs (In EV, projections suggest 10 million direct and 50 million indirect jobs by 2030- to absorb 35 million ICE workers).		preparing workers for new jobs, but about managing labour displacements and transition.	reskilled/ upskilled for emerging jobs/ are they replaced and if so by whom- how are workers and trainees identified to match jobs.	structural shifts in labour demand, where gains in some segments are offset by losses in others.
Structural Mismatch between Training and Labour Absorption	Despite large-scale training expansion, placements are limited (over 100000 candidates trained in solar technician and installation roles while 175000 roles expected to be generated in manufacturing by 2050).	Gap between training outputs (supply) and labour absorption (demand). TVET systems are expanding ahead of labour market transformation, creating surplus of trained workers vis-à-vis jobs.	Challenge existing industry–TVET alignment strategies- training must be more tightly integrated with sectoral value chains, production structures, and long-term employment pathways.	Labour absorption, retention and protection- Addressing perceptions of trainees on placements and nature of jobs they hope to enter into post-training are important.	Demand-supply understanding- Institutional mechanisms needed to identify growing sectors and activities projected to demand labour and align training initiatives in a phased manner per needs.
Inequality and Exclusion in Green Skills and Jobs	Green transition remains socially uneven (85% of solar trainees were men, 90% of women reporting social barriers; migrants dominate construction).	Access to training and jobs remains uneven in terms of gender, migration status and for marginalised groups.	Reduce systemic barriers to inclusion- without addressing these barriers, greening TVET risks reinforcing inequality, undermining its role in inclusive development.	Reduction of labour segmentation in training by social groups- Enable green TVET systems which bridge social gaps and are inclusive in training and placements.	Addressing barriers to access- access to green skills and employment is shaped by pre-existing social hierarchies, gender norms and labour segmentation.

The ‘green skills–employment paradox’ refers to the possibility that green skilling systems can expand faster than capacity of labour markets to absorb, retain and adequately employ workers being trained. The concept brings the training and employment sides of the transition together, building on existing debates. Skill-mismatch debate explains problems of alignment between training and labour demand; employability discourse helps explain capacity of workers to enter and remain in employment; and labour precarity discussion helps explain insecurity and quality of work available. The green skills–employment paradox connects these dimensions by examining the divergence between expanding institutional efforts to produce green skills and limited capacity of labour markets to convert skills into sustained inclusive employment.

The 4 sectors examined in this paper demonstrate different manifestations of the same broader relationship: employment expansion without stability in solar, job reconfiguration and potential displacement in electric mobility, green activity embedded within informal labour regimes in e-waste management, and green upgrading layered onto subcontracted and migrant-dependent employment in construction. The evidence suggests that green skill formation is expanding, but that labour-market structures through which these skills are absorbed do not necessarily provide stable, decent and inclusive employment. The form of this divergence varies by sector; through employment instability in solar, occupational restructuring in electric mobility, informality in e-waste, and subcontracted and migrant-dependent employment in construction, but the underlying relationship between expanding skill formation and constrained employment outcomes provides the basis for the paper's central argument. The green skills–employment paradox therefore provides an analytical lens for examining not just whether green skills and green jobs are expanding, but whether the transition is creating labour-market conditions through which skills can translate into sustainable livelihoods. In doing so, the concept connects the supply side of green TVET with the demand-side, absorption and quality dimensions of green employment, providing a basis for assessing green skilling systems.

3.4 Synthesis

In repositioning greening of TVET for sustainable development, this section summarises the core arguments and contributions from the analysis so far. Building on the sectoral analysis, the core argument that the paper puts forth is the structural misalignment between skill formation systems and labour market realities, leading to a *green skills-employment paradox* in India. TVET frameworks are designed with the presumption of formal sector expansion, technological upgrades and stable industry linkages. But evidence across solar, electric mobility, e-waste and green construction sectors demonstrates that green economies are also dominated by informality, subcontracted employment, labour mobility and weak institutional support. Skill formation in such labour markets is constrained in absorption, utilization and sustainable retention of trained workforce. Thus, green skilling, despite policy impetus may not automatically translate into stable, decent and inclusive jobs.

