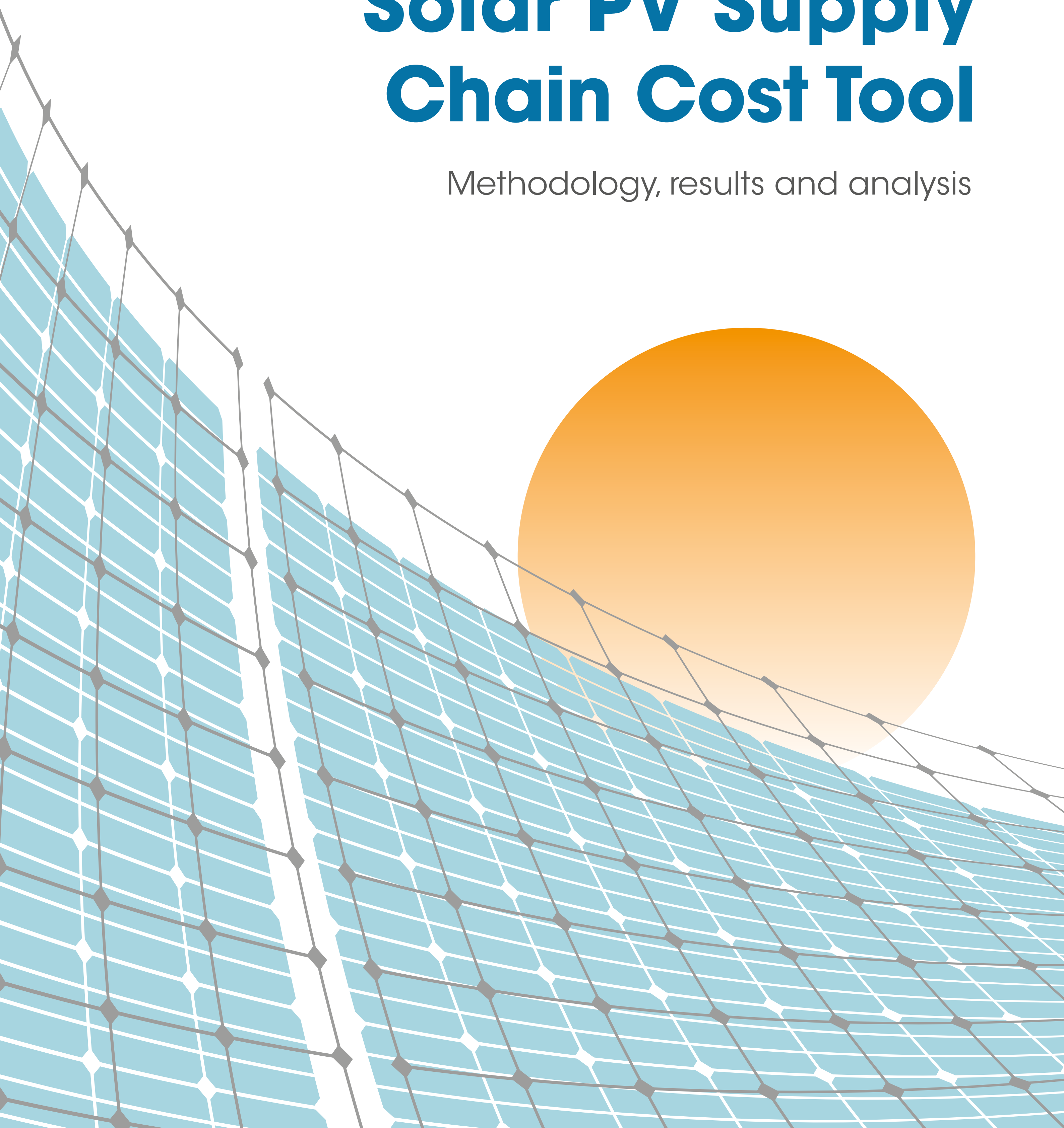
Solar PV Supply Chain Cost Tool

Methodology, results and analysis



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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. www.irena.org

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ABOUT THIS DOCUMENT

This document presents a comprehensive methodology for assessing the cost of all the stages of the solar PV supply chain. It includes the calculations, assumptions, overall methodology and sources used for the data and analysis. The objective of this report is to provide an overview for users on how to apply the tool.

Methodology and approach

The methodology follows a structured framework comprising data collection, calculations and analysis. The calculations are based on industry-standard formulas, adjusted where necessary to reflect country specific context and project boundaries. Assumptions were made due to data limitation and they are documented to inform on their potential impact on the outcomes.

Data and sources

All data used in this document come from credible and verifiable sources, including research and academic papers, peer-reviewed expert insights, industry reports and articles. Data represent current market trends. A detailed list of sources is provided in Section 7. Where proprietary or estimated data are used, the data source is also documented.

Results and interpretation

Key results are presented in both numerical and visual formats (charts, tables or dashboards). These outputs are meant to support decision-making by offering clear insights into the different proposed scenarios in the tool. A summary of findings is included, highlighting trends, sensitivities and actionable insights derived from the analysis.*

Guidance for using this tool

This document supports an accompanying cost tool (spreadsheet tool and interactive results visualisation dashboard). Users should:

- Review the assumptions before inputting data.
- Understand the scope and limitations of the tool.
- Use the results as directional insights rather than absolute predictions.
- Refer to the analysis and constrains to assess the results.

By following the guidance and reviewing the assumptions and methods carefully, users will be better positioned to analyse the results accurately and apply them effectively in strategic or operational contexts.

* The performance of the tool is determined by the underlying assumptions.

CONTENTS

FIGURES

TABLES

BOXES

ABREVIATIONS

APVI	Australian PV Institute
CEM	Clean Energy Ministerial
DDP	delivered duty-paid
ESG	environmental, social and governance
FCL	full container load
g	gramme
GW	gigawatt
kg	kilogramme
kWh	kilowatt hour
kWp	kilowatt peak
LCOP	levelised cost of production
mm	millimetre
m²	square metre
µm	micrometre
NREL	National Renewable Energy Laboratory
PERC	passivated emitter and rear cell
PV	photovoltaic
R&D	research and development
TOP	Con tunnel oxide passivated contact
TSSC	Transforming Solar Supply Chains
W	watt
Wp	watt peak

1. Introduction

IRENA supports the Clean Energy Ministerial (CEM) Transforming Solar Supply Chains (TSSC) workstream. The TSSC was launched in September 2022 at the CEM in Pittsburgh to foster the adoption of policies that transform the global solar supply chain to be more diverse, transparent and environmentally and socially responsible.

Recently, many countries and private actors in the solar sector have been engaged in developing local PV supply chain capacity. In Australia, for example, the government is actively working to reduce manufacturing costs through a set of policies aimed at promoting domestic production and diversifying solar PV supply chains in the region. These national initiatives highlight the importance of understanding the economic and technical factors that underpin competitive PV manufacturing. To support such policy and investment decisions, the objective of this workstream is to assist public and private actors in different countries by providing a tool that covers every element of production: polysilicon, wafers, cells and module assembly. The deliverable is an Excel-based cost tool that covers the crystalline silicon value chain from polysilicon to module assembly. The tool's architecture enables scenario-based analysis reflecting different production and market conditions, providing a data-driven foundation for industrial and energy policy. It is a decision support tool designed to provide CEM members with quantitative intelligence on the drivers of manufacturing cost competitiveness.

The outcomes of this analysis can act as guidance for regional industry investment and policy development to effectively leverage the diversification of the PV supply chain.

2. Overall approach

A spreadsheet-based tool was developed to estimate country-specific solar PV total module costs (USD per watt peak [Wp]) through to 2030 based on a benchmark of existing models to determine the parameters and calculations to be considered.

The cost components in the tool were based on assumptions and inputs used by the Australian PV Association.[1] The calculation methodology derives from the open-source Detailed Cost Analysis Model (DCAM) developed by the National Renewable Energy Laboratory (NREL),[2] using a simplified approach for the parameters selected due to the lack of data availability for certain specific parameters.

The key features and scope of the tool are as follows:

- **Value chain coverage:** The tool encompasses the crystalline silicon value chain, including polysilicon, wafer and cell manufacturing and final module assembly stages. Each step of the value chain has physical and economic indicators considering process, manufacturing and technological improvements (factoring in economies of scale) through to 2030.
- **Global geographic scope:** It provides a comparative analysis of key manufacturing markets (United States, Germany, China, India, Viet Nam and Australia) across leading process technologies (monocrystalline passivated emitter and rear cell [PERC] and tunnel oxide passivated contact [TOPCon] cell). The focus on selected countries aimed to achieve robust insights and country-specific data. The data have been collected from secondary sources (reports, articles and news) and confirmed with stakeholders (industry and research institutions).
- **Technology scope:** The scope of the tool is the currently dominant PV technologies, with an emphasis on the dominant cell types within the five-year time frame. Cost calculations are made for monocrystalline PERC and TOPCon cell, which are the major technologies present in the market.
- **Scenario and landed cost analysis:** The tool enables scenario analysis, allowing users to calculate the final landed cost (USD/Wp) by incorporating:
    - The impact of tariffs and logistics.
    - Distinct supply chain configurations (*e.g.* domestic vs. imported components).
    - Sensitivity analysis for environmental, social and governance (ESG) costs.
- **Forecasting methodology:** Cost projections to 2030 are derived from a combination of technology improvement roadmaps and manufacturing learning curves that are tied to projected capacity growth.

The tool has location-agnostic and location-dependent inputs. This allows users to input specific data for the location-dependent parameters, while the location-agnostic parameters are general assumptions from the PV supply chain market (Table 1).

