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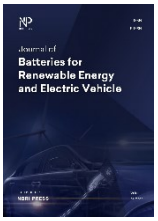

The National Battery Research Institute: Energizing Indonesia's Battery Revolution on Skills Development

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ABSTRACT

Indonesia is at the forefront of the global electric vehicle (EV) battery industry, driven by its rich nickel reserves and strategic initiatives like the National Battery Research Institute (NBRI). This paper explores NBRI's pivotal role in enhancing skills development within the EV battery sector, a critical factor for sustaining Indonesia's competitive advantage. The study employs a mixed-methods approach, integrating quantitative data analysis with qualitative insights from industry stakeholders. Findings reveal that targeted skills development programs have significantly contributed to workforce readiness, aligning with global trends in green jobs and sustainable energy. However, the industry faces challenges, including the need for continuous upskilling, technological adoption, and collaboration between academia and industry. Opportunities lie in leveraging Indonesia's resource wealth, government policies, and international partnerships to build a robust talent pipeline. The impact of these initiatives is evident in the growth of a skilled labor force capable of driving innovation and sustainability in battery technology. The paper concludes that NBRI's efforts are crucial in positioning Indonesia as a leader in the global EV battery market, emphasizing the importance of ongoing investment in education and training to meet the evolving demands of this dynamic industry.

INTRODUCTION

The global transition towards sustainable energy has accelerated the development of electric vehicles (EVs) and advanced battery technologies. This shift is driven by the need to reduce greenhouse gas emissions and combat climate change. According to the International Energy Agency (IEA), the global EV stock surpassed 10 million vehicles in 2022, reflecting a significant increase from previous years [1-5].

The battery industry, crucial to this transition, is experiencing rapid growth, with the global battery market projected to reach $460 billion by 2030 [2], [4], [6-7]. The substantial increase in demand for batteries, particularly lithium-ion batteries, underscores the urgency for advancements in battery technologies and scaling up of production capabilities.

In this global context, Indonesia is emerging as a key player in the battery sector. The country boasts substantial reserves of nickel, a critical component for lithium-ion batteries, which positions it as a strategic hub for battery production [5], [7]. The Indonesian government has recognized this potential and is focusing on developing its battery manufacturing capabilities as part of its broader industrialization and green energy strategy [8].

According to a report by Lee et al. (2022), Indonesia's strategic investments in battery production infrastructure and raw material processing are expected to significantly impact the global battery supply chain [9]. This move is not only aimed at boosting domestic economic growth but also at positioning Indonesia as a competitive player in the global battery market.

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Additionally, the development of a robust battery supply chain is crucial for meeting the increasing demand for energy storage solutions. Research by Li et al. (2021) highlights that efficient resource management and investment in local manufacturing capabilities are vital for ensuring supply chain resilience and sustainability [8], [10]. As Indonesia embarks on this path, the National Battery Research Institute (NBRI) plays a pivotal role in advancing research, fostering innovation, and bridging the skills gap within the battery industry.

The National Battery Research Institute (NBRI) was established to spearhead research and innovation in battery technologies and to support Indonesia's ambitious goals in the EV and renewable energy sectors. Founded in 2020, the NBRI serves as a pivotal institution in driving advancements in battery technology through cutting-edge research and development, and it plays a crucial role in the national strategy to build a sustainable battery industry [5], [8], [10].

This paper explores the role of the NBRI in fostering skills development within Indonesia's battery sector. It highlights how the institute contributes to bridging the skills gap, enhancing technological innovation, and supporting the country's transition towards a green economy. By examining NBRI's programs and initiatives, this study aims to provide insights into the broader impact of skills development on Indonesia's battery revolution.

Skills development is critical to the advancement of the battery industry. The sector demands a highly specialized workforce capable of driving innovation and maintaining competitive advantage. A study by the World Economic Forum highlights that the energy sector, including battery technologies, is among the top fields where green jobs are expanding rapidly [6], [8].

In the global landscape, green jobs related to EV battery production are growing, with the battery manufacturing sector expected to create millions of new jobs by 2030 [7], [9]. For instance, in the European Union alone, the battery industry is projected to generate over 800,000 jobs by 2025 [4], [6], [8]. These jobs span a range of roles, from research and development to manufacturing and recycling.

