



SKILLS GAP AS A HIDDEN COST OF ENERGY TRANSITION: EVIDENCE FROM UZBEKISTAN'S OIL AND GAS WORKFORCE

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Abstract: *Energy transition in Uzbekistan is typically assessed in terms of investment, renewable capacity and emission targets. The human-capital dimension - specifically the growing mismatch between existing oil and gas workforce competencies and transition requirements - remains analytically underexplored and financially unquantified. Thus, this paper identifies and analyses the skills gap in Uzbekistan's oil and gas workforce as a hidden economic cost of the energy transition. The skills gap generates five categories of hidden cost — operational, investment, productivity, compliance and social. These compound across a portfolio of transition projects and are systematically absent from ex ante project appraisals. Addressing them requires a coordinated sectoral skills roadmap, internal corporate reskilling, updated university and TVET curricula, and explicit labour-mobility policy.*

Keywords: *energy transition; skills gap; oil and gas workforce; Uzbekistan; methane management; reskilling; hidden costs; just transition; human capital.*

Introduction

Energy transitions are most commonly measured in gigawatts installed, tonnes of CO₂ reduced and dollars invested. Less commonly measured is the adequacy of the workforce required to implement them. This gap in analytical attention has practical consequences: when skilled human capital is not available to operate, maintain and optimise transition technologies, capital investments underperform and mitigation targets are missed. The costs are real but rarely appear in project budgets, making them a hidden cost of the transition.

Uzbekistan represents an analytically important case. The country has committed to ambitious climate goals under its Third Nationally Determined Contribution [1] and its Green Economy Strategy 2019–2030 [9], while simultaneously maintaining a large, hydrocarbon-dependent industrial workforce. In 2023, state-owned enterprises (SOEs) employed 79,741 workers in oil and gas and 51,766 in the energy sector [3]. These workers are directly implicated in the 64% share of national GHG emissions attributed to the energy sector [1]. Yet no public policy document in Uzbekistan systematically addresses the skills required to make these workers effective participants in the transition rather than bystanders to it.

The international literature identifies workforce preparation as a structural precondition for transition effectiveness. The ILO [7] distinguishes between ‘just transitions’ - where workers in fossil-fuel sectors are actively supported - and transitions that produce ‘stranded workers’ alongside stranded assets. The IEA [4] documents that global oil and gas employment reached ~12.4 million in 2024 but could range from 6.9 to 13.4 million by 2035 depending on the policy pathway, indicating that the future of these workers is not predetermined: it is a

function of deliberate policy choices. The EBRD [8] identifies human capital as one of the most persistent bottlenecks in green economy transitions across Central Asia and Eastern Europe.

Despite this international evidence, the skills dimension of Uzbekistan's energy transition has not been empirically examined. This paper addresses that gap. Using official employment, revenue and emissions data alongside an analytical framework of hidden transition costs, it produces the first quantitatively grounded assessment of the skills-gap problem in Uzbekistan's oil and gas sector. The contribution is both empirical - assembling and interpreting scattered official statistics - and analytical: the five-category hidden-cost typology developed here offers a conceptual tool applicable beyond Uzbekistan to other fossil-fuel-dependent emerging economies undergoing similar transitions.

The paper's research questions are: (1) What transition pressures generate skills gaps in Uzbekistan's oil and gas workforce? (2) What are the economic consequences of leaving those gaps unaddressed? (3) What policy and institutional responses are indicated by the evidence?

Research Methodology

The study employs a mixed qualitative-quantitative design. The absence of a dedicated survey instrument measuring skills gaps in Uzbekistan's oil and gas sector - no such instrument exists in the public domain - means that official statistics and policy documents serve as the primary evidence base. This is a recognised approach in labour-market research on transition economies where granular micro-data are unavailable [7, 8].

Three methods are combined. Documentary analysis interrogates ten official and institutional sources (Table 1) to identify emissions,

employment and economic data relevant to the skills-gap problem. Secondary statistical analysis processes the extracted data to produce the key indicators summarised in Table 2. A skills-gap diagnostic matrix (Table 3) maps each identified transition pressure onto required competencies and the hidden cost generated when those competencies are absent. This matrix integrates findings across methods and constitutes the primary analytical output.