1 *This refers to Solar PV Supply Chain and Australia's Bottom Up Cost Model – a Techno-Economic Analysis, developed by the APVI and available at https://apvi.org.au/wp-content/uploads/2024/01/Vaqueiro-S2S-APSRC.pdf.*

2 *This refers the Detailed Cost Analysis Model (DCAM) developed by NREL and DOE, available at Detailed Cost Analysis Model (DCAM).*

Table 1 Selected inputs for each supply chain component

Location-agnostic inputs	Location-dependent inputs
Electricity consumption for a given manufacturing tool or process (kWh/kg for polysilicon and kWh/unit for wafers, cells and modules).	**Average electricity price for Industry** (USD/kWh) is the cost of purchasing electricity for the manufacturing facility.
Building and facility costs refer to expenses associated with constructing, maintaining, operating, and improving a physical building or facility (USD/kg for polysilicon and USD/kWp for wafer, cells and modules).	**Average salary** (USD/year) is the salary per year for a full-time employee working in the manufacturing facility.
Lifetime of facilities and building (years) is the period of time that the facility will be used to produce the PV components.	**Price of material** (USD/kg for polysilicon and USD/unit for wafers, cells and modules) is the expenses incurred in purchasing the material used to produce the components.
Average number of workers needed (per tonne for polysilicon and per GW for wafers, cells and modules) at the production site for each specific component of the PV supply chain.	**Production capacity** (tonne for polysilicon and GW for wafers, cells and modules) is the maximum annual output of components to be produced in the facility.
Maintenance cost (%) is the expenses incurred to maintain the facility and equipment functioning in good condition.	**Equipment cost** (kWh/kg for polysilicon and kWh/kWp for wafers, cells and modules) is the expenses incurred to acquire, install and maintain the equipment.
Quantity of materials needed for each component production (kg/unit for wafers, cells and modules).	**Tariff** (USD/Wp) is a tax imposed by a country on the imported component.
Equipment lifetime (years) is the period of time that the equipment operates before it needs to be refurbished or replaced.	**Shipment cost** (USD/Wp) is the cost incurred in shipping the component from the factory to the buyer's location.
Overheads (%) are indirect business costs that support overall operations and sales.	

Notes: GW = gigawatt; kg = kilogramme; kWh = kilowatt hour; kWp = kilowatt peak. Water consumption is considered under building and facilities costs, while waste treatment is not incorporated in the tool, as it has a minimal impact on overall costs and the focus remains on key cost drivers.

2.1 Methodological cost tool framework

The cost tool is built with assumptions data, country-specific data and cost projections through to 2030 with outputs being the total module costs. Figure 1 illustrates the overall workflow of the cost tool, showing how inputs and assumptions are processed through calculations to generate outputs.

The tool includes **Assumption** and **Input** values. The key difference between them is that assumptions represent fixed underlying conditions essential for calculations, while inputs are user-defined values that can be adjusted based on different scenarios.

The tool provides users with three output options:

- Module production cost (EXW) – This is the total factory gate cost, which includes all direct production manufacturing costs, including overheads, and profit.

- Landed cost – This represents the final delivered module price as delivered duty-paid (DDP). The DDP price includes all costs the seller pays to deliver the goods to the buyer's location, such as shipping, insurance and tariffs. The DDP price aligns with the landed cost, covering all expenses up to the point of delivery. This is considered in all components of the value chain depending on import scenarios.

- ESG-compliant landed cost – This is where the cost of ESG-related certification is incorporated into the landed cost.

Figure 1 Overall cost tool workflow

Exogenous parameters & assumptions	User-editable inputs	Cost projection 2025-2030	Output
Electricity consumption System lifetime Conversion efficiency Maintenance Wafer dimension Material consumption	Electricity price Labour cost Equipment cost Total building & facilities costs	Module cost projections until 2030, based on technology improvement roadmaps and manufacturing learning curves tied to capacity growth.	**Module production cost (EXW) – the factory gate cost, overheads and profit** **Landed cost includes ex-works plus tariffs and logistics to the port of entry** **ESG-compliant landed cost**

2.2 Module technologies

The module includes specific inputs for the type of technology of the user's interest, which will affect the final total module cost. Monocrystalline and TOPCon are the two technologies considered because they are predominant in the market. Monocrystalline technology has become the dominant choice in crystalline silicon (c-Si) production, while multicrystalline technology is being phased out (Fraunhofer ISE, 2024). Other advanced technologies such as PERC, heterojunction technology (HJT) and hybrid passivated back contact (HPBC) have their own advantages; however, TOPCon's superior performance makes it the preferred choice for large-scale solar installations. A significant increase in TOPCon's market share is projected, rising from 23% in 2023 to 86% by 2028 (Solar, 2024).

Next-generation solar technology, particularly perovskite-silicon tandem cells and modules, are rapidly advancing from pilot to commercial scale manufacturing, with higher efficiency surpassing the limits of established technologies like TOPCon and PERC. Driven by breakthroughs in stability, cost reductions and flexible formats, these high-efficiency architectures have the potential to become market leaders in PV technologies by 2030 and beyond, as they overcome current manufacturing scale and durability challenges (Foehringer Merchant, 2024).

Both monocrystalline and TOPCon technologies have different manufacturing processes and technical specifications that lead to different production costs. When comparing technology efficiency, monocrystalline cells are less efficient, reaching a rate of 21.6% (Fraunhofer ISE, 2024), while TOPCon cells reach higher values of 23.2% (ITRPV, 2025). In terms of cost, monocrystalline cells are between 10% and 15% lower due to less complex manufacturing processes. TOPCon cells incur higher upfront costs due to the complexity of the manufacturing process and additional materials required to produce the thin-film layers.

2.3 Calculations and key assumptions for each supply chain component

This section details the calculations and formulas used to build and support the tool. It includes the definitions of parameters and step-by-step processes employed to derive the outputs. Each component of the tool is broken down to show how input variables are transformed through equations. References to standard formulas, assumptions and units are provided as well.

The calculation parameters used in the tool were selected for being the primary cost drivers, ensuring that the tool accurately reflects the most significant factors influencing overall cost. This approach allows for a more focused and realistic representation of cost behaviour, aligning the tool's structure with the key elements that drive expenditure.

Table 2 presents the selected parameters that are the most relevant and have a major impact on costs in PV manufacturing.

Table 2 Main parameters for polysilicon, wafers, cells and modules

Parameters	Unit
Overheads	%
Electricity consumption	kWh/kg for polysilicon and kWh/unit for wafer, cell and module
Building and facilities	USD/kg for polysilicon and USD/kWp for wafer, cell and module
Equipment costs	USD/kg for polysilicon and USD/kWp for wafer, cell and module
Maintenance	%
Labour	Number of workers per tonne for polysilicon and per GW for wafer, cell and module
Material	USD/kg for polysilicon and USD/unit for wafer, cell and module
Other material	USD/kg for polysilicon and USD/unit for wafer, cell and module

Notes: kg = kilogramme; kWp = kilowatt peak; USD = United States dollar.

The formulas used are as follows:

Overheads account for 10% of revenues, comprising research and development (R&D) expenses, selling, general and administrative (SG&A) expenses and net profit. The number of units sold is assumed to be 90% of the production volume, accounting for unsold stock, damaged items and other potential losses. The price per unit is determined by adding to the total costs a 15% operating profit margin.

$$\text{Overheads} = \frac{\textit{Number of units sold} \times \textit{Price per unit}}{\textit{Production volume}} \times 0.10$$

Electricity costs refer to the total expenditure on electricity in kWh/unit required by manufacturers to produce a specific unit of product within the PV value chain. It refers to the manufacturing process – specifically the amount of electricity required to produce one unit of polysilicon, wafer, cell or module (each of these being one segment), depending on production stage.

$$\text{Electricity costs} = \textit{Electricity needed for a segment unit} \times \textit{country-specific electricity price}$$

Building and facilities costs are calculated according to the straight-line depreciation method and refer to the systematic allocation of the initial cost of buildings and facilities (minus any expected salvage value, which usually varies from 0 to 10% of total costs) over their estimated useful life. Years of utilisation vary between the components, and assumptions are described in Section 2.4.

$$\text{Building and facilities costs} = \frac{\textit{Total building and facilities costs}}{\textit{Years of utilisation}}$$

Equipment costs refer to the systematic allocation of the initial cost of all equipment (minus any expected salvage value, which typically ranges from 0 to 10% of the total cost) over the equipment's estimated useful life.

$$\text{Equipment costs} = \frac{\textit{Equipment costs}}{\textit{Years of utilisation}}$$

Maintenance expenses are calculated as a percentage of the sum of equipment costs and total building and facilities costs, assumed that to be 4% of CAPEX, based on NREL data.

$$\text{Maintenance} = 4\% \times (\textit{equipment costs} + \textit{total building and facilities costs})$$

Labour costs refer to the total expenditure on workforce-related expenses incurred by manufacturers to produce a specific unit of product within the PV value chain. These costs are calculated based on the number of workers required and their average yearly salaries.

$$\textit{Labour costs} = \frac{\textit{Total number of workers needed} \times \textit{average annual salary}}{\textit{Total capacity}}$$

Material costs refer to the total expenditure on materials required to produce a specific unit of product within the PV value chain (USD/kg for polysilicon and USD/Wp for wafer, cell and module). This cost is calculated by multiplying the quantity of each material needed by its respective price.

$$Materials = material\ needed\ for\ production \times price$$

Operating profit refers to the profit made by the company from the manufacturing production, assumed to be 15% of the final cost, based on NREL data. The unit is USD/Wp.

$$Operating\ profit = 15\%\ of\ final\ cost$$

Final price is determined by summing all individual cost components included in the tool. The unit is USD/Wp. These components represent the various direct and indirect expenses associated with the product or service and are the following:

- Overheads
- Electricity
- Building and facilities
- Equipment depreciation
- Maintenance
- Labour
- Materials
- ESG certification
- Operating profit.

