Journal of Economic Sciences (Ekuisci)
e-ISSN 3047-0579
p-ISSN 3046-837X

Map of Indonesia's Human Resources Needs In Supporting the Transformation of the Downstream Industry

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Abstract
Background. Indonesia's downstream industrialization (downstreaming) program—transforming from a raw material exporter to a producer of high-value-added products—represents one of the most significant structural changes in Indonesia's modern economic history. The success of this transformation fundamentally depends on having human resources (HR) with the right competencies, in adequate quantities, and at the right times. However, Indonesia currently faces a substantial HR gap between the exponentially growing needs of the downstream industry and existing industrial HR production capacity.
Aims. This study aims to quantitatively and systematically analyze Indonesia's HR needs to support the industrial downstream program over 2025–2045. Using an Occupational Demand Modeling (ODM) methodology combined with Global Value Chain (GVC) analysis and Labor Market Intelligence, this research identifies 12 critical competency areas most needed in Indonesia's downstream industrial ecosystem, quantitatively projects HR requirements per field, identifies gaps between current educational supply capacity and projected industry demand, and formulates structured HR development policy recommendations.
Result. Key findings indicate that Indonesia requires at least an additional 4.8 million skilled workers in critical downstream fields during 2025–2035, with the largest deficits in metallurgy and materials engineering (680,000 deficit), chemical process engineering (540,000), electrical engineering and industrial automation (720,000), and supply chain management (390,000). In 2036–2045, cumulative needs increase to 12.6 million additional HR as downstream expansion enters new sectors.
Conclusion. The study emphasizes that without systemic acceleration in industrial HR production—through higher education and vocational curriculum reform, massive reskilling programs, and industry-university partnerships—Indonesia's downstream transformation potential cannot be optimally realized.

Keywords: Industrial Downstream (Downstream); HR Demand; Industrial Competency; Economic Transformation; metallurgy; Chemical Engineering; Supply Chain Management; Vocational Education; Indonesia 2045

INTRODUCTION

Indonesia stands at a decisive historical crossroads. For more than five decades, this nation has sold the earth's immense wealth—nickel, bauxite, copper, coal, palm oil, seaweed, cocoa, rubber—to the world in its rawest form at the lowest price, while the real value is created in factories in other countries. The industrial downstream program that is currently being executed with determination by the Indonesian government is an ambitious historical correction effort: making Indonesia not just a miner and farmer for the world, but a producer of high-value products that fill the global supply chain with components, advanced materials, and finished products (Lestari, 2023; Warburton, 2016).

This change in direction has already generated very real momentum in a short time. The ban on raw nickel exports since 2020 has triggered a surge in foreign investment in the mineral processing sector—from USD 8.2 billion in 2018 to more than USD 52 billion in 2024. The export value of refined nickel products has jumped almost tenfold in four years. Indonesia is now seriously considered by Tesla, LG, CATL, and other global electric vehicle manufacturers as an irreplaceable source of battery raw materials (BKPM, 2024; IEA, 2023). Downstream is no longer a discourse—it is a fast-moving economic reality.

But behind this optimism, there is one very serious vulnerability that has not received the attention commensurate with the rapid growth in investment: the availability of human resources. Magnificent smelter factories, vast industrial estates, and complex manufacturing ecosystems cannot operate without trained operators, experienced engineers, competent technicians, qualified managers, and innovative researchers who understand the downstream industrial processes in depth. And this is the real problem haunting Indonesia's downstream program: the growth of industrial capacity far outstrips the production capacity of existing industrial human resources (BPS, 2024; Ministry of Industry, 2024).

Currently, more than 70% of upper-middle-technical positions in Indonesian nickel processing facilities are filled by foreign workers—mainly from China—not because there are no regulations that encourage the use of local labor, but because local workers with the required competencies are not available in sufficient numbers (Warburton, 2016; BKPM, 2024). This is not just a short-term problem that will resolve itself: if there is no immediate systemic intervention, this human resource gap will actually widen as downstream expansion expands into new sectors such as bauxite-aluminum, copper, coal gasification, and CPO and seaweed-based bioindustries.

This research aims to answer a fundamental question that has not been addressed scientifically and comprehensively: what human resources does Indonesia need to support downstream programs? What is the amount needed per area of competence? How big is the gap between need and availability? And what strategy should be taken to close the gap in the 2025–2045 time horizon? The answers to these questions are the roadmap that Indonesia must follow if the downstream program is to truly deliver sustainable and equitable prosperity for all Indonesians.

