



P-ISSN: 1978-2853
E-ISSN: 2302-8890

MATRIK: JURNAL MANAJEMEN, STRATEGI BISNIS, DAN KEWIRAUSAHAAN

Homepage: <https://ejournal1.unud.ac.id/index.php/jmbk>

Vol. 20 No. 1, 2026 (February), 95-110



THE COMPETITIVENESS OF NATIONAL SOLAR MODULES IN THE RESIDENTIAL MARKET: PERSPECTIVE OF EPC COMPANIES

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DOI: <https://doi.org/10.2484/MATRIK:JMBK.2026.v20.p06>

ABSTRACT

Indonesia has substantial potential for solar energy development, supported by abundant silica sand, a key raw material for solar module production. However, solar energy adoption in the residential sector remains below national targets, despite this sector being the largest electricity consumer. Engineering, Procurement, and Construction (EPC) companies play a crucial role in selecting solar modules, whether national or imported. This study analyses EPC companies' perspectives on sourcing solar modules in the Indonesian residential market. Data obtained from experienced EPC professionals and analysed using the Analytic Hierarchy Process (AHP) using Expert Choice software. The results indicate that cost related considerations dominate procurement decisions. Although national solar modules show advantages in delivery reliability, they remain less competitive than imported products across most evaluation criteria. Strengthening research and development efforts and implementing effective cost reduction strategies are essential to improving the competitiveness of national solar modules.

Keywords: national; solar; modules; residential; criteria.

INTRODUCTION

The use of fossil fuels is becoming increasingly intensive due to the high reliance on limited reserves, which is inversely proportional to Indonesia's final energy consumption. Data review of the 2023 energy balances of Indonesia reveals that the overwhelming majority of the final energy consumption level is attributable to fossil fuels, with coal (34,83%), petroleum product (32,43%), gas (13,64%), natural gas (8,20%), and electricity include renewable energy source (15.56%) comprising the majority of this consumption (Central Bureau of Statistics of Indonesia, 2024). In parallel, the issue of converting energy from fossil fuels to renewable sources has attracted considerable attention. Indonesia has enormous solar energy potential, ranging from 3,300 to 20,000 Gigawatts (GW), making it one of the countries with the largest solar energy reserves in the world. However, the realisation of this potential remains very minimal.

One of the primary obstacles to greater solar energy utilisation is the continued high cost compared to fossil fuels. To analyse and assess the energy sector, the LCOE (Levelized Cost of Energy) provides an average cost of energy, enabling comparisons and supporting

decision-making in a financially viable manner (Emblemsvåg, 2025). In Indonesia, as in the rest of the world, the costs of renewable energy sources are considered high.

A study by the National Renewable Energy Laboratory confirms that Indonesia has the highest average LCOE among ASEAN member states at 165 USD/MWh, significantly lower than Burma's average of 79 USD/MWh. The levelized cost of electricity (LCOE) for renewable sources such as solar and wind in ASEAN countries like Malaysia and Thailand ranges from 59 to 98 USD/MWh. It is lower than the same number for Indonesia (Institute for Essential Services Reform, 2019); (National Renewable Energy Laboratory - United States Agency International Development, 2020). It shows that solar energy is still significantly more expensive to implement initially. Most of these costs (47%) are allocated to solar module costs (Dehghanimadvar et al., 2022). It is ironic to observe such low adoption of solar modules in Indonesia, given that the country has reserves of silica sand totaling 332,113 kilotons, the primary material used in solar module construction (Center for Mineral, Coal, and Geothermal Resources, 2021).

As most of Indonesia's electricity consumption comes from the residential sector (Secretariat General of the National Energy Council, 2023), the sector needs to adopt domestic solar modules as a step toward sustainable development. However, for solar modules, the Domestic Component Level (DCL) has not been fully realised due to issues related to product quality and economics. Therefore, it is important to understand the factors that influence the decisions made by Engineering, Procurement and Construction (EPC) companies. The EPC company performs project planning and design activities before construction commences. In the solar panel industry, the EPC role is to oversee the construction of both large and small-scale solar power plants.

National products are defined as items manufactured by businesses that operate and invest in Indonesia, even if they use imported components in their production. It is clear from these definitions that companies that invest in Indonesia must make domestic products there, meet DCL minimum standards of 25%, and allow both imported and domestic parts, as long as they are made and put together in Indonesia (Presidential Regulation of the Republic of Indonesia Number 46 of 2025 Concerning the Second Amendment to Presidential Regulation Number 16 of 2018 Concerning Government Procurement of Goods/Services, 2025). The source of each part comes after the DCL proportion and production site in Indonesian law. If a solar module meets the 25% DCL requirements, it can be considered a "domestic product," even if most of its parts come from other countries and the module is manufactured in Indonesia. Modules that do not contain any parts from the country where they were made are considered fully imported, regardless of where they come from. This difference is important for understanding EPC's buying strategy, which may include a mix of fully imported modules and modules made in the U.S. with varying levels of foreign content.