3. Data

3.1 Key assumptions for each supply chain component

This section presents the key assumptions applied to each component of the supply chain; these are inherent data, meaning that users are not able to change the assumptions in the tool. They refer to the location-agnostic parameters, reflecting trends in the current manufacturing of both technologies – TOPCon and monocrystalline modules – and are the same for all countries considered in the tool. The data can be visualised under the tab "Assumptions" in the Excel tool.

3.1.1 Polysilicon

Table 3 presents the key assumptions for polysilicon production for each technology. The conversion rate of polysilicon expressed in g/W is different between TOPCon and monocrystalline technologies due to the higher efficiency of TOPCon, leading to more watts produced for each gram of silicon.

Table 3 Key assumptions for polysilicon costs

Parameters	Unit	TOPCon	Monocrystalline	Source
Electricity consumption	kWh/kg	40	40	PV Magazine and Shaw, 2024
Equipment lifetime	years	10	10	NREL, 2025
Lifetime of building and facilities	years	20	20	NREL, 2025
Maintenance	% of CAPEX	4	4	NREL, 2025
Labour required	number of workers per kg	0.000021	0.000021	IRENA calculations
Materials (silicon metal)	USD/kg	1.7	1.7	NREL, 2025
Conversion rate for polysilicon material	%	1.26	1.26	NREL, 2025
Conversion rate	g/W	2.1	1.9	Solar Panel, 2023
Overheads	%	0.1	0.1	NREL, 2025
Metal silicon price in China	USD/kg	1.7	1.7	Business Analytiq, 2025
Other material	USD/kg	1.2	1.2	NREL, 2025

Notes: CAPEX = capital expenditure; g = gramme; kg = kilogramme; USD - United States dollar; W = watt.

3.1.2 Wafers and ingots

Table 4 presents the key assumptions for the costs of the most common 182 millimetre (mm) wafers and 247 mm diameter ingots. For TOPCon, the G12R wafer (182 × 210 mm) was used, whereas for monocrystalline, the M10 wafer (182 × 182 mm) was used. The difference in wafer dimensions results in variations in both wafer area and thickness for each technology. The distinction between TOPCon and monocrystalline modules is also influenced by variations in electricity consumption and the use of other materials during production.

Table 4 Key assumptions for wafer and ingot costs

Parameters	Unit	TOPCon	Monocrystalline	Source
Wafer area	m^2	0.03822	0.033124	ITRPV, 2025
Wafer thickness	µm	130	145	ITRPV, 2025
Lifetime of equipment	years	7	7	NREL, 2025
Lifetime of building and facilities	years	20	20	NREL, 2025
Maintenance	% of CAPEX	4	4	NREL, 2025
Electricity consumption	kWh/wafer	0.9	0.81	NREL, 2025
Other materials	USD/Wp	0.077	0.0693	NREL, 2025
Overheads	%	0.1	0.1	NREL, 2025
Labour	number of workers per W	0.000000215	0.000000215	IRENA calculations
Irradiance	W/m^2	1000	1000	IRENA calculations

Notes: CAPEX = capital expenditure; kWh = kilowatt hours; m^2 = square metre; µm = micrometre; W = watt; Wp = watt peak.

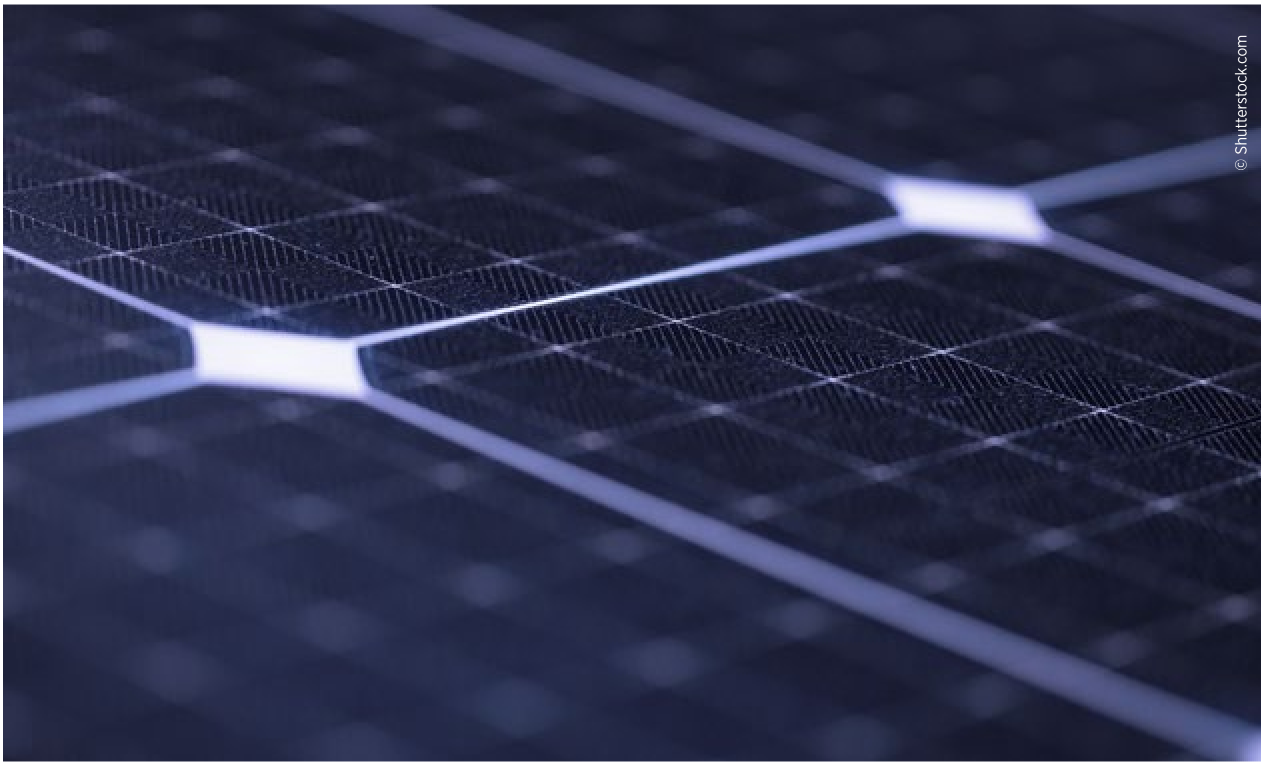
3.1.3 Solar cells

Table 5 presents the key assumptions for the manufacturing of TOPCon and monocrystalline solar cells. The primary difference between these solar cell technologies lies in the electricity consumed during manufacturing, with monocrystalline cells requiring less energy due to their simpler production process and fewer high-temperature processing steps.

Table 5 Key assumptions for solar cell costs

Parameters	Unit	TOPCon	Monocrystalline	Source
Lifetime of equipment	years	5	5	NREL, 2025
Lifetime of building and facilities	years	20	20	NREL, 2025
Maintenance	% of CAPEX	4	4	NREL, 2025
Electricity consumption	kWh/wafer	0.056	0.0504	CMPE, 2025
Silver price	USD/kg	853	853	ITRPV, 2025
Overheads	%	0.1	0.1	NREL, 2025
Labour	number of workers per W	0.000000215	0.000000215	IRENA calculations

Notes: CAPEX = capital expenditure; kg = kilogramme; kWh = kilowatt hours; W = watt.



3.1.4 Solar PV modules

Table 6 presents the key assumptions for the manufacturing of TOPCon and monocrystalline solar modules. Standard monocrystalline solar cells, such as PERC, use a simpler layer structure that includes high-purity silicon wafers, aluminium frames, tempered glass, ethylene-vinyl acetate encapsulants and small amounts of silver in metallisation. Unlike TOPCon technology, they do not require advanced layers or specialised materials, making their components more affordable. The overall lower material cost is due to fewer specialised inputs and a less complex manufacturing process.

Table 6 Key assumptions for PV module costs

Parameters	Unit	TOPCon	Monocrystalline	Source
Lifetime of equipment	Years	5	5	NREL, 2025
Lifetime of building and facilities	Years	20	20	NREL, 2025
Maintenance	% of CAPEX	4	4	NREL, 2025
Electricity consumption	kWh/module	0.025	0.025	IEA PVPS, 2025
Other materials	USD/Wp	0.057	0.0513	NREL, 2025
Overheads	%	0.1	0.1	NREL, 2025
Labour	number of workers per W	0.000000264	0.000000264	IRENA calculations
ESG certification	USD/W	0.0006	0.0006	IRENA calculations

Notes: CAPEX = capital expenditure; kWh = kilowatt hours; m^2 = square metre; USD = United States dollar; W = watt; Wp = watt peak; ESG certification includes initial costs and maintenance.

As **ESG certification** becomes increasingly important for PV manufacturing, the tool has an optional parameter to incorporate the cost of certification into the modelling. The certification costs typically involve:

- Initial assessment
- Implementation of ESG practices
- Documentation and reporting
- Third-party verification.

While the exact figures are difficult to provide without specific company details, a general range is used:

- Small to medium-sized manufacturers (under 2-3 GW): USD 10 000-50 000
- Large manufacturers (from 3 GW): USD 50 000-200 000
- Ongoing costs: annual maintenance and re-certification fees: USD 5 000-50 000.

The tool assumes a fixed value, indicated in Table 6, considering a production facility of 5 GW capacity. Based on consultations with ESG certification stakeholders, cost variations between countries are minimal; therefore, the tool assumes uniform costs across all selected countries.

3.2 User-editable inputs

This section presents the user-editable inputs for each component of the supply chain. Unlike the fixed assumptions, location-dependent inputs can be modified by the user. The tool uses a country-specific index as a default value based on the location where the module is manufactured. However, the tool gives the user the flexibility to input values if they have a preference to override the tool's default values. Data are available for the following major markets: Australia, China, India, Germany, Viet Nam and the United States (See Appendix 8.1).