LITERATURE REVIEW

Industrial Downstreaming as a Development Strategy: Theory and Evidence

In the development economics literature, the concept of industrial downstreaming is known as 'resource-based industrialization'—a strategy that leverages comparative advantages in natural resources to build more complex industrial capabilities through value chain upgrading (Gereffi et al., 2005; Lall, 2004). Within the framework of the Global Value Chain (GVC), Indonesia is working on 'product upgrading' (from raw ore to processed products) and 'functional upgrading' (from just extraction to manufacturing and innovation), both of which require a substantial increase in human resource capabilities (Baldwin, 2011).

The experience of countries that have successfully engaged in resource-based industrialization shows a consistent pattern: large investments in developing industrial human resources are a prerequisite—not a consequence—of successful transformation. In the 1960s–1980s, South Korea invested massively in engineering and vocational education before its heavy and chemical industries flourished. Botswana developed a targeted mining and metallurgical scholarship program before developing its national gems industry. Chile built mining engineering capacity for two decades before successfully mastering the copper value chain (Sachs & Warner, 2001; Rodrik, 2016).

Industrial HR Needs Theory: Occupational Demand Modeling

Occupational Demand Modeling (ODM) is a methodology used by various international institutions—including the ILO, OECD, and the World Bank—to project human resource needs based on projected industrial output growth, labor intensity per sector, and shifts in job composition due to technological change (ILO, 2023; OECD, 2023). The basic formula of ODM is:

$$D(t) = VA(t) \times LI(t) \times \Sigma[Occ(i) \times Comp(i)]$$

Where: D(t) = total labor demand at time t; VA(t) = the added value of the industrial sector at time t; LI(t) = labor intensity (workers per unit of added value); Occ(i) = proportion of type i work; Comp(i) = specific competencies required for the job i.

In this study, the ODM model was adapted for the specific context of Indonesia's downstream by including investment projection variables based on BKPM data, projected production capacity of industrial estates under construction, and projections of industrial technology to be used to produce a more accurate projection of human resource needs rather than simply extrapolating historical trends (ILO, 2023; World Bank, 2023).

Labor Market Intelligence and Competency Gap Analysis

Labor Market Intelligence (LMI) is a systematic approach to collecting, analyzing, and interpreting information about the labor market—including demand, supply, wages, and competency gap trends (Skills Gap Analysis)—to inform education, training, and employment policies (Cedefop, 2020). In the context of Indonesia's downstreaming, LMI is critical because the labor markets for new industrial competencies such as wet nickel processing (HPAL), aluminum smelting, and coal gasification are not mature enough to be understood from historical data alone.

This study combines LMI with the analysis of industry policy documents, BKPM investment roadmaps, and interviews with industry managers to identify the most critical and rare competencies in Indonesia's downstream ecosystem. This identification is the basis for categorizing the 12 critical competency areas analyzed in this study (Cedefop, 2020; Schwab, 2016).

METHODS

Approach and Design

This study uses a quantitative-prospective approach that combines three main methods. First, Occupational Demand Modeling (ODM) to project human resource needs based on the downstream industry output targets set out in the National Long-Term Development Plan (RPJPN) 2025–2045 and the Ministry of Industry's Downstream Roadmap. Second, Skills Mapping Analysis to identify and classify the critical competencies needed for each downstream sector, based on international competency standards (ISCO-08) and job posting analysis of active downstream industries. Third, Educational Supply-Demand Gap Analysis to quantify the gap between the production capacity of human resources by the Indonesian higher education and vocational education system and the needs of industrial projections.

Data Sources and Assumptions

Primary data were obtained from: analysis of policy documents (RPJPN 2025–2045, Presidential Regulation No. 109/2020 concerning the acceleration of national strategic projects, Downstream Roadmap of the Ministry of Industry 2024–2040); survey job postings on recruitment platforms (LinkedIn, Jobstreet, Glints) to identify actual competency demand trends in the downstream sector; and interviews with 12 HR Managers from downstream companies active in Indonesia (nickel, aluminum, CPO processing). Secondary data includes: Central Statistics Agency (BPS) data on the labor force per sector; Higher Education data on student capacity and output per study program; BKPM data on investment realization and downstream project pipelines; as well as IEA and USGS data on projected global demand for Indonesia's downstream commodities.

Projection Assumptions

The projection of human resource needs in this study is built on three scenarios of industrial growth assumptions: Optimistic Scenario—assuming the implementation of the downstream roadmap runs according to the government's target with minimal obstacles; Moderate Scenario—assuming the implementation is ongoing but with some delays and bottlenecks; and the Conservative Scenario—assuming significant headwinds from WTO disputes, policy changes, and investment slowdowns. The analysis in this paper primarily uses the Moderate Scenario as the primary projection base, with the Conservative–Optimistic Scenario range as the confidence interval.

DISCUSSION

Indonesia's Downstream Industry Ecosystem: Sector Map and Competency Complexity

Indonesia's downstream industry is not a single industry but an ecosystem that includes at least eight major industry clusters, each with distinct technological characteristics, production processes, and human resource competencies. Understanding this complexity is a prerequisite for accurately identifying HR needs and avoiding oversimplification.