This study aims to identify discrepancies between domestic and foreign solar module products and their ability to meet the demands of the existing market. An improvement plan can be formulated for the national product, solar modules, by identifying these gaps. Most current research on renewable energy implementation in Indonesia has focused on macro level policy analysis and the effects of these policies on project viability. One such analysis examines the impact of fiscal policies on the feasibility of solar photovoltaic (PV) and wind projects in Indonesia; it shows that policy provisions such as tax holidays and tax allowances can most effectively reduce power costs (Halimatussadiah et al., 2023).

EPC firms decide whether to own the product. Similarly, even though the energy sector has started to implement what are considered to be innovative strategic frameworks for the management of green supply chains, using higher order soft-system thinking based approaches, the focus has been on the development of strategic frameworks to obtain and implement broader green management practices, as opposed to examining the competitive position of specific products at the operational procurement level (Dhumras & Bajaj, 2024). Furthermore, extensive techno economic evaluations of prospective residential rooftop photovoltaics have been undertaken; however, user centric analyses of self consumed electricity, within the context of end-user electricity self consumption, overlook supply-side procurement choices and fail to distinguish between domestic and imported solar PV modules (Saez et al., 2023).

All the research has pointed to the same significant gap: the absence of analysis connecting the EPC operational perspective to the competitive relationship between domestic and imported products in the residential solar market. The research on how EPC companies, important gatekeepers in the solar module supply chain, choose and purchase products made in the country versus those made abroad is limited. There is also no research on the standards and performance gaps that explain why national solar modules are not competitive in the Indonesian residential market. This gap is especially important because of the Indonesian government's ambitions for local manufacturing and renewable energy, as well as the Indonesian DCL legislation.

This research addresses existing gaps by, first, focusing on the EPC perspective to provide an understanding of procurement as the decisive linkage between manufacturers and end-users; second, addressing multi-criteria procurement decisions via the Analytic Hierarchy Process (AHP) to compare the procurement criteria within a rational framework; third, conducting a comprehensive competitive gap analysis in relation to the criteria and sub-criteria to identify specific performance gaps between domestic and imported solar modules; and forth, contributing to the achievement of energy independence for Indonesia by providing specific recommendations geared to improving the competitiveness of domestic products in the residential market. This study contributes to the understanding of the dynamics of procurement in the downstream energy transition in Indonesia. It provides EPC firms, manufacturers, and regulators with tools to foster national innovation.

METHODS

This research examines the competitiveness of solar modules in the residential market from the perspective of EPC enterprises, using a mixed methods approach that integrates qualitative and quantitative research methodologies (Fàbregues et al., 2024). This integrative technique is suitable due to the intricate nature of decision-making in procurement within the solar energy industry. The complexity arises from its technological, economic, supply chain, and strategic elements, which cannot be comprehended from a unique perspective. It provides both academically robust and pragmatically valuable evidence for stakeholders in the Indonesian residential solar photovoltaic sector.

The study uses an exploratory sequential design. Qualitative data are collected from semi structured interviews to create and confirm decision criteria, followed by the quantitative phase (Campbell et al., 2020). Research found that 25.6% of AHP publications in Scopus over the last 40 years have been focused on engineering (Madzik & Falát, 2022). The research commences with concurrent investigations conducted alongside a literature review and a field study. It closely examines current theoretical frameworks, methodologies, and empirical data

regarding the competitiveness of solar modules, the decision-making process involving multiple criteria, and the procurement of renewable energy-related products that align with these observations. Figure 1 illustrates the research process employs a systematic, multitiered framework to achieve both methodological and practical relevance. The systematic approach of this research is illustrated in the flowchart below.