Advancing the debate from green skills to sustainable livelihoods, the central challenge identified by the paper is lack of systemic alignment between training systems, industry needs, labour markets and socio-economic organization of work to reflect equity and inclusion rather than just being a narrative on deficit or mismatch of skills. Building on this argument, the paper advances three inter-related contributions: *First*, a sectorally grounded analysis beyond institution-centric approaches to examine green skills and employment; *Second*, a reframing of green jobs from aggregate projections to the nature, stability, and inclusiveness of work; and *Third*, an integrative analytical framework advocating for connecting formal skilling systems with informal labour markets.

The paper contributes in five ways: *First*, demonstrating that current policy frameworks must shift focus from scaling training to ensuring alignment with sectoral employment and labour

absorption; *Second*, showcasing the need for rethinking industry-training linkages beyond formal sector assumptions for sectors dominated by informality; *Third*, reconceptualising reskilling/ upskilling within labour transitions, displacement, and occupational restructuring; *Fourth*, advocating for equity and inclusion to be embedded as design principles within green TVET systems rather than as peripheral concerns; and *Fifth*, highlighting that greening TVET must engage with informal economies, labour mobility, livelihood diversification, and address labour precarity.

The paper argues for green TVET to transcend narrow focus on curricula and scaling to an integrated systemically-aligned framework, and suggests five policy pathways for the same: *First*, redesigning TVET systems to align with informal employment regimes, subcontracting networks and non-standard work arrangements; *Second*, strengthening sector-specific alignment integrating training with production systems, supply chains, and employment pathways; *Third*, repositioning reskilling initiatives within broader employment transition strategies and occupational restructuring; *Fourth*, linking green TVET with labour regulation, social protection, and inclusive development; and *Fifth*, differential approaches and context-sensitive green TVET pathways integrating skills with informal economies, local production systems, and enabling livelihood strategies.

4 Broader Implications and Concluding Remarks

The paper finds that greening TVET in India is characterised by structural misalignment between skill formation systems and labour market realities. While TVET frameworks often cater to formal sector assumptions, green sectors continue to be shaped by informality, labour mobility, and fragmented employment systems. Thus, skill expansion may not automatically translate into decent sustainable livelihoods. This argument holds broader relevance for the Global South as well. Labour Markets in India and across much of the Global South differ from those in advanced economies; with deeply embedded informality and labour precarity. Effectiveness of TVET in such contexts cannot be evaluated in terms of training outputs or certification alone, but must also be assessed through labour absorption, employment quality and job stability.

The paper contributes to literature on greening TVET by reframing the discourse from skill provision to employment outcomes, by advancing a sectorally-grounded and structurally informed perspective on labour market-industry–TVET alignment and inclusion. Broader policy implications include the need to align greening TVET with informal labour markets, strengthening sector-specific understanding, integrating reskilling with employer priorities, and embedding green TVET within broader development frameworks.

The paper also advances the concept of *green skills–employment paradox*, where training systems expand in response to sustainability imperatives, but their capacity to translate into stable and inclusive employment remains structurally constrained. Addressing this paradox calls for moving beyond skill-centric approaches and narrow focus on technical skill

provision to integrated frameworks that align training systems with labour markets, institutional structures, industrial strategies and inclusive development pathways.

More fundamentally, the paper demonstrates that the challenge of greening TVET is not limited to technical or institutional factors, but is often structural in nature. Thus, it requires a rethinking on how skills, employment and inclusion are connected within evolving green economies. Without such alignment, green transitions may risk reproducing employment that is socially and economically precarious in the form of informal, contractual and transitory jobs. The paper therefore contributes to discussions on greening TVET for sustainable development by foregrounding the need to align policy frameworks, industry–training linkages, and reskilling strategies with realities of labour markets, embedding equity and inclusion at the centre of green TVET.

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CITATION:

Rajagopalan, A. & Kumar, R.R. (2026). From Green Skills to Sustainable Livelihoods: Repositioning TVET in India's Informal Green Economy. In: TVET@Asia, issue 27, 1-22. Online: https://tvet-online.asia/startseite/from-green-skills-to-sustainable-livelihoods-repositioning-tvet-in-indias-informal-green-economy/ (retrieved 30.10.2026).

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