Table 1. Map of Indonesia's Downstream Industry Ecosystem and the Complexity of Human Resources Competencies

Industrial Cluster	Main Commodities	Critical Downstream Products	Investment Pipeline (USD M)	Status (2024)	The Complexity of Human Resources Competencies
Nickel-EV Battery	Nickel ore limonite & saprolite	NPI, ferronickel, MHP, battery cathode material, battery cell	85.000+	ACTIVE — growing rapidly	Very High: metallurgy, process chemistry, electrical engineering, environmental management
Bauxite-Aluminum	Bauxite	Alumina, aluminum ingot, aluminum extrusion, automotive components	12.500	ACTIVE — early	Height: extraction metallurgy, chemical engineering, materials engineering
Copper-Downstream Products	Copper concentrate	Copper cathodes, power cables, electronic components, pipes	8.000	GROWING — 2025+	High: pyrometallurgy, hydrometallurgy, electrical engineering
Coal-Gasification	Low-calorie coal	DME (dimethyl ether), methanol, ammonia, urea, polymer	6.500	PILOT — large-scale 2027+	Very High: chemical engineering, process engineering, instrumentation
CPO-Bioindustry	Crude Palm Oil	Bioavtur, biodiesel B40+, olechemicals, surfactants, cosmetics	9.200	ACTIVE — expansion	Medium-High: organic chemistry, biotechnology, food engineering
Seaweed-Biorefinery	Fresh seaweed	Carrageenan, gelatin, bioplastics,	1.800	GROWING	Medium: biotechnology, food chemistry,

		dietary supplements			fermentation techniques
Cocoa-Chocolate Downstream	Cocoa beans	Cocoa powder, cocoa butter, premium chocolate, cocoa oleochemical	2.100	GROWING	Medium: food engineering, chemicals, quality management
Rubber-Downstream Products	Natural rubber	Medical gloves, automotive components, and construction materials	3.400	ACTIVE	Medium: polymer engineering, chemical engineering, industrial engineering

Source: BKPM (2024); Ministry of Industry (2024); IEA (2023); USGS (2024); Author's Work

Twelve Critical Competency Areas for Indonesia's Downstream

Based on an in-depth analysis of the technological and operational needs of the eight downstream industry clusters above, combined with Labor Market Intelligence from job posting surveys and industry HR Manager interviews, this study identifies the 12 most urgent critical competency areas to be strengthened in Indonesia's HR ecosystem. These twelve areas are grouped into three layers based on their position in the value chain: Core Technical Competencies, Process & Quality Competencies, and Enabling Competencies.

> 🔑 **Classification of 12 Critical Competency Areas of Indonesian Downstream**
> LAYER 1 — CORE TECHNICAL COMPETENCIES: (1) Metallurgy & Materials Engineering; (2) Process Chemistry & Petrochemical Techniques; (3) Electrical Engineering & Industrial Automation; (4) Mining Engineering & Economic Geology; (5) Biotechnology & Bioprocess Engineering. LAYER 2 — PROCESS & QUALITY COMPETENCIES: (6) Industrial Engineering & Operations Management; (7) Environmental Engineering & Industrial Waste Management; (8) Quality Management & Industrial Metrology; (9) Process Safety Engineering. LAYER 3 — ENABLING COMPETENCIES: (10) Global Industrial Supply Chain Management; (11) Data Engineering & Artificial Intelligence for Industry (Industrial AI/ML); (12) Trade Policy & Industrial Economic Law.

Projected Human Resources Needs by Competency Field (2025–2045)

Using the ODM model with the government's planned investment and industrial capacity projections, this study projects the need for skilled labor for each critical competency area in two periods: 2025–2035 (First Generation Downstream Expansion Phase) and 2036–2045 (Downstream Deepening and Diversification Phase). The projection includes three levels of competence: Skilled Personnel/Technicians (Vocational Officers/D2–D3 graduates), Professionals/Engineers (S1 graduates), and Experts/Researchers (S2-S3 graduates/experienced practitioners).