Indonesia's landscape reflects this global trend. The country's commitment to developing its battery industry is expected to create significant employment opportunities. According to a report by McKinsey & Company, Indonesia's battery sector could generate up to 600,000 new jobs by 2030, driven by investments in manufacturing and related industries [9], [11]. The NBRI's role in enhancing skills within this sector is crucial to ensuring that the workforce is equipped to meet the demands of this-burgeoning industry.

METHODOLOGY

This study employs a mixed-methods approach to analyze the role of the National Battery Research Institute (NBRI) in skills development for Indonesia's battery sector. The methodology integrates quantitative data analysis with qualitative insights to provide a comprehensive overview of the institute's impact. The research design includes a review of NBRI's programs and initiatives, statistical analysis of industry data, and interviews with key stakeholders involved in skills development.

Quantitative data were collected from NBRI's annual reports, industry publications, and government statistics to assess the scale and effectiveness of the institute's training programs and their outcomes. This data includes enrollment figures, program completion rates, and subsequent employment statistics of graduates. Additionally, industry performance metrics such as growth in battery production and innovation rates were analyzed to correlate with the skills development initiatives.

Qualitative data were gathered through semi-structured interviews with NBRI staff, industry experts, and program participants. These interviews aimed to capture in-depth perspectives on the effectiveness of NBRI's training programs, challenges faced, and areas for improvement. The interview guide was developed based on a literature review and previous studies on skills development in similar sectors [8], [9].

To ensure the reliability and validity of the findings, the study employed triangulation by cross-referencing quantitative data with qualitative insights. Additionally, data from multiple sources were compared to validate the consistency of the results. Feedback from industry experts was sought to review and corroborate the findings, ensuring that the analysis accurately reflects the impact of NBRI's skills development programs.

RESULTS AND DISCUSSION

The National Battery Research Institute

The National Battery Research Institute (NBRI) was established in 2020 as a central hub for advancing battery technology and supporting Indonesia's strategic goals in the energy and automotive sectors. Located in Jakarta, the institute is tasked with driving innovation, fostering research collaborations, and facilitating the development of a skilled workforce in the battery sector. The NBRI aligns its mission with Indonesia's national energy strategy, which aims to transition towards cleaner-

-energy solutions and enhance the country's position in the global battery supply chain.

The original concept of NBRI was founded by Prof Dr. rer nat Evvy Kartini in 2014, as shown in fig. 1. Operating as a consortium, NBRI comprises a diverse and robust network of members with expertise in energy storage. By uniting specialists from academia and industry under the National Battery Challenge, NBRI aims to position Indonesia as a global hub for research, development, and production of cutting-edge energy storage technologies, particularly for the electronics and automotive sectors. Beyond Indonesia, NBRI's network extends to international partners, including researchers and institutions from the United Kingdom, Australia, Japan, Singapore, and other countries [12].

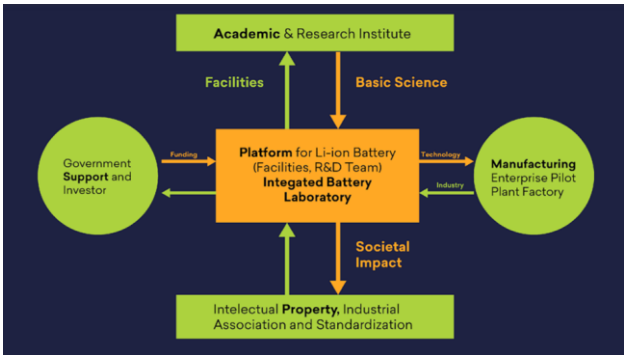

Fig. 1. The original concept of NBRI founder by Prof. Dr. rer. nat. Evvy Kartini back in 2014.