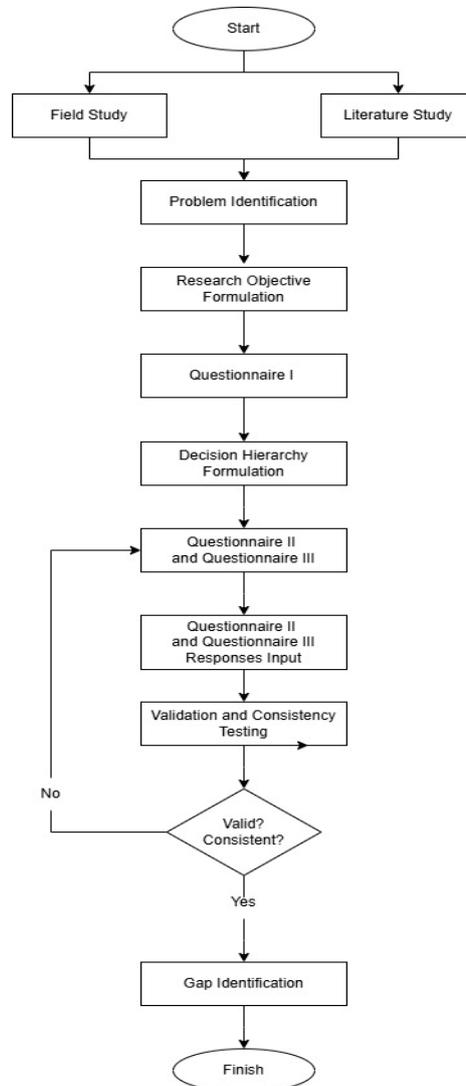


Figure 1. Research Flowchart

Source: Developed by authors, 2025

The study included ten experts from seven Indonesian solar EPC companies. The main solar PV markets in Indonesia, Java, Bali, and Kalimantan are enough for this study (Ministry of Energy and Minerals Indonesia, 2024, The Directorate General of New Renewable Energy and Energy Conservation, 2024). Companies that wanted to take part had to build more than 10 solar power plants with a total capacity exceeding 1 MW. According to AHP inquiry standards (Darko et al., 2019), companies that want to participate must have sufficient market experience and business operations to assess how competitive a module is. All responders are solar energy professionals with 4–20 years of experience in engineering and procurement roles,

whose companies supported the Ministry of Energy and Mineral Resources' Solar Power Initiative Movement Program. This experience range ensures the sample includes both new industry experts and seasoned experts with experience in historical market evolution. Standard AHP investigations require expert responses with topic knowledge for valid multi-criteria assessments (Darko et al., 2019). Table 1 presents the comprehensive profile of participating companies and respondents, demonstrating the sample's diversity across multiple dimensions.

Table 1. Participating Companies and Respondents

Company Code	Region	Firm Size (Employees)	Residential Market Focus	Respondents	Division (Experience)
EPC-1	Java	Medium (50-100)	High (>60%)	2	Engineering and Procurement (5-15 years)
EPC-2	Java	Large (>100)	Medium (40-60%)	1	Procurement (8 years)
EPC-3	Bali	Medium (50-100)	High (>60%)	1	Engineering (12 years)
EPC-4	Java	Large (>100)	Medium (40-60%)	2	Engineering and Procurement (5-18 years)
EPC-5	Kalimantan	Medium (50-100)	Low (40%)	1	Engineering (6 years)
EPC-6	Java	Large (>100)	High (>60%)	2	Engineering and Procurement (4-18 years)
EPC-7	Java	Medium (50-100)	Medium (40-60%)	1	Procurement (10 years)

Source: Data processed, 2025

The sample composition, with 57% medium-sized organizations and 43% large firms, matches Indonesia's EPC market, where medium and large sized firms play substantial roles in residential solar installations. The Solar Power Initiative Movement Program is being developed in Java (5 companies), Bali (1 company), and Kalimantan (1 company). These are the places with the most home solar installations. The sample contains both low (<40%) and high (>60%) specialization in the residential market, which yields different views on business strategies and approaches in the industry.

Questionnaire I is sent to the chosen expert, along with answers from the EPC firms participating. The goal of this semi-structured questionnaire is to gather information about customer preferences, common module specifications, and market trends. The interview questions were meant to be open-ended and cover the decision-making processes, the criteria for choosing modules, the competition between suppliers (advantages and disadvantages), and the experiences of performance brands (modules from both domestic and foreign manufacturers). Questionnaires II and III are used to assign weights to each listed criterion and sub-criterion. Saaty's basic scale, which ranges from 1 (equal importance) to 9 (extreme importance), is used for comparisons, as shown in Table 2. Saaty's Pairwise Comparison Scale (T. L. Saaty, 2001) (Salomon & Gomes, 2024).

Table 2. Saaty's Pairwise Comparison Scale

Scale	Compare Factor
1	Equal Significance
3	Moderately Significant
5	High Significance
7	Extremely Important
9	Extremely Important
2, 4, 6, 8	Values near the middle of the adjacent scale

Source: Data processed, 2025

This systematic comparison across all sub-criteria allows for multiple evaluations of alternative competitiveness. All respondent-derived pairwise comparison matrices undergo multiple consistency checks to ensure the logic and reliability of the judgments. The Consistency Ratio (CR), an AHP construct of Saaty that measures consistency and helps find paired preference contradictions (T. Saaty, 2008); (Kuo & Chen, 2023), is used to give credit to respondents' degree of consistency with a CR exceeding 0.10 indicates a logical inconsistency, necessitating adjustments to enhance the reliability of the prioritisation estimates (Tavana et al., 2023).

RESULT AND DISCUSSION

The National Energy Council's Secretariat General says that homes in Indonesia use more than 10.1 million Tons of Oil Equivalent (TOE) of energy every year (Secretariat General of the National Energy Council, 2023), making them the country's biggest power users. The need for so much energy is due to a growing population and more electrical appliances in homes, such as air conditioners, water pumps, washing machines, refrigerators, lighting systems, and electric stoves. People use energy in their homes less often and in smaller amounts than businesses and factories do, which is more predictable and focused. Table 3 shows the decision-making framework that EPC companies use to buy solar modules for homes.