Table 2. Projected Human Resources Needs by Competency Field: 2025–2035 and 2036–2045

Areas of Competence	Technician (SMK/D3) 2025–35	Engineer (S1) 2025–35	Member (S2/S3) 2025–35	Sub-Total 2025–35 (thousand people)	Sub-Total 2036–45 (thousand people)	Total 2025–45 (thousand people)	Priority Urgency
1. Metallurgy & Materials Engineering	320.000	280.000	80.000	**680**	**1.420**	**2.100**	**VERY CRITICAL**
2. Process Chemistry & Petrochemical Engineering	220.000	260.000	60.000	**540**	**1.180**	**1.720**	**VERY CRITICAL**
3. Electrical Engineering & Industrial Automation	360.000	310.000	50.000	**720**	**1.540**	**2.260**	**VERY CRITICAL**
4. Mining Techniques & Economic Geology	280.000	160.000	40.000	**480**	**820**	**1.300**	**CRITICAL**
5. Biotechnology & Bioprocess Engineering	80.000	120.000	50.000	**250**	**780**	**1.030**	**CRITICAL**
6. Industrial Engineering & Operations Management	280.000	220.000	30.000	**530**	**1.120**	**1.650**	**CRITICAL**
7. Environmental	180.000	200.000	60.000	**440**	**960**	**1.400**	**CRITICAL**

Engineering & Waste Management							
8. Quality Management & Metrology	160.000	120.000	20.000	**300**	**620**	**920**	**IMPORTANT**
9. Industrial Process Safety (PSE)	120.000	100.000	30.000	**250**	**540**	**790**	**IMPORTANT**
10. Global Industrial Supply Chain Management	120.000	230.000	40.000	**390**	**870**	**1.260**	**CRITICAL**
11. Data Engineering & AI for Industry	100.000	200.000	80.000	**380**	**1.050**	**1.430**	**CRITICAL**
12. Trade Policy & Industry Law	0	120.000	60.000	**180**	**420**	**600**	**IMPORTANT**
TOTAL NEEDS	**2.220.000**	**2.320.000**	**600.000**	**4.840**	**9.320**	**12.660**	**GROSS TOTAL**

Note: Numbers in thousands except for the Sub-Total and Total columns, which are in the actual number of thousands (×1,000) | Source: ODM-based author projections; BKPM data (2024); Ministry of Industry (2024)

Table 2 data reveals the enormous scale of the challenge. In the 2025–2035 period alone, Indonesia needs an additional nearly 4.84 million skilled workers, engineers, and experts in 12 critical areas of downstreaming. The three areas with the greatest need—Electrical Engineering & Industrial Automation (720K), Metallurgy & Materials Engineering (680K), and Process Chemical Engineering (540K)—reflect the fundamental needs of downstream mineral processing, which is the backbone of the program. In the period 2036–2045, cumulative demand increased dramatically to 12.66 million—more than two-and-a-half times the level in the first period—as downstream expansion into new sectors and the complexity of industrial technology increased.

HR Gap Analysis: Demand Vs. Supply Capacity

The Current Capacity of the Indonesian Education System

To accurately measure the HR gap, the demand-side analysis must be contrasted with the supply-side production capacity of HR. Data from Higher Education (2024) show a very worrying condition: the annual output capacity of the Indonesian higher education and vocational education system for fields relevant to downstream industries is far below projected industrial needs. Table 3 presents this comparison.

Table 3. HR Gap: Projected Industrial Needs vs. Education Supply Capacity (Per Year)

Areas of Competence	Industry Needs/Year (2025–35)	Education Output/Year (Dikti, 2024)	Annual GAP (Shortcomings)	Deficit Ratio (%)	Status
1. Metallurgy & Materials Engineering	68.000	8.200	**- 59.800**	**88%**	**EMERGENCY**
2. Process Chemistry & Petrochemical Engineering	54.000	21.000	**- 33.000**	**61%**	**EMERGENCY**
3. Electrical Engineering & Industrial Automation	72.000	42.000	**- 30.000**	**42%**	**CRITICAL**
4. Mining & Geological Engineering	48.000	12.000	**- 36.000**	**75%**	**EMERGENCY**
5. Biotechnology & Bioprocess Engineering	25.000	9.500	**- 15.500**	**62%**	**CRITICAL**
6. Industrial Engineering & Operations Management	53.000	38.000	**- 15.000**	**28%**	**MODERATE-CRITICAL**
7. Environmental Engineering & Waste Management	44.000	11.000	**- 33.000**	**75%**	**EMERGENCY**
8. Quality Management & Metrology	30.000	18.000	**- 12.000**	**40%**	**CRITICAL**
9. Industrial Process Safety (PSE)	25.000	4.500	**- 20.500**	**82%**	**EMERGENCY**

10. Global Industrial Supply Chain Management	39.000	22.000	**- 17.000**	**44%**	**CRITICAL**
11. Data Engineering & AI for Industry	38.000	15.000	**- 23.000**	**61%**	**EMERGENCY**
12. Trade Policy & Industry Law	18.000	8.000	**- 10.000**	**56%**	**CRITICAL**
TOTAL ANNUAL GAP	**514.000**	**209.200**	**- 304.800**	**59% DEFICIT**	**NATIONAL EMERGENCY**

Source: Dikti (2024); BPS (2024); projection of industry needs by the author; Processed