Table 7 County-specific inputs for polysilicon, wafer, cell and module

Parameter	Unit
Installed capacity* in 2025	kg
Projected installed capacity in 2030	kg
Electricity price	USD/kWh
Average engineer salary	USD/year
Equipment costs	USD/kg
Total building and facilities costs	USD/kg

Notes: kg = kilogramme; USD = United States dollar; installed capacity refers to the factory on-the-ground production capacity.

Projected increases in manufacturing capacity are based on industry announcements, with some countries anticipating significantly higher expansion rates than others due to differing strategic priorities and investment levels.

For polysilicon production, installed capacity was estimated at 50 tonnes in 2025 to be expanded to 70 tonnes through to 2030 for all markets.

For wafer, cell and module manufacturing, Germany has the lowest production capacity at 200 MW in 2025, reaching 2 GW in 2030. Current manufacturing production capacities in China and India are 5 GW and 4 GW, respectively, with the projected increase through to 2030 reaching a total of 10 GW production capacity for each country (Sinovoltaics, 2025).

3.3 Selective import scenario

To support comparative analysis, the input tab enables users to explore different sourcing scenarios – specifically, the option to import selected components from other countries versus producing them domestically. The goal is to assess the potential impacts of sourcing decisions based on the cost of domestic production vs. imported components across the supply chain.

To facilitate this analysis, we integrated the option to import polysilicon, wafers and solar cells – three key components in the solar supply chain. Users can choose to source these components internationally to compare with domestic production. Specifically, the tool allows imports from China for all selected countries, except the United States, where imports are enabled from Viet Nam instead due to currently high tariffs for imports from China.

When a user opts to import one of the components – polysilicon, wafers or solar cells – the tool retrieves the market price for the selected component and adds the following costs to calculate the total landed import cost (DDP) (Table 8).

Table 8 Cost assumptions for calculating landed import cost (DDP)

Step	Cost assumption	Source
Port-to-port ocean freight per load for 40 FCL	USD 0.35/km	Calculated based on quotes from IContainers, 2025
Insurance	0.5% of cargo value for insurance	ICE Global Transport, 2025
Customs duties	0% for all countries, except 45% for US imports from Viet Nam for polysilicon, wafers and solar cells	The Harmonized Tariff Schedule of the United States (HTS), 2025

Notes: FCL = full container load; USD = United States dollar.

While price projections through to 2030 decrease for all three components (Wood Mackenzie, 2025), shipment, insurance and customs duties remain constant over the years (See Appendix 8.2).

The tool intentionally excludes anti-dumping and countervailing duties (AD/CVD) because these trade remedies are highly specific to individual manufacturers and countries of origin, and they are subject to frequent administrative changes. Including them would complicate the tool and obscure the influence of broader policy and technological drivers.

As a result, the calculated landed costs for certain US import scenarios may not fully capture the impact of all applicable trade remedies and should be interpreted with this limitation in mind.

3.4 Cost projections

Based on historical trends and future technological improvements, the tool also presents a forecast of factory gate module costs until 2030. The cost projection methodology follows a technology-based approach, supported by research literature and industry reports. Aspects taken into consideration for the development of the forecast methodology are as follows:

- **Historical trend extrapolation:** Historical data (2015-2024) are analysed to establish trends for each variable. For example, efficiency improvements contributed to ~23% of past cost declines (Kavlak *et al.*, 2018). Future projections assume continued advancements, tempered by physical or practical limits (*e.g.* efficiency nearing theoretical maxima).

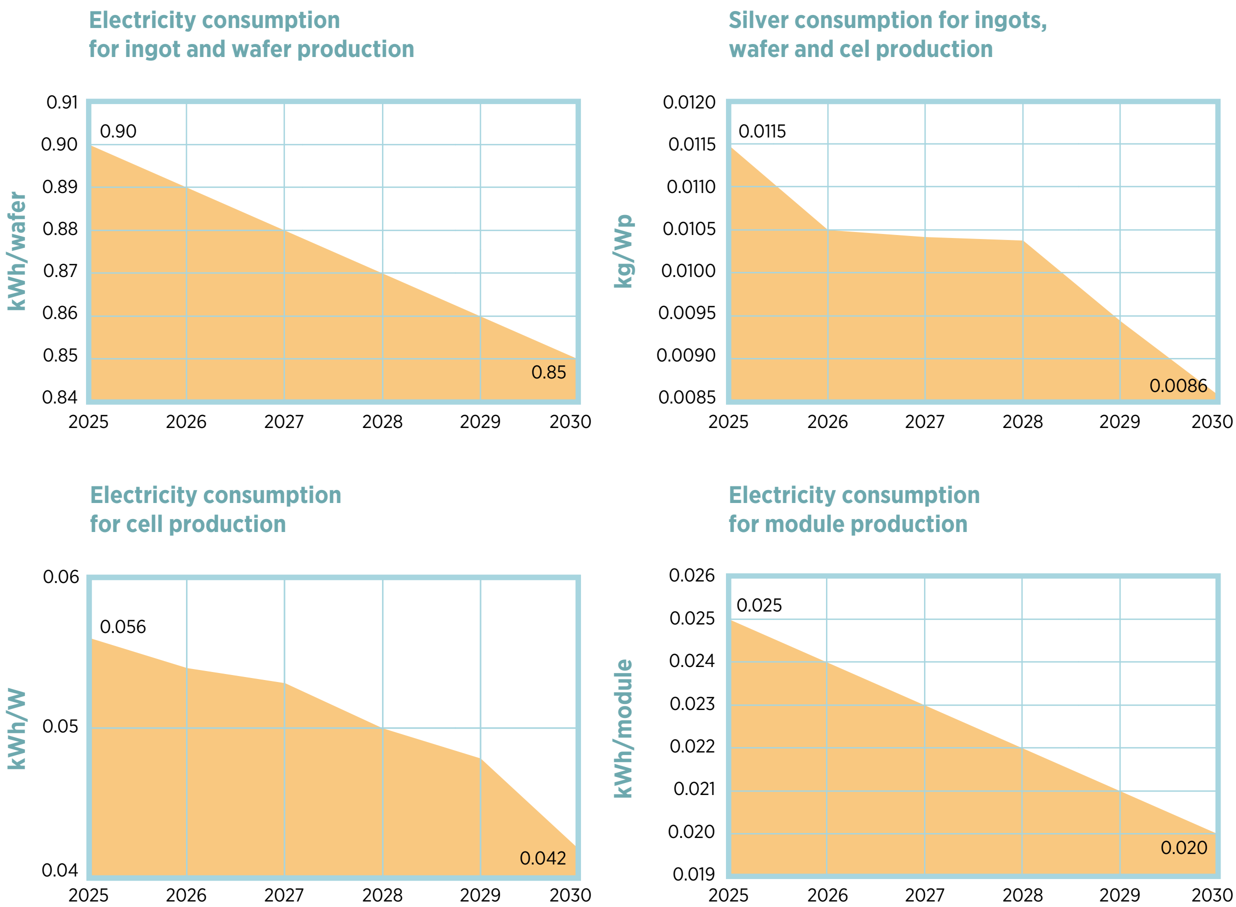
- **Economies of scale in PV module manufacturing:** Lower unit costs are achieved by spreading fixed costs over larger output, improving manufacturing efficiency, enabling bulk purchasing of materials, reducing labour and logistics costs, and accelerating innovation through learning effects – ultimately driving down the price of solar energy. The tool assumes an industry-wide evolution towards larger-scale manufacturing facilities (from 4 GW to 6 GW on average). This increase in production capacity is projected to reduce both capital and operational expenditure per unit of output, in line with established learning curves.

- **Technological improvements:** Reductions in materials and use of resources in the PV supply chain are critical for decreasing costs and enhancing sustainability. These innovations span the entire lifecycle of PV modules, from the consumption of raw materials and use of alternative materials, to manufacturing process improvements leading to a higher material efficiency.

Cost projections through to 2030 are also driven by a technology roadmap that anticipates technological advancements in key parameters, primarily related to reduced material consumption and increased process efficiency. These improvements reflect research and industry expectations based on the International Technology Photovoltaics Roadmap (ITRPV, 2025).

Figure 2 shows the reduced specific energy consumption (kWh/unit) across all manufacturing stages and the decreased consumption of key consumables, most notably silver paste.