Table 3. Criteria and Sub-Criteria in Sourcing Solar Modules

No	Criteria	Sub Criteria
1.	Product Quality	1. Module Efficiency
		2. Peak Wattage
		3. Product Innovation
2.	Cost	1. Solar Module Price
		2. Shipping Cost
3.	Customer Service	1. Product Availability
		2. Product Warranty
4.	Risk Management	1. On-Time Delivery
		2. After Sales Service
5.	Supplier Characteristics	1. Product Tier
		2. Supplier Relationship

Source: Data processed, 2025

The operational definitions of Table 3 are delineated as follows. Product Quality consists of module efficiency, cost, customer service, risk management, and supplier characteristics. Module efficiency denotes the conversion rate of solar irradiance to electrical energy (%), assessed under standard test conditions (1000 W/m², 25°C) (Demir et al., 2024); Peak Wattage signifies the highest possible power output under STC, expressed in watts peak (Wp); and Product Innovation pertains to the incorporation of advanced technologies and designs that improve performance or installation versatility. Cost includes solar module price indicates the unit cost per watt peak at the time of purchase, excluding shipping charges (Ishizaka & Mu, 2023). In contrast, Shipping Cost includes the total logistical expenses from the supplier's location to the designated site, or as a percentage of the module cost, covering freight charges, customs duties, and insurance. Customer Service includes product availability evaluates the supplier's capacity to meet order quantities within designated timeframes, measured by lead time (weeks) and historical order fulfilment rate (%) (Tavana et al., 2023). In contrast, Product Warranty delineates the period during which the product warranty covers manufacturing defects, and the performance warranty ensures that power output degradation remains within specified thresholds throughout the module's operational lifespan. Risk Management includes on-time delivery tells you what percentage of orders were delivered on time; after-sales service checks how well the supplier can handle problems that come up after delivery by looking at the time it takes to respond to claims, the percentage of warranty approvals, and the time it takes to send a replacement. Supplier characteristics refers to the classification system used by Bloomberg New Energy Finance (BNEF), a system called Product Tier to put manufacturers into three groups: Tier 1 (bankable producers with automated manufacturing processes and verified performance history), Tier 2 (established manufacturers with partial automation), or Tier 3 (smaller manufacturers or resellers) (BloombergNEF, 2025). Supplier Relationship, on the other hand, looks at how strong the relationship is and how well people work together to fix things.

In line with the definition of "Customer Service," the sub criteria "After-Sales Service" were deliberately placed under "Risk Management" rather than "Customer Service." There is a definite reason for this classification. Initially, within the solar module industry, after sales concerns primarily manifest as risk events, such as module defects, claims of performance degradation, and warranty disputes that constitute contingency situations rather than standard service operations (Shafiee & Chukova, 2013). Second, from the EPC company's perspective, the supplier's ability to address post-delivery issues directly influences project risk exposure. This differentiation aligns with the literature on supply chain risk management, in which post sales issue resolution is regarded as a risk mitigation strategy rather than a conventional service provision (Gatzert & Kosub, 2016).

Based on these operationalized criteria and sub-criteria, the decision hierarchy needs to be structured. This study applied AHP, integrating both national and imported solar modules into the analysis along with the relevant criteria and sub criteria. To make it easier to understand the problems, these will be put in a decision hierarchy (Tavana et al., 2023). The order of importance for making decisions is as follows: Level 0 is about what the study wants to learn, Level 1 is about the rules that will be used to reach those goals, and Level 2 is about the choices that have been made in the past for solar modules. Figure 2 correctly shows the decision hierarchy, listing the criteria and sub-criteria needed to select solar modules, as explained in detail in Table 3.