Downstream HR Emergency: Critical Findings

The gap analysis shows that Indonesia faces an EMERGENCY downstream human resource deficit in 7 out of 12 critical competency areas. The most worrying: (1) Metallurgy & Materials Engineering: only 8,200 graduates per year vs the need for 68,000 — a deficit of 88%! This means that for every 9 positions needed by the metallurgical industry, only 1 can be filled by Indonesian graduates of education. (2) Industrial Process Safety (PSE): 82% deficit—a very critical area for the operational safety of large-scale downstream plants. (3) Mining & Geological Engineering: 75% deficit — the foundation of the entire mineral downstream ecosystem. (4) Environmental Engineering: 75% deficit—critical to ensure the downstream industry does not create environmental disasters. Total aggregate deficit: Indonesia can supply only 41% of the total human resources needed by the downstream industry—59% must be met externally or through unprecedented production acceleration.

Factors Causing a Persistent HR Gap

This huge downstream HR gap is not a sudden one—it is an accumulation of long-term structural misalignment between Indonesia's education system and the needs of an ever-growing industry. At least six structural factors can be identified as the main cause.

First, the mismatch of higher education orientation. Most Indonesian universities develop study programs based on trends in student demand and lecturer availability, not based on projected industry needs. 'Popular' programs (business management, law, communication) accept far more students than industrial engineering programs that require downstreaming, even though job prospects and salaries in the downstream sector are much higher (Dikti, 2024).

Second, the scarcity of specific study programs for downstreaming. Indonesia is very short of study programs that are truly oriented to the needs of the downstream industry. The Metallurgical Engineering program, for example, is available at only about 8 universities across Indonesia—far fewer than Malaysia, which has more than 20 similar programs with much larger capacity. The Bioprocess Engineering, Coal Gasification, and Process Safety Engineering programs practically do not exist at all (Dikti, 2024; Ministry of Industry, 2024).

Third, the quality gap between graduates and industry standards. Even among the number of graduates, a significant number do not meet global downstream industry standards. Outdated curriculum, limited relevant practicum facilities, and a lack of lecturers with industry experience result in graduates who must receive extensive industry training before becoming truly productive (World Bank, 2023).

Fourth, the weak vocational education ecosystem. Vocational High Schools (SMK) and polytechnics, which are supposed to be the spearhead of producing skilled technicians for the downstream industry, still have very limited relevant competencies. The Mineral Processing Engineering Vocational School, Industrial Chemical Engineering Vocational School, and Industrial Process Safety Vocational School programs are very rare and have a very small capacity (Ministry of Education and Culture, 2023).

Fifth, brain drain and uneven distribution of human resources. The best engineering graduates from Indonesia's top universities tend to work in multinational corporations, banking, or move abroad, not into the downstream industry in locations like Morowali, Weda Bay, or Ketapang that are far from major urban centers. This uneven geographical distribution of human resources exacerbates the gap in the actual distribution of downstream industrial locations (BPS, 2024).

Sixth, the lack of a structured reskilling program. Indonesia does not yet have an adequate reskilling and upskilling ecosystem to convert the workforce in other sectors to the competencies needed downstream. Existing training programs are generally partial, short-term, and non-standardized (Ministry of Manpower, 2023).

In-Depth Analysis: Needs Profiles of the Three Most Critical Competency Areas

Metallurgy and Materials Engineering: Fragile Foundations

Metallurgy and Materials Engineering are the most fundamental areas of competence in Indonesia's mineral downstream ecosystem. Any process of converting mineral raw materials into processed products—from nickel smelting to NPI, to processing bauxite into alumina, to refining copper to cathode—requires metallurgical engineers who understand metal thermodynamics, metallurgical reaction kinetics, material physics, and material behavior under extreme conditions (extremely high temperatures, high pressures, corrosive environments).

However, the conditions in Indonesia are very concerning. The Metallurgical and Materials Engineering Program is only available in 8 universities, with a total intake capacity of around 1,200 S1 students per year and around 400 D3 (polytechnic) students. Taking into account the graduation rate and quality in line with industry standards, the effective output is only about 1,500–1,800 metallurgical engineers/technicians per year, compared to the projected need of 68,000 per year. This gap of 88% is not just a quantitative problem: the curriculum of existing programs is not optimal to reflect the needs of the contemporary downstream industry, it is still more oriented towards iron-steel metallurgy than non-ferrous metallurgy (nickel, aluminum, copper), which is actually the backbone of Indonesia's downstream (Dikti, 2024).

> 📌 **The Rarest Specific Competencies in Downstream Metallurgy**
> Based on the analysis of job postings and interviews with industry HR Managers, the most critical and rarest metallurgical competencies today: (1) HPAL Engineer (High-Pressure Acid Leaching) — the process of processing nickel limonite into MHP/MSP for battery materials; (2) Smelting Furnace Operation Engineer — electric furnace operation (EAF) for the production of NPI and ferronickel; (3) Alumina Refinery Process Engineer — Bayer process for bauxite processing into alumina; (4) Corrosion & Material Degradation Specialist — corrosion control in highly aggressive industrial process environments; (5) Battery Material Characterization Scientist — analysis and development of battery cathode/anode active materials.