Figure 2 Electricity consumption improvements in solar PV manufacturing through to 2030

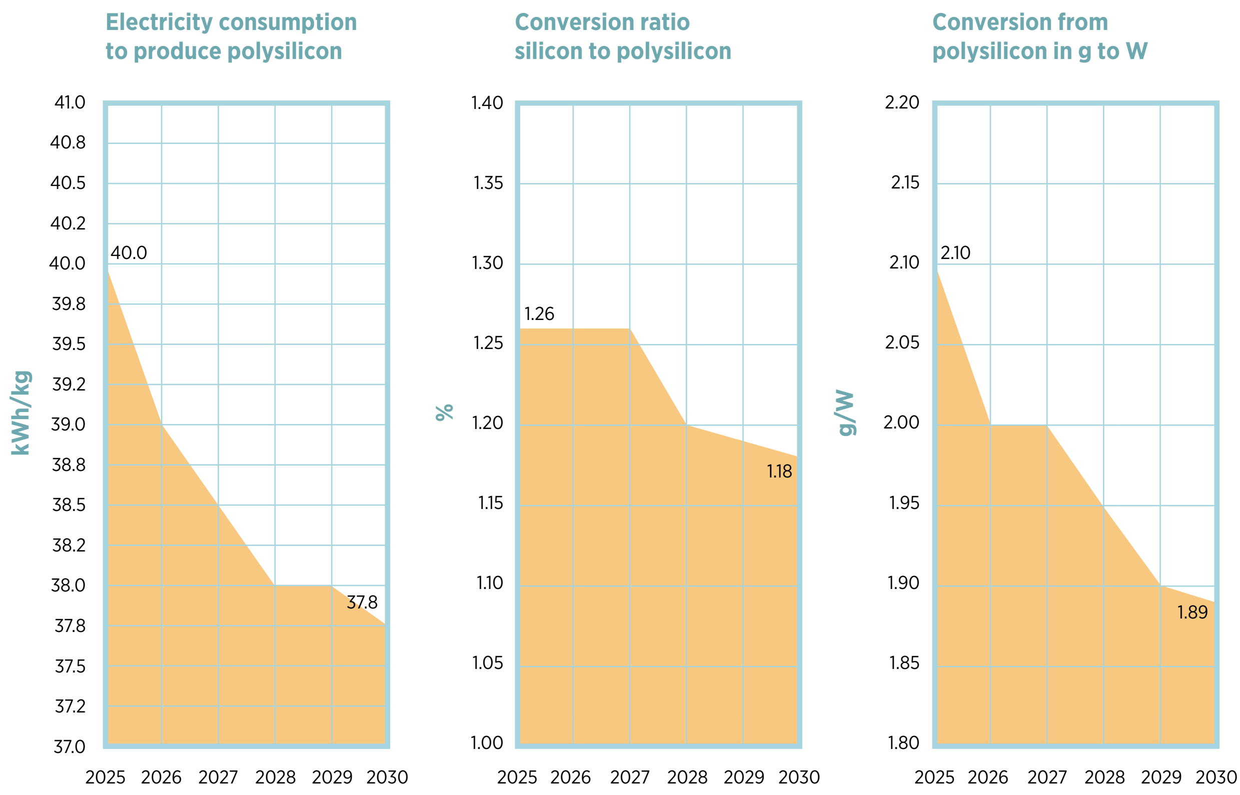


Source: (ITRPV, 2025).

Notes: kg = kilogramme; kWh = kilowatt hour; W = watt.

Figure 3 shows the improved polysilicon-to-wafer conversion yield, reflecting advances in areas like kerf loss reduction, as well as the decreased specific polysilicon consumption (g/Wp) resulting from thinner wafers and higher yields.

Figure 3 Technological improvements in the polysilicon manufacturing through to 2030

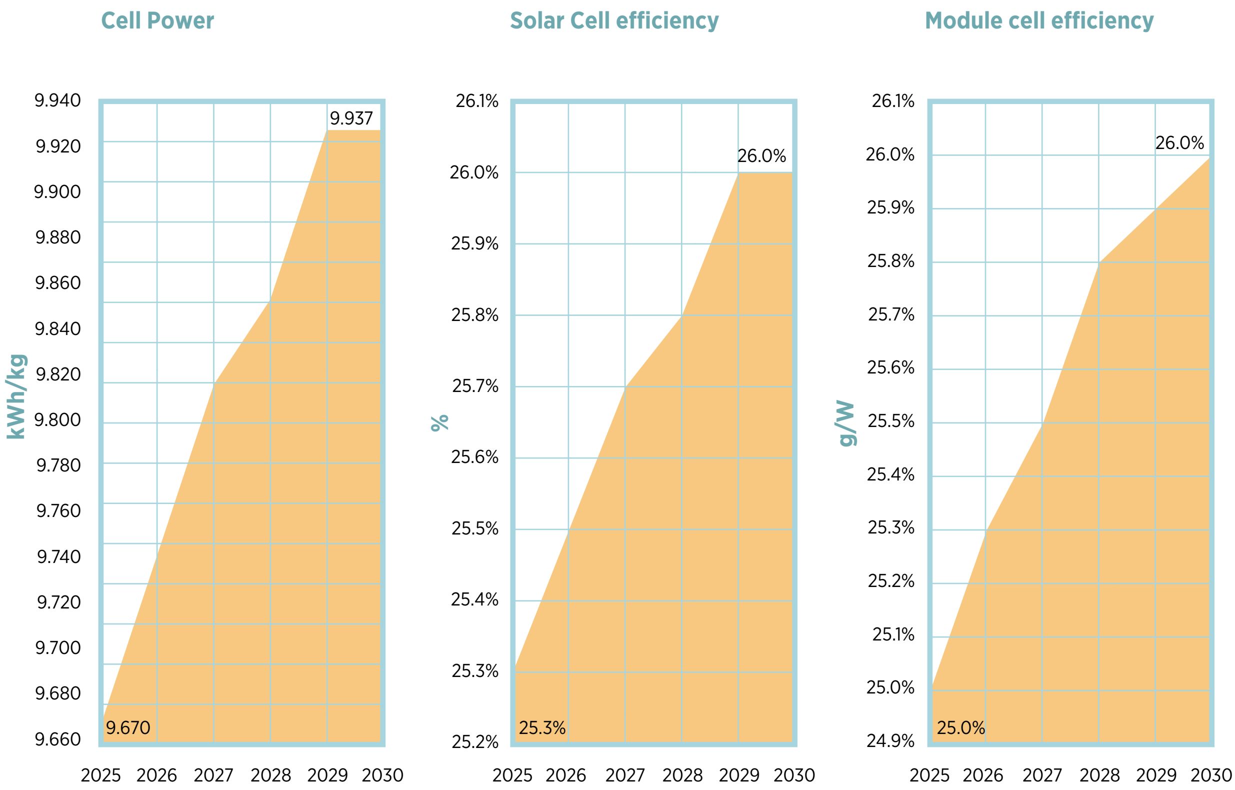


Source : (ITRPV, 2025).

Notes: g = gramme; kWh = kilowatt hour; W = watt.

Figure 4 shows the increased cell and module conversion efficiency, as well as the increased cell power leading to solar cells that produce more watts.

Figure 4 Technological improvements in cell manufacturing through to 2030



Source: (ITRPV, 2025).

Notes: g = gramme; kg = kilogramme; kWh = kilowatt hour; W = watt.

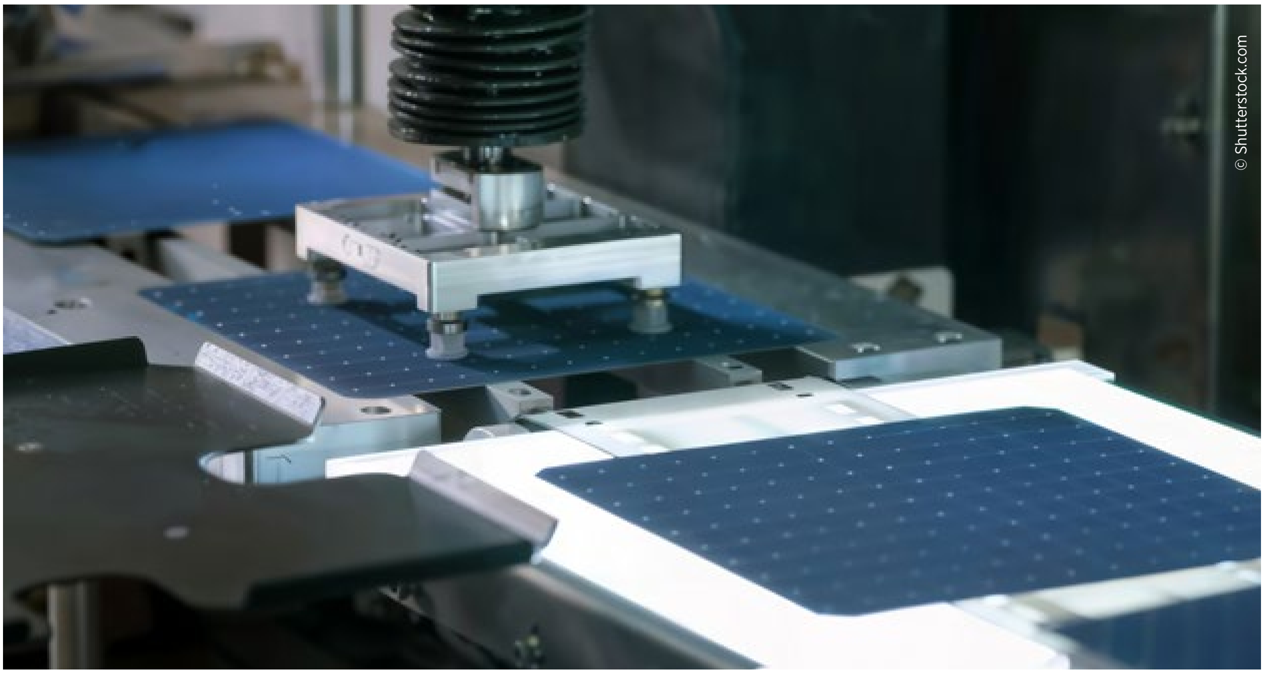


Table 9 presents the change in all parameters in the timeframe from 2025 to 2030 and the year-on-year average improvement.

Table 9 Estimated cost reduction per parameter and manufacturing component by 2030

Parameter	Manufacturing component	2025	2030	Change 2025-2030	Yearly change*
Electricity consumption (kWp per unit)	Polysilicon	40 kWh/kg	37.8 kWh/kg	-6%	-1.1%
	Wafer and ingot	0.9 kWh/wafer	0.85 kWh/wafer	-6%	-1.1%
	Cell	0.056 kWh/W	0.042 kWh/W	-25%	-5%
	Module	0.025 kWh/module	0.020 kWh/module	-20%	-4%
Conversion ratio silicon to polysilicon	Polysilicon	1.26 %	1.18%	-6%	-1.3%
Conversion from polysilicon to W	Polysilicon	2.1%	1.89%	-10%	-2%
Silver consumption	Cell	0.01	0.008	-25%	-5%
Solar cell efficiency	Ingot and wafer, cell	25.3%	26%	+3%	+0.6%
Cell efficiency	Module	25%	26%	+4%	+0.8%
Cell power	Module	9.67 W/cell	9.94 W/cell	+3%	+0.4%

Source: (ITRPV, 2025).