Analysis and Discussion

Table 1. Information base: sources, data and relevance to the study

Source	Data used	Relevance
Third NDC of Uzbekistan (2025) [1]	Total GHG 209.6 Mt CO ₂ e; energy sector 64%; fugitive O&G ~19%; BAU and mitigation scenarios	Primary climate benchmark; defines mitigation scope and urgency
World Bank CCDR: Uzbekistan (2023) [2]	Gas demand decline 40% in net-zero scenario; renewables 70–85% by 2060; green jobs +30% by 2035; STEM ~30%	Long-run structural demand shift in energy labour market
Agency for State Assets Management (2023) [3]	SOE employment by sector; oil & gas 79,741; energy 51,766; revenue data (99,783.7 bn UZS; 85,636.9 bn UZS)	Quantifies direct workforce and economic exposure
IEA World Energy Employment 2025 [4]	Global O&G employment 12.4 mn (2024); scenario range 6.9–13.4 mn by 2035; corporate upskilling examples	International benchmark and scenario uncertainty
IEA World Energy Outlook 2024 [5]	Net-zero demand trajectories; fossil-fuel role by scenario; clean energy jobs by sector	Macro framework for transition timelines relevant to Uzbekistan
IRENA Renewable Power	LCOE of solar and wind below new gas capacity in most markets; deployment acceleration	Technology substitution pace driving skills-change pressure

Generation Costs 2023 [6]		
ILO World Employment and Social Outlook 2024 [7]	Just transition framework; stranded-worker fiscal costs; reskilling cost estimates in fossil-fuel sectors	Labour-rights and social-cost framework for workforce transition
EBRD Transition Report 2023–2024 [8]	Human capital as transition bottleneck in Central Asia and Eastern Europe; green reform indicators	Comparative regional context; identifies institutional barriers
Green Economy Strategy 2019–2030 [9]	National targets: energy efficiency, renewables share, emission reductions by 2030	Domestic policy mandate creating the transition obligation
ADB Education and Skills for Inclusive Growth: Uzbekistan (2023) [10]	TVET system capacity gaps; STEM participation; vocational training investment needs	Institutional capacity gap underlying the skills shortage

Note. All sources are institutional and publicly available. ASAM = Agency for State Assets Management of the Republic of Uzbekistan. TVET = Technical and Vocational Education and Training.

The energy sector generated 64% of Uzbekistan's 209.6 Mt CO₂ of GHG emissions in 2022 - approximately 134 Mt CO₂ (Figure 1). Within the energy sector, fugitive emissions from oil and gas infrastructure contributed approximately 19% of the sectoral total [1]. These are primarily methane emissions from natural gas transportation and distribution systems.