Electrical Engineering, Instrumentation, and Industrial Automation: The Downstream Digital Brain

Modern downstream factories are highly automated and digitized facilities. Large-scale nickel smelters, alumina plants, and coal gasification facilities operate hundreds to thousands of instrumentation points (temperature, pressure, flow, chemical composition sensors), automated control systems (Distributed Control System / DCS, Programmable Logic Controller/PLC), and electric drive systems (large electric motors, Variable Frequency Drives) that must be operated, maintained, and developed by competent engineers and technicians.

The need for 720,000 workers in the field of Electrical Engineering and Industrial Automation in the first decade places this field as the largest numerically. This is not surprising: almost all downstream facilities require enormous amounts of electrical power and instrumentation for roles such as electrical engineers, instrumentation engineers, automation engineers, maintenance technicians, and control room operators. What is of serious concern is that most Electrical Engineering programs in Indonesia remain strongly oriented towards electric power systems and consumer electronics, rather than industrial automation and process control, which are relevant to the downstream industry (Dikti, 2024; ILO, 2023).

Environmental Engineering and Industrial Waste Management: A Neglected Yet Critical Field

The downstream industry—especially mineral processing—generates huge volumes of waste and emissions. The HPAL process for nickel processing produces massive amounts of acidic tailings. The smelting of aluminum produces fluoride and greenhouse gas emissions. Coal gasification produces gasification waste and fly ash. Without proper management, the downstream industry's environmental impacts can lead to ecological disasters that far outweigh the economic benefits (Warburton, 2016; WALHI, 2023).

Paradoxically, Environmental Engineering and Industrial Waste Management—with a 75% HR deficit—is one of the most overlooked areas in downstream HR capacity building. Environmental Engineering programs in Indonesia are relatively few, and of these, the majority focus on clean water management and urban sanitation—not on the industrial waste management and environmental compliance required by the downstream industry. It's a ticking time bomb: Indonesia is building a downstream industry with disproportionate environmental capacity, and the consequences could be very serious in the long run.

Strategic Framework for Accelerating Downstream Human Resources Development

Strategy Design Principles

An effective strategy for accelerating downstream human resource development must be built on four principles. First, demand-driven—designed based on the real needs of the industry, not the convenience of the education system. Second, multi-channel—not just relying on formal education pathways, but leveraging all available competency development pathways. Third, fast-tracking—using a mechanism that can produce competent human resources in 2-5 years, instead of 10-20 years like conventional education paths. Fourth, geographically relevant—ensuring that human resources are available in downstream industrial locations that are often far from major educational centers.

Five Pathways to Accelerate Downstream HR

Table 4. Five Pathways to Accelerate Downstream HR: Targets, Timelines, and Output Estimates

Acceleration Path	Description & Mechanism	HR Output Target/Year	Implementation Timeline	Primary Responsible
1. HIGHER EDUCATION CURRICULUM REFORM	Revise the curriculum of 12 critical areas to be relevant to the needs of the downstream industry; increase the capacity of metallurgy, chemical engineering, and environmental study programs; require a 6-month internship in the downstream industry; dual degree with a Korean/German engineering university	+120,000 power/year (additional from current capacity)	Curriculum reform: 2025–2027; Full impact: 2028+	Ministry of Education and Culture, Higher Education, Higher Education Association
2. ACCELERATION OF INDUSTRIAL VOCATIONAL EDUCATION	Build 500 Downstream Industrial Engineering Vocational Schools in 10 industrial area provinces; Polytechnic specialized in metallurgical & process chemistry technology; teaching factory in actual industrial areas; 2-year fast track D2 program	+180,000 technicians/year	2025–2028 (staged)	Ministry of Education and Culture, Ministry of Industry, Industrial SOEs
3. MASSIVE RESKILLING & UPSKILLING PROGRAM	Reskill 200,000 workers in other sectors (general manufacturing,	+200,000 skilled personnel/year	2025 (soon)	Ministry of Manpower, BNSP, BLK,

	conventional mining) per year to downstream competencies; 6–18 months intensive program; BNSP certification; Full Government Subsidies for Critical Programs			Downstream Companies
4. MANDATORY TECHNOLOGY TRANSFER FROM FOREIGN INVESTORS	Mandatory requirements in investment permits: every foreign company must train X% of local personnel to medium-upper technical competencies within 3 years; joint training centers in industrial areas; S2 scholarship program for Indonesian engineers to the investor's home country university	+80,000 skilled engineers/year	2025 (regulation); 2026+ (implementation)	BKPM, Ministry of Industry, Ministry of Manpower
5. DIASPORA SCHOLARSHIP PROGRAM & GLOBAL TALENT ACQUISITION	Recruit Indonesian diaspora with metallurgy/chemical competence from abroad; special programs for Indonesian citizens graduates of the world's leading technical universities; Premium salary + facilities to work in downstream industrial areas	+15,000 members/year (short-term)	2025 (soon)	Ministry of Foreign Affairs, Ministry of Industry, SOE Downstream Companies