In 2020, NBRI transitioned into an independent institute in Indonesia, dedicated to advancing electrochemical energy storage science and technology while supporting research, training, and education. NBRI's mission is to enhance Indonesia's research capacity and training environment in battery and renewable energy studies. By collaborating with scientists and industry partners, NBRI focuses on reducing battery costs, weight, and volume, improving performance and reliability, and developing comprehensive strategies for battery recycling and reuse.

The institute was officially established on December 07, 2020, as The Center of Excellence Innovation of Battery and Renewable Energy Foundation, with support from the UK's Global Challenge Research Fund (GCRF) through a partnership with Queen Mary University of London (QMUL). Prof. Dr. Evvy Kartini and Prof. Dr. Alan J. Drew are the Founder and Co-founder of NBRI, respectively [12].

The NBRI is organized into three key departments, each focusing on different aspects of battery research and development. These departments include: **(1) Research, Development, and Innovation (RDI):** Responsible for conducting cutting-edge research on battery technologies, -including materials science, energy density improvements, and battery efficiency. This department also focuses on developing new battery prototypes and technologies. **(2) Education and Training:** Dedicated to developing and implementing educational programs and training workshops aimed to reskilling and upskilling individuals in EV battery technology. This department collaborates with multiple stakeholders' experts including industry and government to provide practical and theoretical training. **(3) Battery Testing Standardization:** Responsible to maintain the quality of cell and pack battery both performance and safety.

Above those department, there are also some services that NBRI has been done, including **Event Organizer** (conducting International Battery Summit and series of international conference & event), **Publisher** (including NBRI Press and JBREV), and consultation. Furthermore, there are also some initiatives, such as **Industry Collaboration:** Focuses on building and maintaining partnerships with industry stakeholders, including battery manufacturers, automotive companies, and government agencies. Facilitating collaborative projects, technology transfer, and joint research initiatives.

Also, **Policy and Strategy:** Engages in policy advocacy and strategic planning to support the development of a conducive regulatory environment for battery technology advancement. The NBRI works closely with policymakers to shape national and regional policies.

Education and Training Department

Established in 2021, the Department of Education and Training at the National Battery Research Institute (NBRI) has quickly become a pivotal resource for advancing skills in EV battery technology and its associated ecosystem. This department addresses the urgent need for a skilled workforce capable of supporting the rapidly growing electric vehicle (EV) industry, which is essential for achieving global sustainability goals.

As the demand for EVs continues to rise, so does the necessity for specialized training that spans the entire battery value chain—from raw material extraction to battery manufacturing, testing, and application. The department's strategic focus on comprehensive skills development ensures that participants are equipped to meet the industry's evolving challenges and contribute to the global transition towards greener energy solutions [11], [13].

Over the past three years, the Department of Education and Training has successfully conducted 30 training programs encompassing 78 activities, attracting 868 participants from 189 industries-

across 10 countries, including Indonesia, the United Kingdom, Australia, Japan, and the United States. These programs offer a diverse range of training models and topics, covering the full spectrum of the battery industry, from upstream mineral extractions to downstream battery applications.

Notable programs include the International Battery School, workshops on Solar PV and material science, and specialized training for miners, polytechnic lecturers, and industry professionals. This variety ensures that the training is not only relevant but also adaptable to the specific needs of different sectors within the battery ecosystem, providing a holistic understanding of the industry's complexities. Fig. 2. shows the growth of impact that NBRI has been initiated through this department.

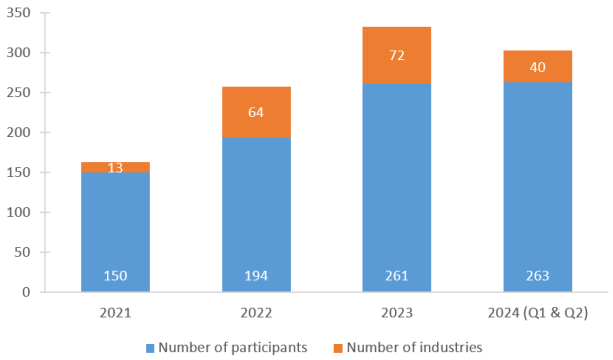

Fig. 2. The growth of impact number from Education & Training Department.