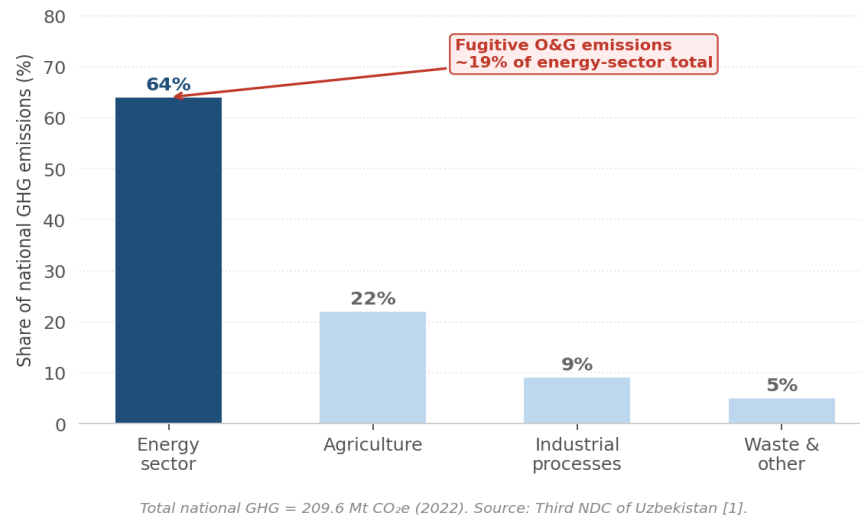


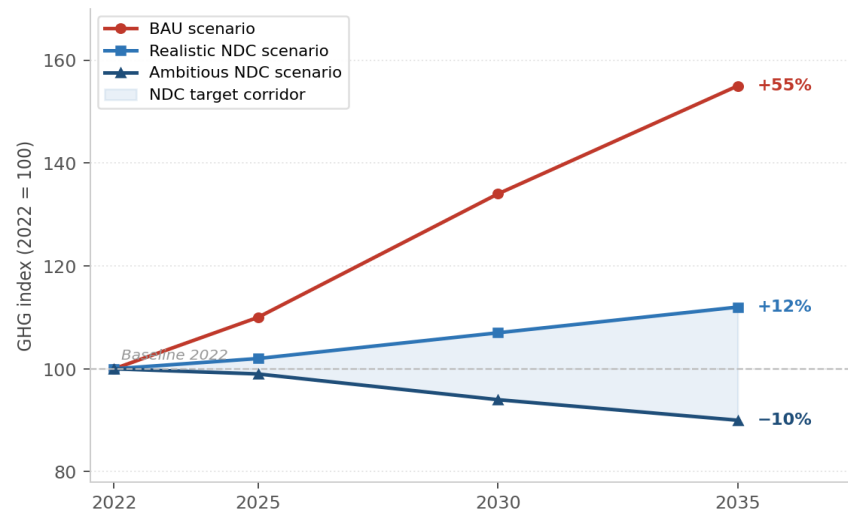
Figure 1. Sectoral structure of national GHG emissions, Uzbekistan (2022)

Source: Third NDC of Uzbekistan (2025) [1]. Total national GHG = 209.6 Mt CO₂.

Methane's global warming potential is approximately 80 times that of CO₂ over a 20-year horizon [5]. This means that the fugitive emissions component - controllable through technical interventions in gas distribution infrastructure - represents a disproportionately high near-term mitigation opportunity. The World Bank notes that Uzbekistan's energy-related methane losses, while declining, remain very high by international comparison and require dedicated measurement campaigns and investment roadmaps [2]. Such campaigns presuppose a workforce trained to conduct them.

Figure 3 shows the three emission trajectories to 2035. Under the BAU path, emissions grow to an index value of 155 (2022 = 100), representing a +55% increase. Under the realistic NDC scenario, growth is moderated to +12%; under the ambitious scenario, a 10% reduction is achieved. The distance between BAU and NDC scenarios - 45 index

points by 2035 - represents the mitigation task. A workforce unable to implement LDAR, energy-efficiency and digital-monitoring measures narrows that gap from the achievable end rather than the required end.

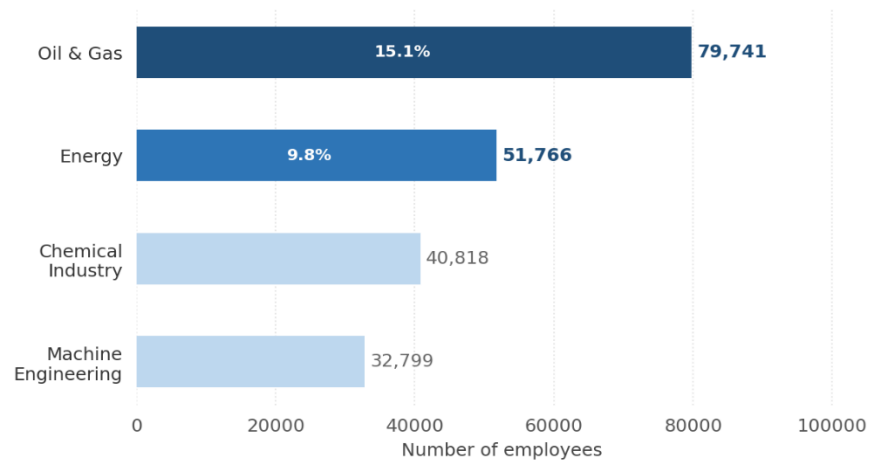


Source: Third NDC of Uzbekistan (2025) [1]. Index values: author's calculations based on NDC scenario parameters.