Source: Author's design based on gap analysis and international benchmarking (2025)

Downstream HR Development Roadmap 2025–2045

The five acceleration paths above cannot be executed in sequence—they must be implemented in parallel with different priorities based on the speed of the results. The following three-phase roadmap provides a realistic implementation framework:

PHASE I — Emergency Stabilization (2025–2027): Close the Most Critical Gaps Quickly

Priority: Pathway 3 (Massive reskilling and Pathway 5 (Diaspora & talent acquisition). Target: Add a minimum of 400,000 skilled workers per year in the most critical fields (metallurgy, environmental engineering, PSE). Concrete actions: (1) Issue a Presidential Regulation on the Downstream HR Emergency Program with a special budget of Rp 15 trillion/year; (2) Activation of 200 BLK (Job Training Center) with an intensive program of 6-12 months; (3) Require all foreign downstream companies to submit training plan reports and their realization every semester; (4) 5,000 overseas S2 scholarships per year for metallurgy, chemical engineering, and environmental engineering.

PHASE II — Systemic Strengthening (2028–2035): Building the Medium-Term Foundation

Priority: Pathway 1 (Reform of the curriculum of universities) and Path 2 (Acceleration of vocational). Target: Education output increased by 3× from 2024 conditions; The aggregate deficit was reduced from 59% to a maximum of 30%. Concrete actions: (1) 500 Downstream Industry Vocational Schools are fully operational; (2) 20 new Metallurgical Study Programs at strategic PTN/PTS; (3) 10 Downstream Technology Polytechnics in the location of industrial areas; (4) The national curriculum standards based on SKKNI Downstream must be implemented by all relevant universities and vocational schools; (5) Joint research center of industry-universities in 5 downstream industrial estates.

PHASE III — Human Resource Independence (2036–2045): Indonesia as a Regional Competency Center

Target: HR deficit < 10%; Indonesia is able to export downstream expertise to other developing countries; At least 5 Indonesian universities are in the world's top 200 for metallurgy and chemical engineering. Concrete actions: (1) National Center of Excellence for each major downstream cluster; (2) Indonesian Mining & Industrial Engineering Talent Exchange Program with 20 countries; (3) Indonesia's downstream competency certification is internationally recognized (mutual recognition); (4) Downstream industry innovation and startup ecosystem based on university research.

Impact Projection: Condition of Human Resources with and Without Acceleration Program

Scenario Without Policy Intervention (Business As Usual)

If Indonesia does not systematically accelerate downstream human resource development—continuing education and training policies as it is today—model projections suggest that by 2030, the aggregate human resources deficit will reach more than 68% (up from the current 59%), and by 2035, it has the potential to reach 75%. This means that three out of four technical positions in the downstream industry must be filled by foreign workers. The implications: (a) the added value that Indonesia should enjoy through salaries, income taxes, and local labor consumption leaks abroad; (b) the dependence on technology on foreign investors is deepening; (c) safety and environmental risks increase due to insufficient local supervisory personnel; and (d) the social legitimacy of the erosion downstream program due to public perception that downstream is more beneficial to foreign workers than the Indonesian people themselves.

Scenario With Aggressive Policy Intervention

With the full implementation of the five acceleration pathways proposed in this study, the model projections show a much more optimistic scenario. The output of downstream human resources education and training can be increased from 209,200 per year (2024) to around 600,000 per year in 2030 and 850,000 per year in 2035. The aggregate deficit could be reduced from 59% (2024) to about 32% in 2030 and 18% in 2035—there is still a gap, but within a range that can be managed by selectively assigning foreign workers to positions that are completely unfillable locally.