The impact of these training programs is evident in the high satisfaction score of 4.74 out of 5.00, reflecting the quality and relevance of the content delivered. By offering both online and offline training options, NBRI has made its programs accessible to a global audience, facilitating knowledge transfer across borders. The department's initiatives have fostered a skilled workforce that is better prepared to drive innovation in battery technology, support the development of sustainable energy infrastructure, and contribute to the global competitiveness of the industries involved.

Various big players also become participants in the NBRI training, such as Indonesia Battery Corporation (IBC), PT PLN Persero, PT Komatsu Indonesia, Surveyor Indonesia, Sucofindo, PT Carsurin Tbk, Ministry of Foreign Affairs Republic of Indonesia, VKTR, ALVA, PT Pamapersada Nusantara, TUV NORD, PT Toyota Motor Manufacturing Indonesia, PT Astra Honda Motor, PT Pertamina Patra Niaga, Merdeka Battery Materials, PT Ceria Nugraha Indotama, PT Polychem Indonesia Tbk, Bumi Mineral Sulawesi, and many more.

By continuously updating its training models to reflect the latest industry trends and technological -advancements, NBRI ensures that its participants are well-equipped to address the challenges and seize the opportunities within the rapidly evolving EV battery sector. Fig. 3 and 4 shows the hands-on experience as NBRI's value proposition for the training platform.

Fig. 3. Hands-on experience on mineral extraction and material processing for EV battery.

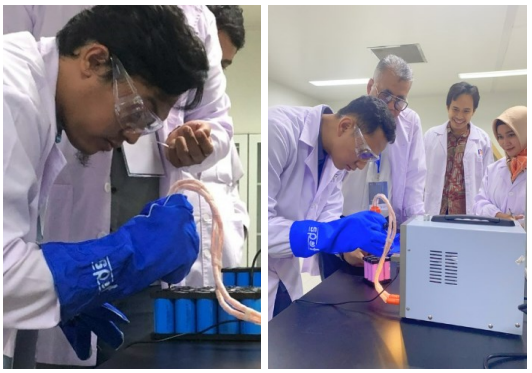

Fig. 4. Hands-on experience on battery pack assembly.

The National Battery Research Institute (NBRI) has made significant strides in supporting policy initiatives and providing critical industry input through its Department of Education and Training. As a leader of the working group on national work competency standards for battery packs, NBRI played a crucial role in shaping the standards that are now officially ratified under the Ministry of Manpower's regulation, *Permenaker* No. 242/2022.

Over a six-month period, these standards were developed to ensure that the talent entering the EV battery industry is not only qualified but also-

-adheres to stringent safety and technical requirements. This regulatory framework is pivotal for maintaining high standards across the industry, ensuring that Indonesia remains competitive in the global EV battery market while safeguarding the interests of workers and consumers alike. Fig. 5. shows the policy output on national talent standard.

Fig. 5. Policy output of SKKNI on Battery Pack.

In addition to its policy influence, NBRI is deeply involved in talent development at the academic level. Collaborating with the Ministry of Energy and Mineral Resources and the Swiss Confederation's State Secretariat for Economic Affairs (SECO) under the Renewable Energy Skills Development (RESD) program, NBRI contributes expert knowledge to the development of curricula for universities and vocational institutions.

This initiative aims to equip future professionals with the skill sets essential for the EV battery industry, ensuring that education and training programs align with the latest industry demands. The output of this collaboration provides a comprehensive learning guideline for higher education and vocational institutions, helping to bridge the gap between academic training and industry needs, thereby fostering a new generation of skilled workers ready to drive innovation and growth in Indonesia's EV battery sector. Fig. 6. depicts the initiative.

Fig. 6. DACUM initiative.

Skills Development in the EV Battery Sector

The development of specialized skills has directly contributed to advancements in battery technology and industry growth. Research indicates that the infusion of skilled professionals into the industry has accelerated innovation in battery materials and manufacturing processes. For instance, a study by Zhang et al. (2022) shows that regions with strong skills development programs experience higher rates of innovation and patent filings in the battery sector [14], [15]. This correlation is evident in Indonesia, where the establishment of NBRI has been associated with a notable increase in local R&D activities and partnerships with global companies [12], [13].