Notes: kg = kilogramme; kWh = kilowatt hour; kWp = kilowatt peak; W = watt; yearly change refers to the average year-on-year improvement through to 2030.

Sensitivity and uncertainty factors such as silicon price volatility, supply chain constraints and policy shifts are not considered in the cost projection. The price for all materials is fixed throughout the period analysed to reduce the impact of price volatility. This relates to the two main material parameters: “Silver prices” and “Other materials”

4. Tool input and output

4.1 Structure of user input

The tool requires the user to follow specific steps to configure specific data inputs (Figure 5). Each selection will affect the tool output according to the chosen manufacturing and supply chain scenarios.

Step 1: Select country of manufacturing

- The user should choose the country where the final module is assembled. Module assembly is always assumed to be domestic to this selected country.

Step 2: Module technology

- The module considers two module technologies: TOPCon and monocrystalline. Each module type produces a different cost output, as the input data are specific to each technology.

Step 3: Define component sources

- The user should specify the source of each component in the solar module supply chain. It can be either:
  - › Domestic: the component is produced within the selected country, or
  - › Imported: the component is sourced from another market. User can select China or Viet Nam.
- This step applies for all components in the supply chain, such as polysilicon, wafer and cell, and will influence the final output. The total delivered module cost includes the DDP price of each supply chain component, adjusted according to the country where the module is assembled.

Step 4: Results

- Once all inputs are selected, proceed to the tab "Output_Visualization" to view the results based on the user-configured supply chain and manufacturing setup.

Figure 5 User input tab

MODEL INPUTS

Select Country: Vietnam

Technology Type: **TOPCon**

Key Inputs - Polysilicon

Select source of Polysilicon supply Domestic

Parameter	Unit	Default Value	User Input	Final Value
Installed Capacity in 2025	kg	50000		50000
Projected Installed Capacity through 2030	kg	70000		70000
Electricity Price	USD/kWh	0.07		0.07
Average Engineer Salary	USD/year	9000		9000
Equipment Costs	USD/kg	15		15
Total Building & Facilities Costs	USD/kg	5		5

Key Inputs - Wafer/Cell/Module

Select Source of Wafer Supply Domestic

Select Source of Solar Cell Supply Domestic

Parameter	Unit	Default Value	User Input	Final Value
Installed Capacity in 2025	Wp	4000000000		4000000000
Projected Installed Capacity through 2030	Wp	6000000000		6000000000
Equipment Costs for Wafer	USD/kW	40		40
Equipment Costs for Cell	USD/kW	35		35
Equipment Costs for Module	USD/kW	13		13
Electricity Price	USD/kWh	0.07		0.07
Average Engineer Salary	USD/year	9000		9000
Total Building & Facilities Costs for Wafer manufacturing	USD/kWp	30		30
Total Building & Facilities Costs for Cell manufacturing	USD/kWp	30		30
Total Building & Facilities Costs for Module manufacturing	USD/kWp	20		20

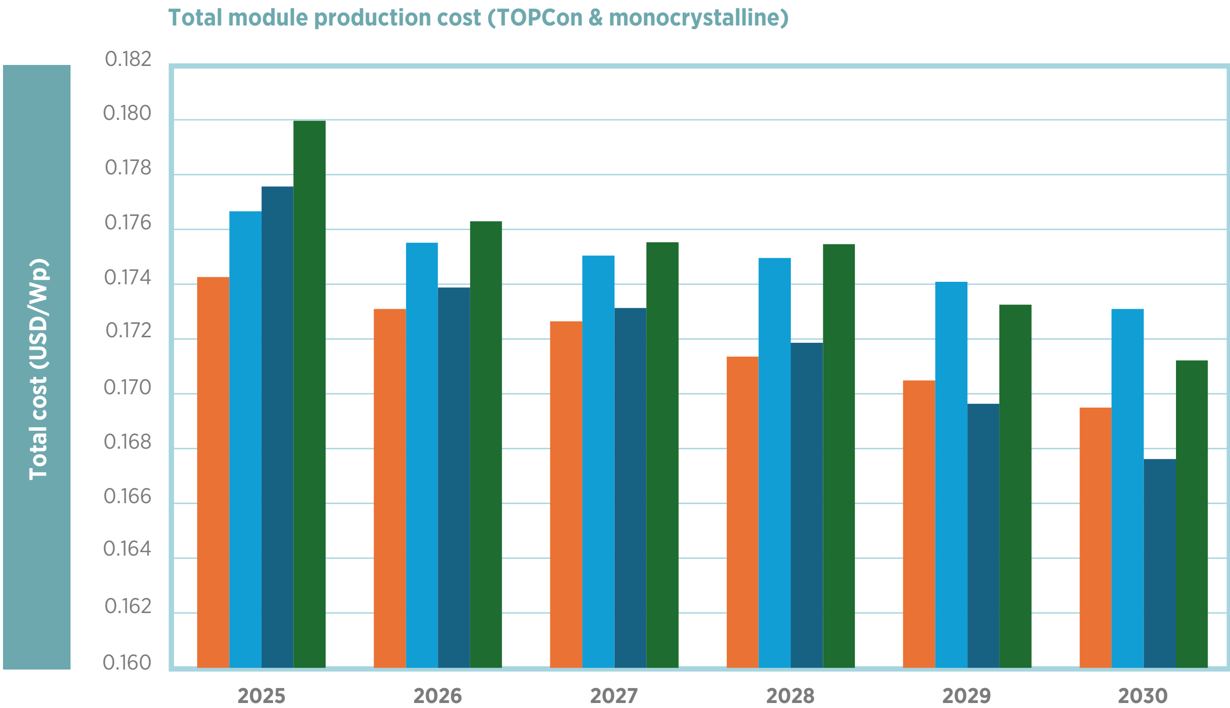
4.2 Tool output

The "Output_Visualization" tab presents a comprehensive set of graphs[3] designed to allow analysis and comparison of the production costs of TOPCon and monocrystalline solar modules from 2025 to 2030 across different manufacturing components. The graphs in the Excel file automatically update according to the inputted data and the selected scenario. The graphs are categorised as follows.

4.2.1 Total module production cost (2025-2030)

This graph (Figure 6) compares the overall module production cost for both TOPCon and monocrystalline technologies, with and without the inclusion of ESG-related expenses. It allows users to observe how cost projections change over time and how sustainability factors influence cost. The graph updates dynamically according to the input data and supports both domestic production and import scenarios.

Figure 6 Cost tool chart for the total module production cost



	2025	2026	2027	2028	2029	2030
Monocrystalline (without ESG)	0.174	0.173	0.173	0.171	0.170	0.169
Monocrystalline (with ESG)	0.177	0.176	0.175	0.175	0.174	0.173
TOPCon (without ESG)	0.178	0.174	0.173	0.172	0.170	0.168
TOPCon (with ESG)	0.180	0.176	0.176	0.175	0.173	0.171

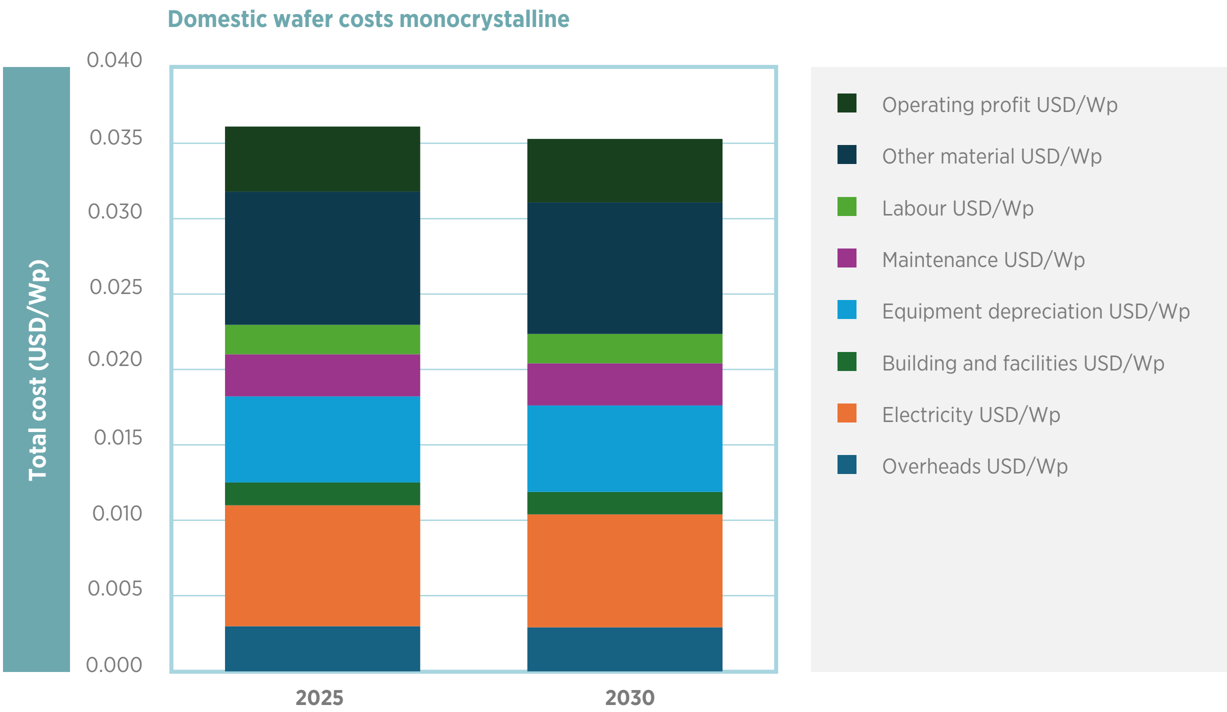
Notes: ESG = environmental, social and governance; USD = United States dollar; Wp = watt peak.