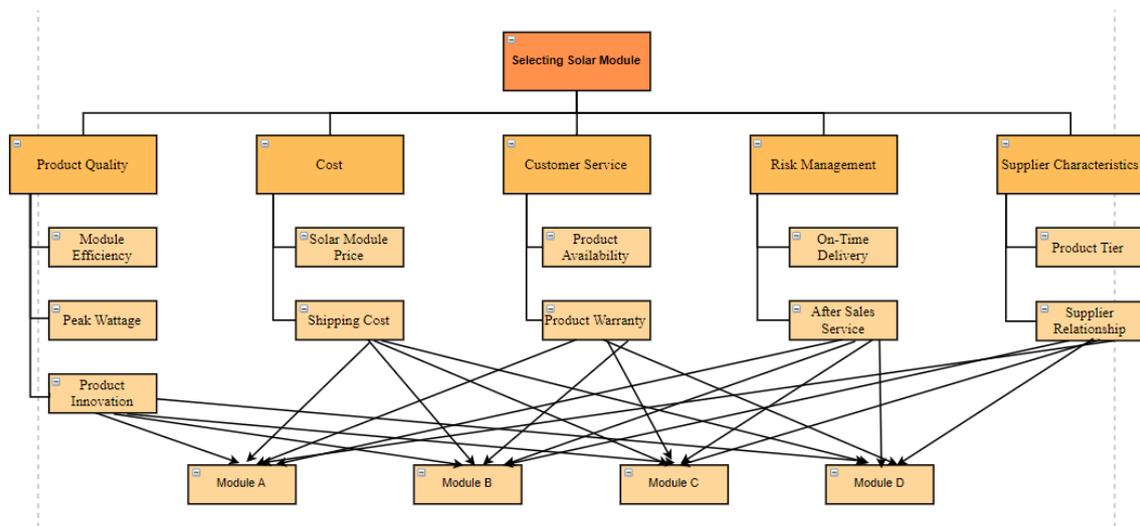


Figure 2. Decision Hierarchy

Source: Author, 2025

Table 4 shows the main parts of the solar panels that were studied. As per Presidential Regulation, 25% of the items in Module A must be produced in Indonesia. Modules B, C, and D, on the other hand, only have things that were made in other (Presidential Regulation of the Republic of Indonesia Number 46 of 2025 Concerning the Second Amendment to Presidential Regulation Number 16 of 2018 Concerning Government Procurement of Goods/Services, 2025). Brand names are kept secret to keep the study honest and stop bias from businesses.

Table 4. Attributes of the Solar Modules

Parameter	Module A (National)	Module B (Imported)	Module C (Imported)	Module D (Imported)
Peak Wattage (Wp)	400-450	500-550	520-570	500-540
Efficiency (%)	18.0-19.5	20.5-21.5	21.0-22.0	20.0-21.0
Warranty (Years)	10-12	12-15	15-25	12-15
Bloomberg Tier	Tier 2-3	Tier 1	Tier 1	Tier 1
Price (USD/ Wp)	0.20-0.25	0.18-0.22	0.19-0.23	0.18-0.22

Source: Market survey and EPC expert validation, 2025

Upon establishing the technical and commercial attributes of the assessed modules (Table 4), this study applies the AHP method to determine the weighted prioritisation of the selection criteria. To understand the weighted priorities in the Indonesian solar sector, one needs to understand the most influential factors in the supplier selection. Weights for the criteria and sub-criteria were derived from the second questionnaire, and the Expert Choice program was utilised to analyse and provide the final assessments. This popular decision-aiding method provides more detailed analysis of individual experts, greater efficiency in evaluating the consistency ratio of individual respondents, and reliable aggregation of expert opinions without losing significant data (Ishizaka & Mu, 2023). Weighted values were used to combine the opinions of experts from different EPC companies in order to get a sense of what a lot of people in the industry thought. This got rid of any bias that might have come from one person. Adding the CR to results with judgmental errors greater than 0.10 makes the prioritization more valuable and trustworthy (Tavana et al., 2023). All of the respondents' assessments in this study were consistent enough (CR < 0.10) to show that the experts'

assessments were logically sound and to build trust in the results. From the perspective of an EPC, the importance of each factor in the solar module supplier selection process is illustrated in Figures 3 and 4.