Figure 3. National GHG emission scenarios to 2035 (index: 2022 = 100)

Source: Third NDC of Uzbekistan (2025) [1]. Index values: author's calculations based on NDC scenario parameters.

Figure 2 shows SOE employment across the four largest sector groups. Oil and gas (79,741 employees; 15.1% of SOE total) is the largest single sector. Together with the energy sector (51,766; 9.8%), it accounts for 131,507 workers - one quarter of Uzbekistan's entire SOE workforce [3].



SOE = State-Owned Enterprise. Source: Agency for State Assets Management [3].

Figure 2. Employment in selected SOE sectors, Uzbekistan (2023)

Source: Agency for State Assets Management, Consolidated Report on Enterprises with State Participation (2023) [3]. Percentages denote share of total SOE employment (527,914 workers).

The economic exposure compounds this labour risk. Oil and gas generated 99,783.7 billion UZS in 2023 (20.6% of SOE revenue), growing at 154.4% year-on-year. The energy sector contributed 85,636.9 billion UZS (17.7%), growing at 293.5% [3]. These are expanding, not contracting, sectors. Transition pressure is therefore being applied to industries simultaneously carrying significant fiscal weight. A skills gap that reduces their productivity or competitiveness carries macroeconomic consequences beyond individual project-level underperformance.

The gender structure adds a further dimension: 78.4% of SOE employees are male and 21.4% female [3]. In oil and gas, this imbalance is likely more pronounced. Reskilling programmes must therefore contend not only with technical content but with access - ensuring that the emerging green-energy workforce, which will include a higher

proportion of digital, analytical and ESG roles [4], is not replicated as a male-dominated enclave.

Table 3 integrates the emissions, labour-market and economic findings into a diagnostic matrix structured around five transition pressures. For each pressure, the matrix specifies the evidential basis, required competencies and the hidden cost category triggered by a competency deficit. The matrix is the central analytical contribution of the paper.

Table 3. Skills-gap diagnostic matrix: transition pressures, required competencies and hidden costs

Transition pressure	Evidential basis	Required competencies	Hidden cost if unaddressed
Methane reduction	Fugitive O&G ~19% of energy-sector GHG [1]; losses described as "very high" by World Bank [2]	LDAR protocols; sensor calibration; gas metering; pipeline diagnostics; environmental reporting	Continued gas loss = lost revenue + climate non-compliance; project overruns requiring external contractors
Energy decarbonisation	Energy = 64% of national GHG; BAU +55% by 2035 [1]; cost of renewables below gas [6]	Energy-efficiency diagnostics; process optimisation; digital control; predictive maintenance	Slow NDC implementation; low return on green capital investment; technology deployed without effective operators
Green job creation	Power-sector employment +30% by 2035 in net-zero scenario [2]; IEA scenario range 6.9–13.4 mn [4]	Renewable O&M; grid operations; storage; electrical engineering; hybrid-system management	Dependence on foreign specialists; delayed localisation; wage outflow instead of workforce development
ESG and carbon reporting	EBRD identifies weak disclosure as barrier to green finance [8]; oil & gas SOEs under growing regulatory pressure	Carbon accounting; Scope 1/2 reporting; ESG data management; green finance literacy	Loss of access to concessional green finance; reputational risk; compliance penalties

Education and TVET constraint	STEM ~30% [2]; ADB identifies TVET capacity gaps [10]; fast-growing but low-base system	Engineering; analytics; environmental management; digital skills	High cost of importing qualified personnel; slow absorption of transition technology; bottleneck on reskilling throughput
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Note. LDAR = Leak Detection and Repair; O&M = Operation and Maintenance; ESG = Environmental, Social and Governance; SOE = State-Owned Enterprise. Reference numbers correspond to the information base (Table 1).