3 *The graphs in this section show results for domestic production in Viet Nam.*

4.2.2 Cost breakdown per component in 2025 and 2030

These graphs offer a detailed breakdown of key cost components for domestic production – polysilicon, wafer, cell and module costs – for both TOPCon and monocrystalline technologies in 2025 and 2030. It highlights how each element contributes to the total module cost and how these contributions are expected to evolve through to 2030. Figure 7 is an example of the graph for wafer cost.

Figure 7 Cost tool chart for the wafer cost breakdown



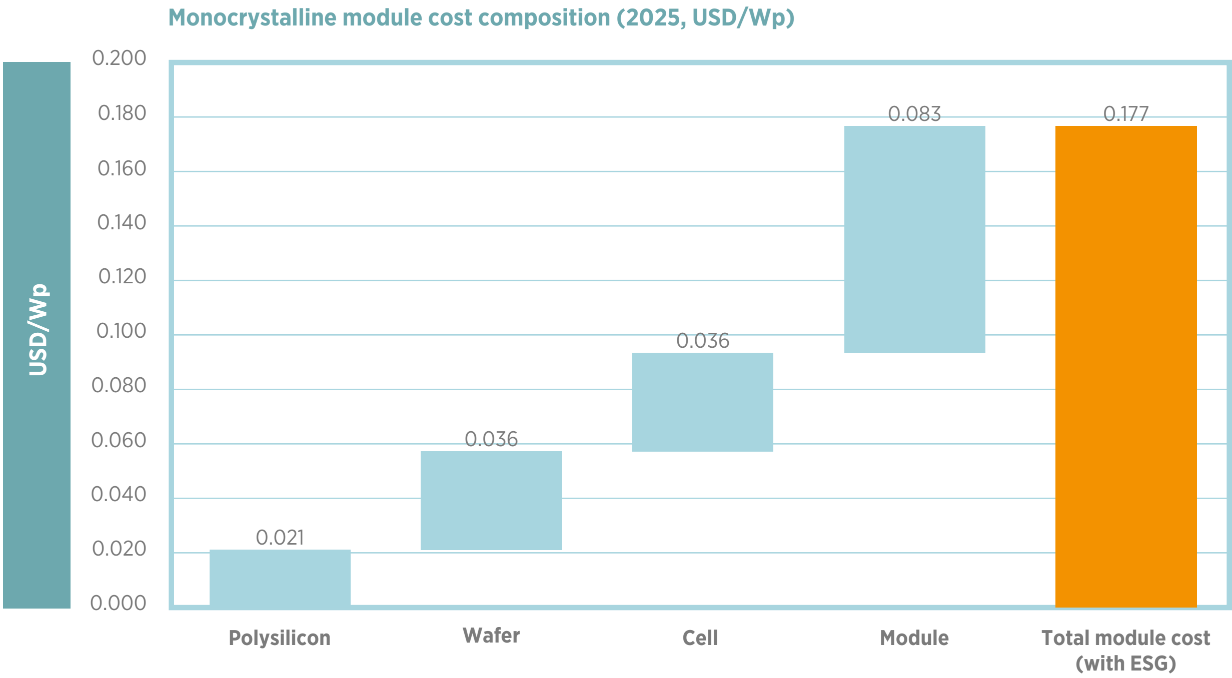
Notes: USD = United States dollar; Wp = watt peak.

Domestic costs for each component exclude the cost of the main input material, *e.g.* polysilicon, wafer and solar cell, to avoid distorting the visualisation. Including it would make it harder to see the breakdown of other cost components. This provides clarity on the additional costs incurred at each step of the supply chain.

4.2.3 Module cost composition (waterfall charts)

A set of waterfall charts is then provided visualising the full module cost structure for TOPCon and monocrystalline technologies in both 2025 and 2030 (Figure 8). These charts illustrate the incremental contribution of each cost component, providing clear insight into cost drivers and reductions over time.

Figure 8 Cost tool chart on module cost (waterfall)



Notes: ESG = environmental, social and governance; USD = United States dollar; Wp = watt peak.

Together, these graphs enable a clear and data-driven comparison of technology pathways, cost structures, and the potential impact of ESG considerations in the solar module industry.

5. Results and analysis

5.1 Country-level analysis: The case of Viet Nam

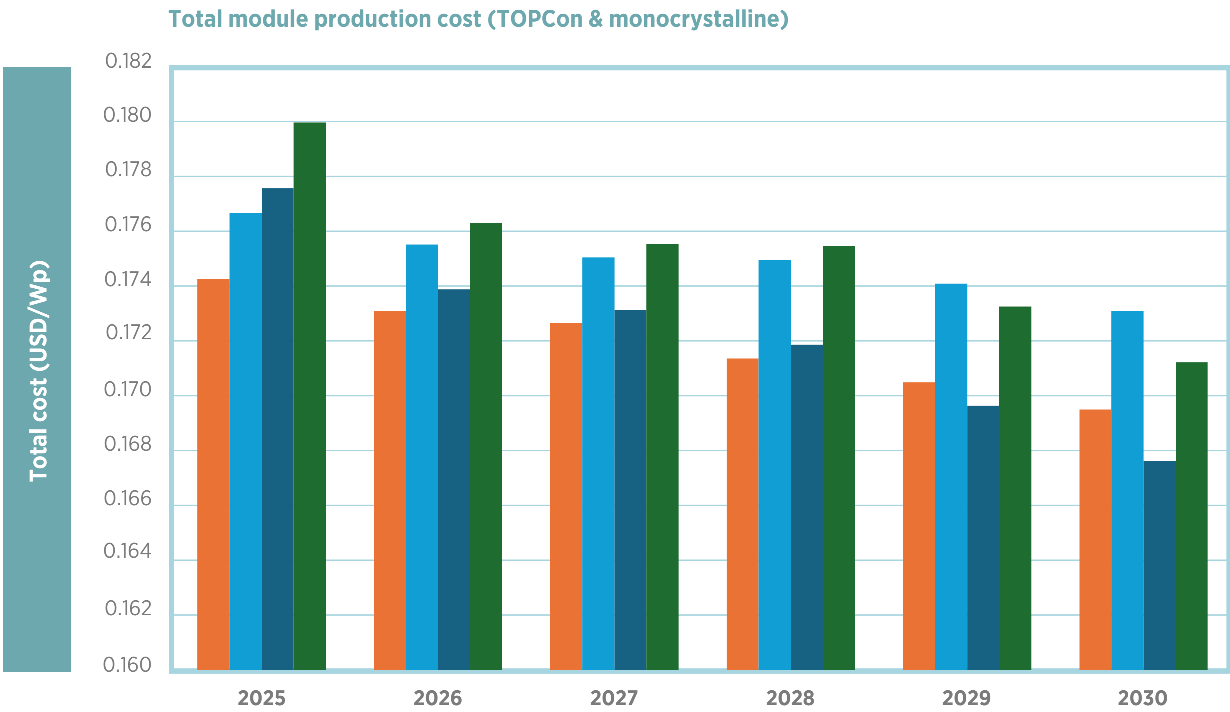
Viet Nam is one of the main locations for solar PV manufacturing in Southeast Asia, driven by favourable government policies and substantial private sector investment. With installed solar production capacity exceeding 18.4 GW as of 2023 (Satriastanti *et al.*, 2024), it is one of the few countries in Asia with production across the entire PV supply chain, following the recent launch of a domestic polysilicon manufacturing facility (Phu My 3, 2025). Therefore, Viet Nam was selected for the case study analysis.

This section explores potential results and analysis for the domestic manufacture of all components in the TOPCon module supply chain in Viet Nam, assuming manufacturing production of 4 GW in 2025 to be expanded to 6 GW through to 2030. The Excel tool includes data for both TOPCon and monocrystalline technologies, allowing users to explore a more detailed overview of each option.

5.1.1 Total module production cost (2025-2030)

While TOPCon modules currently exhibit a higher levelised cost of production (LCOP), their steeper technology improvement roadmap – primarily driven by greater potential for cell conversion efficiency gains – is anticipated to make them the more cost-competitive option (Figure 9). In contrast, monocrystalline PERC technology is approaching its practical efficiency limits, resulting in a flatter cost reduction curve.