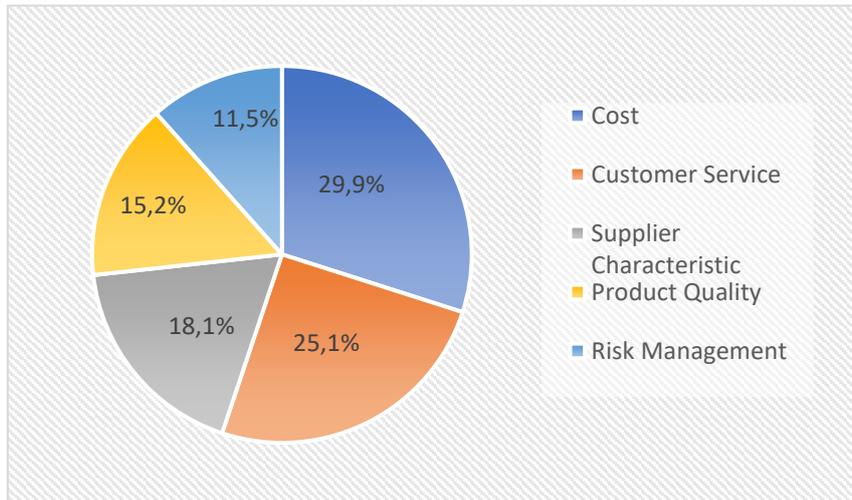


Figure 3. Criteria Weighting

Source: Author, 2025

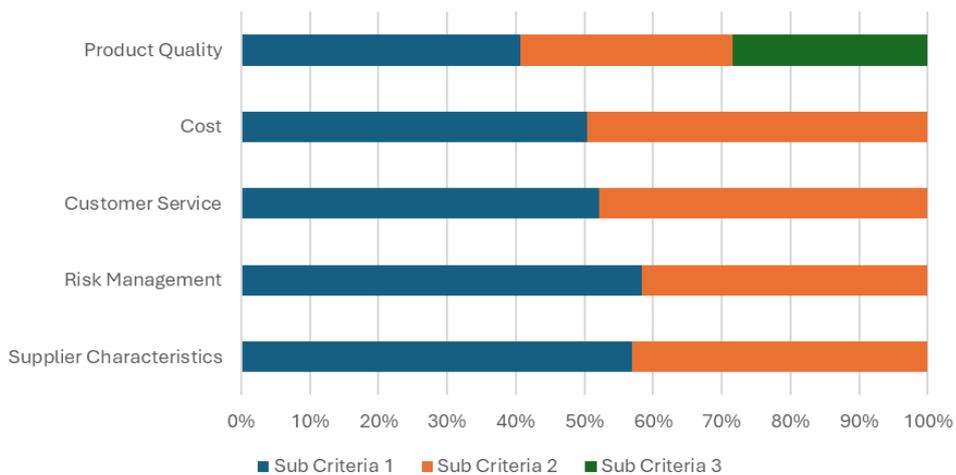


Figure 4. Sub-Criteria Weighting

Source: Author, 2025

Focusing on EPC procurement processes and the accompanying market conditions and economic factors, Figure 3 illustrates that cost is the primary and most weighted factor, followed by supplier, product quality, customer service, and risk. Price, shipping, and availability of the solar modules are the three most critical factors. In comparison, according to Figure 4, product innovation, peak wattage, and post sales service are the least priorities. At the same time, within each of these primary factors, there are sub criteria that EPCs must consider holistically to derive a performance metric spanning all evaluative dimensions. Overall prioritisation of any given criterion or sub criterion is insufficient to make effective sourcing decisions. In this analysis, the AHP method provides for a synthesis to offset this gap. Focused on imported versus locally manufactured modules, the weighted performance

priorities across all evaluative metrics allow for an unambiguous ranking of the different module options. This composite score reflects and facilitates the prioritisation of imported and domestic options. The combined findings are illustrated in Table 5, which, based on the collective expert opinion of Indonesian EPC specialists, provides a final module competitiveness rating.

Table 5. Overall Alternative Weighting

Module	Weight	Priority	Origin
Module A	0.129	IV	National
Module B	0.293	II	Imported
Module C	0.294	I	Imported
Module D	0.284	III	Imported

Source: Data processed, 2025

The table confirmed that Module A scored just 0.129 - less than half the weight of any imported alternative and placing it firmly in 4th the findings in Table 5 give a rather bleak outlook on the competitive status of national solar modules. The gap of 0.165 between the national module and the top imported module, Module C (0.294), is not just a statistical anomaly; it is an enormous gap (128%) that hinders Indonesia's aspirations for energy autonomy and DCL (Domestic Component Level) targets. Therefore, the conundrum for manufacturers, governments, and industry stakeholders is not whether a competitive gap exists; rather, it is about where this gap exists and which performance measures can be enhanced. You can use entity-weighted scores to do a gap identification study that turns metrics into useful information. Table 6 shows the differences in performance and lists the areas of competitive advantage that can be used to boost the use of national modules in the residential market. It also lists the areas of competitive disadvantage that need to be addressed right away.

Table 6. Gap Identification of National and Imported Solar Modules for Each Criterion and Sub-Criteria

Criteria	Module		Sub Criteria	Module	
	National	Imported		National	Imported
Product Quality	10%	34.6%	Module Efficiency	11.4%	34.6%
			Peak Wattage	8.5%	35.7%
			Product Innovation	9.8%	40.5%
Cost	14.2%	31.4%	Solar Module Price	10.6%	33.8%
			Shipping Cost	17.8%	31.5%
Customer Service	9.5%	32.5%	Product Availability	10.1%	30.6%
			Product Warranty	8.8%	36.4%
Risk Management	20.9%	28.7%	On-Time Delivery	28.8%	21.5%
			After Sales Service	9.8%	36.6%
			Tier Product	7.5%	33.5%
Supplier Characteristics	13%	34.7%	Supplier Relationship	20.2%	36.2%

Source: Author, 2026

Indonesia faces a significant challenge in acquiring solar energy, as evidenced by the comprehensive gap analysis in Table 6. Regarding Table 5, local items receive 12.9% of the procurement preference score for EPC companies that do not score highly on most evaluation criteria, despite the government DCL requiring solar modules to contain 25% local content.