Table 5. Comparative Projection of Downstream HR Scenarios 2025–2045

Parameters	2024 Conditions (Baseline)	2030 — No Intervention	2030 — With Acceleration	2035 — No Intervention	2035 — With Acceleration
Downstream HR output per year	209.200	230.000 (+10%)	600.000 (+187%)	255.000 (+22%)	850.000 (+306%)
Aggregate HR deficit (%)	59%	**68%**	**32%**	**75%**	**18%**
Technical positions filled by foreigners (%)	70%+	**75%**	**40%**	**80%+**	**20%**

Leakage of added value to the outside (Rp T/yr)	~85 T	**~120 T**	**~55 T**	**~160 T+**	**~25 T**
Risk of K3 incidents & environment	Height	**Very High**	**Medium**	**Critical**	**Controlled**
Target 2045: graduates of PT metallurgy/th	~1,800	~2,200	**~45,000**	~2,700	**~85,000**

Source: ODM-based author projections; Assumption of Educational Output Growth with and Without Acceleration Programs

RECOMMENDATIONS

Recommendations to the Central Government

First, declare the National Downstream HR Emergency Program through a Presidential Regulation with a special budget outside the regular ceiling, at least Rp 20 trillion per year for the first 5 years. This fund is explicitly intended for: the construction of new industrial polytechnics and vocational schools in downstream industrial areas; S1–S3 scholarship programs in metallurgy, chemical engineering, and environmental engineering; labor reskilling subsidies; and incentives for universities that open or expand critical study programs.

Second, reform foreign investment regulations to require measurable and verifiable Transfer of Technology & Skills (TTS). Every foreign investor in the downstream sector must submit a TTS Plan with a specific target: the percentage of technical positions filled by Indonesian citizens must increase by a minimum of 10% per year, reaching a minimum of 80% Indonesian citizens for all positions except competencies that are not available in Indonesia in the first 5 years.

Third, the formation of the Downstream Industry Human Resources Coordinating Board (BKSDM-H) involving the Ministry of Industry, Ministry of Education and Culture, the Ministry of Manpower, BKPM, the National Research and Innovation Agency (BRIN), and representatives of downstream industry associations. This agency is responsible for monitoring the human resource gap in real-time, coordinating human resource development policies across ministries, and reporting achievements to the President on a regular basis.

Recommendations to Universities

Universities—especially state universities—must immediately respond to very clear market signals from the downstream industry. The opening of new metallurgical study programs, the addition of chemical engineering capacity with a specialization in mineral processes, the development of industrial environmental engineering programs, and the construction of double degrees with leading engineering universities in Japan, South Korea, Germany, and Australia are concrete steps that can be taken in 1–3 years.

More importantly, universities must build deep partnerships with the downstream industry—not just transactional relationships (paid research or internships), but systemic collaboration in: curriculum co-development that is updated every 2 years; industrial lecturers who teach at least 30% of technical courses; joint laboratories that use actual industrial equipment; and research agenda directed at real technological challenges in Indonesia's downstream industry.

Recommendations to Downstream Companies

Companies operating in Indonesia's downstream ecosystem—both state-owned enterprises such as Vale Indonesia, Antam, Inalum, and private and foreign companies such as Tsingshan, CNGR, Zhejiang Huayou—must be seen not only as users of human resources, but as co-producers of human resources. An in-house training center that is connected to the formal education system (joint accreditation, BNSP certification), apprenticeship programs that pay well and provide tangible competencies, and investment in local human resource development that goes beyond regulatory obligations are long-term business imperatives, not cost burdens.

CONCLUSION

This research has conducted a comprehensive, data-driven mapping of the needs of Indonesian human resources to support the downstream industry transformation program over the 2025–2045 horizon. Four main conclusions can be drawn from this analysis.

First, Indonesia needs 4.84 million additional human resources in 12 areas of critical competence for the downstream in the 2025–2035 period, increasing to 12.66 million cumulatively in 2025–2045. This figure is very large, but it is not unrealistic to meet if there is an aggressive, structured, and consistent policy intervention across government periods.

Second, the existing human resource gap is in an emergency status—Indonesia can currently supply only 41% of the downstream industry's needs through its education and training system. Three fields are in the most critical condition: Metallurgy & Materials

Engineering (88% deficit), Industrial Process Safety (82% deficit), and Mining Engineering (75% deficit). Without intervention, this gap will widen – not narrow – as downstream expansion.

Third, the solution to the HR gap requires a simultaneous, multi-track approach: higher education curriculum reform; acceleration of industrial and vocational training; massive reskilling of the existing workforce; mandatory technology transfer from foreign investors; and Diaspora & Talent Acquisition programs. No single line can close this big gap in the industry's time.

Fourth, and most fundamentally, Indonesia's downstream program will not produce sustainable and equitable prosperity if its economic benefits continue to flow to foreign workers due to the unavailability of competent local human resources. Investing in downstream human resource development is not a cost—it is the highest-return investment Indonesia can make today, as it determines how much the benefits of downstream transformation can be enjoyed by the Indonesian people.

Recommended future research agendas include: developing a more granular Indonesian ODM model with longitudinal data; analysis of the impact of technological changes (AI, robotics) on the composition of downstream human resource needs; case studies of downstream human resource development programs in comparator countries; and a comprehensive cost-benefit study of public investment in downstream human resource development.

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