The diagnostic matrix (Table 3) produces a typology of five hidden cost categories. Unlike direct transition costs (capital expenditure, decommissioning), these costs are generated by the interaction between new technology and an inadequately prepared workforce. They are structurally absent from ex ante project appraisals because standard investment analysis evaluates hardware costs and projected operational outcomes without modelling the productivity loss generated by competency gaps.

The operational cost arises when installed technology is not used at design capacity: a digital methane-monitoring system that local staff cannot interpret delivers a fraction of its projected emission-reduction benefit. The investment cost arises when routine technical tasks must be performed by imported specialists: in Uzbekistan's context, where methane-reduction retrofits and energy-efficiency upgrades are expanding, this transfers economic value from domestic labour to external contractors. The productivity cost arises as existing workers in modernised operations lose relevance - a process the IEA documents in global O&G labour-market data showing growing demand for digitalisation skills within the sector [4]. The compliance cost arises from

weak carbon accounting and ESG disclosure capacity: the EBRD identifies this as a material barrier to green finance access across Central Asia [8]. The social cost arises from the absence of transition pathways for workers displaced from traditional energy roles - a dynamic the ILO characterises as increasing the aggregate fiscal cost of transition through income-support expenditure that reskilling would have made unnecessary [7].

These costs compound rather than simply aggregate. A company that incurs operational underperformance from inadequately trained staff also faces higher investment costs for repeat or remedial work, which depresses return on capital, which in turn weakens the financial case for subsequent transition investments. The compounding mechanism means that early investment in reskilling has returns that exceed the direct cost of training.

Uzbekistan's situation differs from the canonical just-transition case (large coal sector in a declining phase) in a way that both increases the complexity and the urgency of the skills challenge. Oil and gas is not declining in Uzbekistan: SOE revenue from the sector grew 154.4% in the most recent annual period [3]. The transition is therefore not managed wind-down but operational transformation: the sector must reduce its environmental footprint while maintaining, and indeed growing, its economic contribution. This creates a requirement for workers who can simultaneously operate at higher environmental standards and support revenue growth - a dual demand that neither standard fossil-fuel workforce training nor standard green-jobs training fully addresses.

The STEM constraint reinforces this challenge. With only ~30% of Uzbekistan's students in STEM fields [2] and TVET capacity gaps

documented by the ADB [10], the pipeline of technically qualified new entrants to the energy sector is insufficient to substitute for the existing workforce. The implication is direct: reskilling the current workforce is not an alternative to building a stronger education system - it is a necessity in the interim, while that system is built.

Conclusion

This paper has demonstrated that the skills gap in Uzbekistan's oil and gas workforce constitutes a category of hidden economic cost with five distinct mechanisms: operational, investment, productivity, compliance and social. These costs are generated by the interaction of new transition technologies with an inadequately prepared workforce, and they are structurally absent from standard project appraisals - making them invisible in the planning phase but real in the implementation phase.

The evidential base for this conclusion is quantitative. The energy sector accounts for 64% of national GHG emissions, with fugitive O&G emissions contributing ~19% of that total [1]. The oil and gas and energy SOE workforce numbers 131,507 workers - 25% of the SOE total - and the two sectors generate 38.3% of SOE revenue [3]. Under a BAU trajectory, emissions grow 55% by 2035. These figures jointly confirm that oil and gas workers are at the centre of both Uzbekistan's climate challenge and its industrial economy, and that unprepared transitions in this sector carry compounding costs.

Three conclusions follow for policy and research. First, methane management reskilling is the highest-priority intervention: it has the highest mitigation leverage, the lowest occupational distance from existing skills, and the clearest dual return (climate + revenue). Second,

the skills gap should be treated as an investment risk requiring explicit management in transition-project appraisals, not an HR externality managed separately from capital planning. Third, Uzbekistan needs a sectoral skills roadmap - analogous to NDC implementation plans for technology and finance - that maps required competencies onto workforce development milestones and institutional responsibilities.

The principal limitation of this study is the absence of granular occupational data for Uzbekistan's oil and gas sector. Future research should conduct primary surveys of SOE O&G workers to quantify competency gaps at the occupational level, estimate the cost of reskilling per worker and per skill cluster, and evaluate the pilot programmes that should begin in the near term.

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