From a quantitative perspective, based on four of the five primary criteria, national modules do not meet the standards of imported modules. Product Quality, Customer Service, Supplier Characteristics, and Cost each have a grade gap of 24.6, 24.0, 21.7, and 17.2 percentage points, respectively. Product Innovation has an even higher shortfall of 30.7 percentage points. The following gaps also stem from technology and service deficiencies: Peak Wattage (27.2), Product Warranty (27.6), and After Sales Service (26.8). These gaps also point to structural issues within domestic manufacturing that, within the defined constraints of policy mandates and price subsidies, may be addressed through coordinated development of R&D investment, quality infrastructure, and labour skill enhancement.

Module A's overall weight in Risk Management was affected by After Sales Services' relatively poor performance (9.8% vs. 36.6% for imported modules). The Expert Choice program shows how various modules integrate. In Product Quality (0.346) and Risk Management (0.287), Module B performs the best, while in Customer Service (0.325) and Supplier Characteristics (0.347), Module C performs the best. Module D has the highest cost (0.314). Of all the modules, Module C is the best, with a composite weight of 0.294, just ahead of Module B (0.293) and Module D (0.284). Module A lags behind at 0.129. Module C is superior until the weight is 34%, after which Module D takes the lead.

Sensitivity gap results of Software Expert Choice indicate that if Customer Service's weight drops below 19.3% (from second to third in importance), Module B would move ahead of Module C. Module B would perform better if the weight of Supplier Characteristics were lowered to 17.6% or less. Increasing Product Quality's weight to 17% or more is beneficial for Module B, but lowering it has a minimal effect. Lastly, if the weight of Risk Management is increased to 13.8% (in fourth place), Module B would be the most preferred. These sensitivity thresholds suggest that Module C has a narrow advantage with the current weighting systems. The competition with imported modules (B, C, D) is dynamic and context sensitive, whereas the competition with Module A is persistent, and the gap is large across priority-set configurations.

To improve the DCL, policymakers should strengthen local content rules to be more supportive and reduce the performance gaps. This discussion goes through each criterion in turn, highlights the main issues, benchmarks them against global best practices, and articulates associated policy and operational recommendations.

The primary reason Module A performs poorly in the Cost criterion, which carries the most weight in procurement decisions, is that its solar module price is not competitive with that of imports. The sensitivity analysis shows that a 21% price reduction for Module A will make it significantly more cost competitive and change purchasing dynamics. Most significant is that Module A's Watt Peak (Wp) capacity range is 400-450 Wp (Table 4), which is narrower than those of its competitors, leading to a cost-per-watt that is, on average, higher than that of competitor modules (500-570 Wp). This is, however, exacerbated by the disparity in how governments support their businesses in each target market. With extensive state support, including manufacturing incentives, soft credit financing, and export support, international suppliers of solar modules can sell their products at significantly lower prices. While Chinese competencies and Tier 1 technologies enable them to produce at the lowest cost in the market, their competitors are, in most instances, forced to adopt a more costly alternative (International Solar Energy Society (ISES), 2024).

Using new cell technologies to boost the peak power output of modules could boost efficiency from 18.0% to 19.5% to 21-22% (Green et al., 2023). To pay for growth, it's important to have soft loan programs, production grants, or tax breaks that make foreign

modules cheaper until domestic production is big enough. One example of an incentive is tax breaks for manufacturing equipment. In an efficient cost-competitiveness model, price, quality, and bankability are all connected in this way.

Constraints on production limit the ability to obtain sufficient quantities more than 300 kilotons of silica sand deposits available in Indonesia (Center for Mineral, Coal, and Geothermal Resources, 2021). In the next decade, global demand for EPC services is expected to increase significantly. For Indonesian producers, this supply gap presents opportunities to gain market share (Allied Market Research, 2025). Utilizing automation is expected to reduce the potential for human error and decrease labour costs by 45-60%, while increasing production levels by 300% (Ou et al., 2024). In Indonesia's residential market, competition will require domestic producers to implement modern manufacturing techniques and supply chain practices to meet the demand.

The global solar EPC market is envisaged to reach USD 1.2 trillion by 2034 (Allied Market Research, 2025), offering lucrative prospects for Indonesian manufacturers if they can remain competitive on pricing. Indonesia's manufacturers and local EPC firms must collaborate to secure additional market share and elevate the DCL to over 25% in the region. Given the government's emphasis on domestic manufacturing (Presidential Regulation of the Republic of Indonesia Number 46 of 2025 Concerning the Second Amendment to Presidential Regulation Number 16 of 2018 Concerning Government Procurement of Goods/Services, 2025), such collaboration will enable manufacturers and EPC firms to sell more solar modules in Indonesia, thus enhancing the country's competitiveness in the regional renewable energy market.

Indonesian solar manufacturers must advance their technology to compete with imported tier-1 modules in the residential market. Module efficiency is a critical factor in determining the level of technological advancement (Tyagi et al., 2013). For Indonesian businesses to achieve this, a significant emphasis on research and development is crucial, especially to reduce costs as research increases (Emblemsvåg, 2025). In this regard, Indonesian manufacturers need to collaborate with foreign counterparts to bridge this technological divide.