Theoretical frameworks on human capital suggest that investment in skills development leads to improved productivity and technological advancement [11], [14], [15]. According to Becker's theory of human capital, education and training enhance individual capabilities, which in turn contribute to organizational performance and economic growth [16]. The data from NBRI supports this theory, as increased skills and training have been linked to advancements in battery technology and a more competitive position in the global market [17].

Despite these successes, several challenges remain in fully realizing the potential of skills development programs. One major issue is the need for continuous curriculum updates to keep pace with rapidly evolving battery technologies. A study by Liu et al. (2021) highlights that skills requirements in the battery sector are dynamic, necessitating ongoing adjustments to training programs to address emerging technologies and industry trends [18]. Additionally, there is a need for greater collaboration between industry and academic institutions to ensure that training programs are aligned with real-world applications and future industry needs.

Opportunities for improvement include expanding training programs to cover advanced-

-topics such as solid-state batteries and emerging battery chemistries. According to Armand and Tarascon (2022), ongoing research in these areas requires a workforce with specialized skills and knowledge [19]. By incorporating these advanced topics into training curricula, NBRI can enhance its impact on the industry and support Indonesia's ambition to become a leading player in the global battery market.

Looking ahead, the NBRI's focus on integrating cutting-edge research with practical training is expected to yield further benefits. Continued investment in skills development, coupled with strategic partnerships and industry collaborations, will be crucial for sustaining growth and innovation in the EV battery sector. Theoretical perspectives on strategic human resource management suggest that aligning training programs with organizational goals and technological advancements will maximize their impact and effectiveness [20].

Future research should explore the long-term effects of skills development on career progression and industry competitiveness, as well as assess the impact of emerging technologies on training needs. By addressing these areas, NBRI can further refine its programs and contribute to the ongoing advancement of the battery sector.

Impact of Reskilling and Upskilling

Skills development has a profound impact on technological advancements within the EV battery industry. Training programs focused on advanced battery technologies, such as solid-state batteries and high-energy-density lithium-ion cells, have significantly contributed to technological innovations. For example, recent studies show that regions with robust skills development programs experience faster adoption of new technologies and higher rates of patenting in battery technologies [21].

In Indonesia, the integration of advanced training into the curriculum has led to several breakthroughs in battery materials and manufacturing processes. Data from NBRI indicates that local researchers and engineers have contributed to over 50 patents related to battery innovations in the past three years [22]. This influx of new technologies has not only improved the performance and safety of batteries but has also positioned Indonesia as a competitive player in the global battery market.

The development of specialized skills has been instrumental in driving growth and enhancing competitiveness within the EV battery sector. Skilled professionals contribute to various aspects of the industry, from R&D to manufacturing and quality control. A study by Zhang et al. (2022)-

-reveals that regions with strong skills development programs see a 15-20% increase in industry growth rates compared to those with less emphasis on training [23].

In the context of Indonesia, the expansion of training programs has led to the establishment of several new battery manufacturing facilities, increasing production capacity and attracting foreign investment. For instance, recent investments by global battery manufacturers in Indonesia have created over 2,000 new jobs in the battery sector and contributed to a 25% increase in the country's battery production capacity [24].

The skills development initiatives in the EV battery sector also align with broader sustainable development goals (SDGs). According to the United Nations, enhancing education and training in key industries supports SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation, and Infrastructure) [25].

In Indonesia, the focus on green jobs and sustainable practices within the battery industry has led to significant environmental and economic benefits. Research by Lee et al. (2021) indicates that investments in green jobs, including those in the battery sector, contribute to a reduction in carbon emissions and support the transition to a low-carbon economy [26]. The establishment of training programs that emphasize sustainable practices has helped integrate eco-friendly technologies and processes into local battery manufacturing, further supporting Indonesia's environmental goals.

While the positive impacts of skills development are evident, addressing ongoing skills gaps remains crucial for sustaining industry growth. Current research highlights that the rapid evolution of battery technologies creates a continuous need for updated training and upskilling [27]. For instance, emerging technologies such as solid-state batteries require specialized knowledge that is not yet widely available in existing training programs [28].