Buying national products has the advantage of being less of a concern for delivery times, as these products are made in Indonesia. Given this factor, solar module manufacturers in Indonesia need to enhance their after-sales service. Areas of after-sales service that need improving are technical support, customer satisfaction, customer service training, and repair job quality. Residential producers in Indonesia need to build lasting relationships with their customers to gain enduring support for their products. Fiscal incentives heavily influence the viability of solar PV projects in Indonesia, underscoring the need for in-depth policy impact evaluation to manage risks in these projects (Halimatussadiyah et al., 2023).

These changes will likely make Indonesian EPC companies more willing to sell national solar modules for homes, thereby helping the government achieve its renewable energy objectives. Indonesia's residential business is growing because of better service, working with EPC providers to automate and work together, and international cooperation on technology. These changes help Indonesian producers compete better with foreign goods, raise the domestic component level of products to over 25% DCL, make the country more energy self-sufficient, and help the country switch to renewable energy while using its silica sand reserves.

CONCLUSIONS

This study fills a major gap in our understanding of how national and imported solar modules compete in Indonesia's residential market by examining the issue from an EPC centric perspective. The research employs the Analytic Hierarchy Process (AHP) methodology, engaging 10 experts from 7 prominent EPC companies, to systematically quantify procurement decision criteria and pinpoint specific performance deficiencies that impact the competitiveness of national modules. The results show that cost is the most important factor (with the most weight), followed by supplier characteristics, product quality, customer service, and risk management. In terms of sub criteria, the three most important factors in procurement decisions are the price of solar modules, shipping costs, and product availability. The competitive gap analysis shows that Module A (national) only gets 12.9% of the procurement preference weight. In comparison, imported modules B, C, and D achieve between 0.284 and 0.294, representing a 128% performance deficit compared to the top-ranked module. National modules do poorly across four of the five main criteria. The biggest problems are with Product Quality (24.6 percentage points), Customer Service (24.0 percentage points), Supplier Characteristics (21.7 percentage points), and Cost (17.2 percentage points). Product Innovation has the biggest difference between sub criteria (30.7 percentage points), followed by Peak Wattage (27.2 points), Product Warranty (27.6 points), and After Sales Service (26.8 points). These gaps in technology and services show that domestic manufacturing is not up to par, and they cannot be fixed just by lowering prices or making rules. The analysis also finds a strategic competitive advantage: national modules are much better at On Time Delivery (28.8% vs. 21.5%), indicating that being close to where products are made gives EPC companies real operational benefits. This finding indicates that strategic positioning focused on supply chain resilience and delivery certainty may mitigate technical performance deficiencies, especially in residential projects where installation schedules are paramount.

The study proposes a comprehensive improvement framework comprising five strategic areas based on these findings. To stay competitive on price, suggestions include using advanced cell technologies to increase the Watt Peak output of modules, switching to manufacturing models that focus on assembly to cut capital costs, and using targeted policy interventions like soft loan programs and production subsidies that are set to make up for the cost difference with imported modules. To improve product quality, it is important to invest more in research and development, make it easier for companies to share technology, and establish quality certification programs that meet international Tier 1 standards. To improve customer service, manufacturing must be automated to produce more products and ensure they are always available. To improve supplier characteristics, EPC companies, manufacturers, and developers need to work together within ecosystems that enhance efficiency and build market trust. Finally, to improve risk management, there needs to be a professional after sales service system and clear channels for customers to communicate. The main problem with this study is that it examines only seven EPC companies in the Java, Bali, and Kalimantan areas that are part of the Solar Power Initiative Movement Program. Even though these companies are major players in the industry and do many residential solar installations, the results can't be used to make generalisations about all Indonesian EPC companies or about the commercial and industrial market segments, which may have different procurement priorities. The study also examines competitiveness at a single point in time (2025–2026), but solar technology and market dynamics change quickly, potentially altering the weights of the criteria and the

performance gaps over time. Subsequent research should broaden the sample to include EPC companies from all Indonesian regions and market segments to improve generalizability. Longitudinal studies monitoring the progression of competitiveness as national manufacturers adopt enhancement strategies would yield significant insights into the efficacy of interventions. Additionally, examining the perspectives of end-users (residential consumers) alongside those of EPCs may uncover additional determinants of adoption decisions. From a policy standpoint, forthcoming research should quantitatively assess the effects of specific interventions, including R&D subsidy levels, reductions in soft loan interest rates, and demand aggregation mechanisms, on bridging identified performance gaps would facilitate evidence-based policy formulation that redefines Domestic Component Level (DCL) compliance from a regulatory requirement into a substantive competitive advantage that bolsters Indonesia's energy independence goals.

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