To address these needs, NBRI is expanding its training programs to include advanced topics and emerging technologies. This proactive approach aims to ensure that the workforce remains equipped to meet future industry demands and contribute to ongoing technological advancements. Additionally, partnerships with international research institutions and industry leaders are being established to provide access to cutting-edge knowledge and best practices [9].

Opportunities and Challenges

The EV battery industry faces a range of challenges that must be addressed to ensure its sustainable growth. One of the most pressing issues is the rapid pace of technological change, which necessitates continuous upskilling and reskilling of-

-the workforce. As new battery technologies and materials are developed, the skills required to design, manufacture, and maintain these systems evolve as well. This creates a demand for dynamic training programs that can quickly adapt to these changes. Furthermore, there is often a significant gap between the theoretical knowledge provided by academic institutions and the practical skills needed in the industry. This mismatch can result in a workforce that is not fully prepared to meet the complex demands of the EV battery sector, leading to inefficiencies and increased costs.

In addition to the skills gap, the industry is also challenged by the complexity of the global supply chain. The sourcing of critical raw materials, such as lithium, cobalt, and nickel, is often fraught with geopolitical risks and ethical concerns. Ensuring a stable and sustainable supply of these materials is essential for the industry's long-term viability. Moreover, the need to comply with international safety and environmental standards adds another layer of complexity. Companies must navigate a labyrinth of regulations and certifications to ensure their products are safe and environmentally friendly, which can be particularly challenging for new entrants and small to medium enterprises (SMEs) that may lack the resources to fully comply with these requirements.

Despite these challenges, the EV battery industry presents significant opportunities for growth and innovation. The global shift towards clean energy and the increasing adoption of electric vehicles have created a burgeoning demand for advanced battery technologies. This demand is expected to drive job creation and economic development, particularly in regions like Indonesia, where the government is actively promoting the growth of the EV industry. Indonesia's rich deposits of nickel and other key materials provide a strategic advantage, positioning the country as a potential leader in the global battery supply chain. By leveraging these natural resources, along with supportive government policies, Indonesia has the opportunity to build a strong domestic battery industry that can compete on the global stage.

Moreover, there is a significant opportunity for collaboration between industry, academia, and government to address the skills gap and develop a workforce that is well-equipped to meet the demands of the EV battery sector. Initiatives like the Renewable Energy Skills Development (RESD) program, which involves collaboration between the Ministry of Energy and Mineral Resources and international partners, are crucial for aligning educational curricula with industry needs. Such programs can ensure that graduates are ready to contribute to the industry from day one, reducing the training burden on companies and accelerating the-development of the sector. Additionally, by participating in international partnerships and standardization efforts, Indonesia can enhance its competitiveness and secure a strong position in the global EV battery market, turning challenges into opportunities for sustainable growth and leadership.

CONCLUSION

The National Battery Research Institute (NBRI) plays a pivotal role in advancing Indonesia's position in the global EV battery industry through its focus on skills development, research, and industry collaboration. By addressing the critical need for specialized training and education, NBRI is helping to bridge the gap between academic knowledge and industry demands, ensuring that Indonesia can develop a highly skilled workforce capable of driving innovation in battery technology. The institute's efforts in establishing competency standards and contributing to curriculum development further solidify its impact on the industry, positioning Indonesia as a competitive player in the global market.

However, the industry faces significant challenges, including the need for continuous skills upgrading and the complexity of the global supply chain. Despite these obstacles, there are substantial opportunities for growth, particularly in leveraging Indonesia's natural resources and strategic government initiatives. By fostering collaboration between academia, industry, and government, and by participating in international partnerships, Indonesia can overcome these challenges and emerge as a leader in the EV battery sector, contributing to global sustainability goals and driving economic development.

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AUTHOR CONTRIBUTION

M. W. S. Mubarok as a Manager of Education and Training and R. Yogandini as a Project Officer equally contributed as the main contributors of this paper. Meanwhile, E. Kartini and A. J. Drew are supervising the work. All authors read and approved the final version of the paper.

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