Figure 9 Results for domestic production of TOPCon and monocrystalline modules in Viet Nam



	2025	2026	2027	2028	2029	2030
Monocrystalline (without ESG)	0.174	0.173	0.173	0.171	0.170	0.169
Monocrystalline (with ESG)	0.177	0.176	0.175	0.175	0.174	0.173
TOPCon (without ESG)	0.178	0.174	0.173	0.172	0.170	0.168
TOPCon (with ESG)	0.180	0.176	0.176	0.175	0.173	0.171

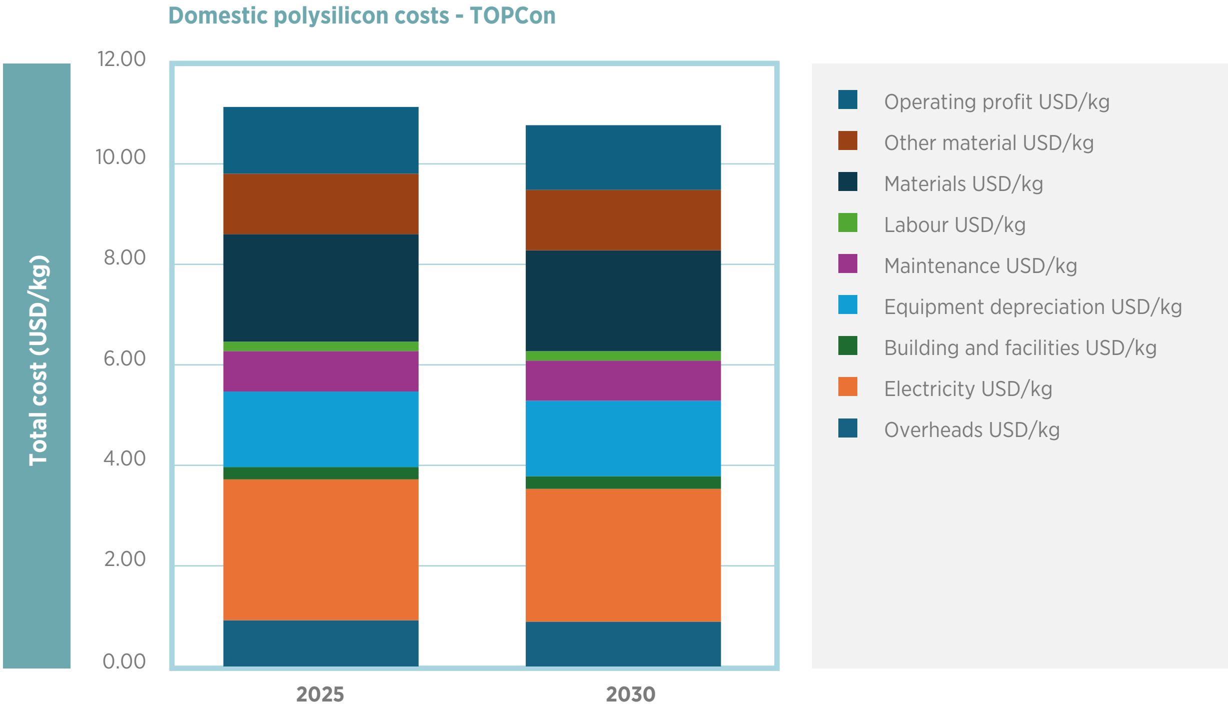
Notes: ESG = environmental, social and governance; USD = United States dollar; Wp = watt peak.

5.1.2 Cost breakdown per component in 2025 and 2030

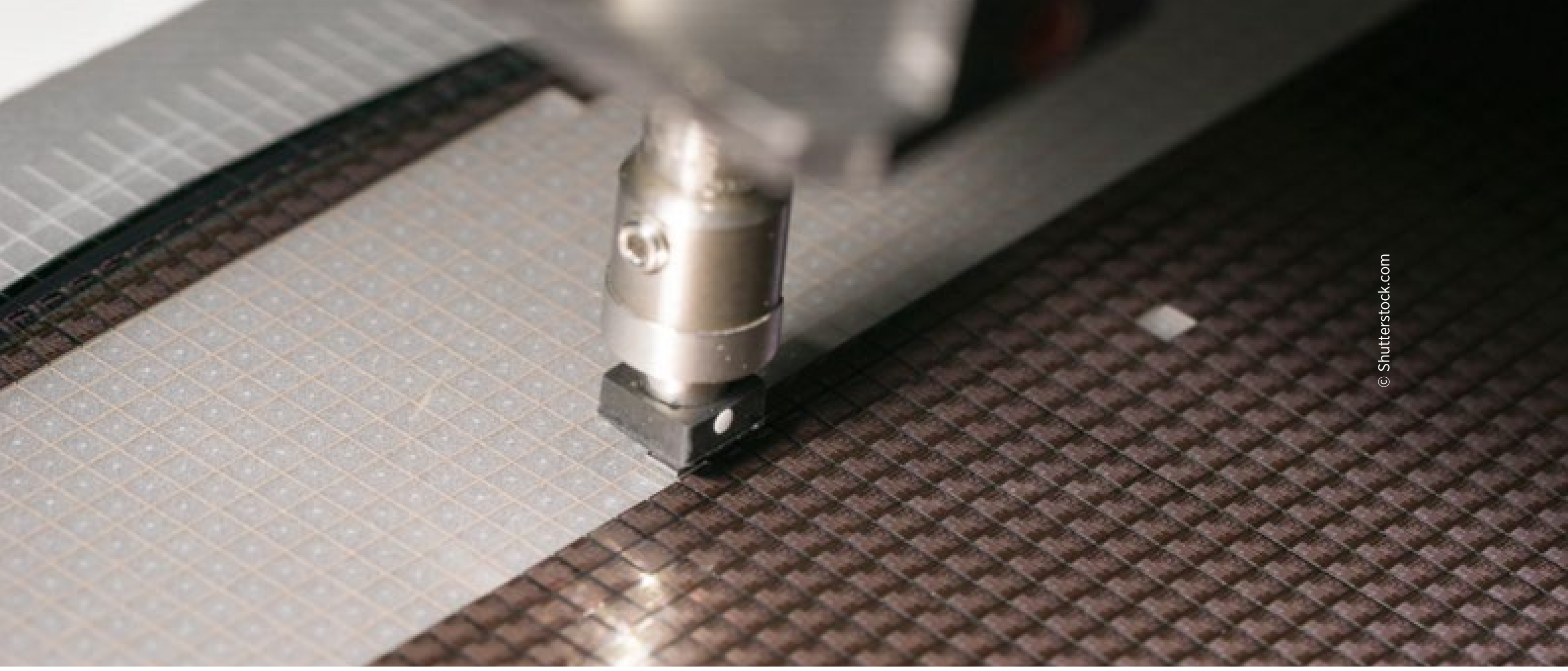
- **Polysilicon**

The chart in Figure 10 indicates an overall cost reduction in domestic polysilicon production over the five-year period. Materials (primary silicon metal) and electricity are the primary cost drivers and key targets for cost-saving efforts. Across every stage of the PV value chain, polysilicon production remains the most electricity-intensive, consuming about 40 kWh of electricity per kilogramme of polysilicon. Although usage has dropped steeply – from roughly 80 kWh/kg five years ago to today's 40 kWh/kg – the ITRPV expects only marginal additional savings in the coming years (ITRPV, 2025). Costs for labour, maintenance, building and facilities, and overheads stay mostly constant.

Figure 10 Results for domestic polysilicon production in Viet Nam



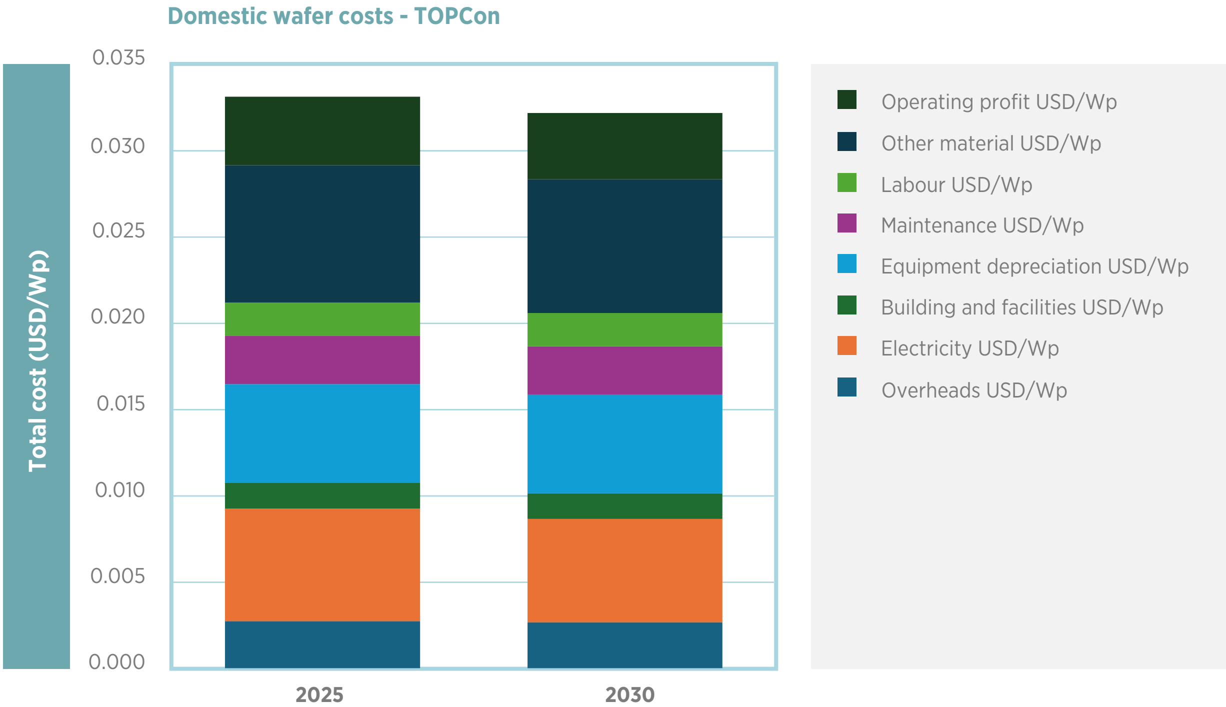
Notes: kg = kilogramme; USD = United States dollar.



- **Ingots and wafers**

The chart in Figure 11 indicates an overall cost reduction for domestic wafer production over the five-year period. This chart excludes polysilicon material costs and includes only other material inputs – such as quartz crucibles, diamond wire and argon – which account for the majority of production costs. Equipment and electricity are the next largest cost components. Establishing wafer production capacity also requires substantial upfront capital investment, with recent announcements indicating approximately USD 500 million being needed to build a 7 GW facility (Jowett, 2024). While the average lifetime of this equipment is relatively short – around seven years – frequent technology upgrades often drive earlier replacement (NREL, 2025). Costs for labour, maintenance, building and facilities, and overheads stay mostly constant.

Figure 11 Results for domestic wafer production in Viet Nam



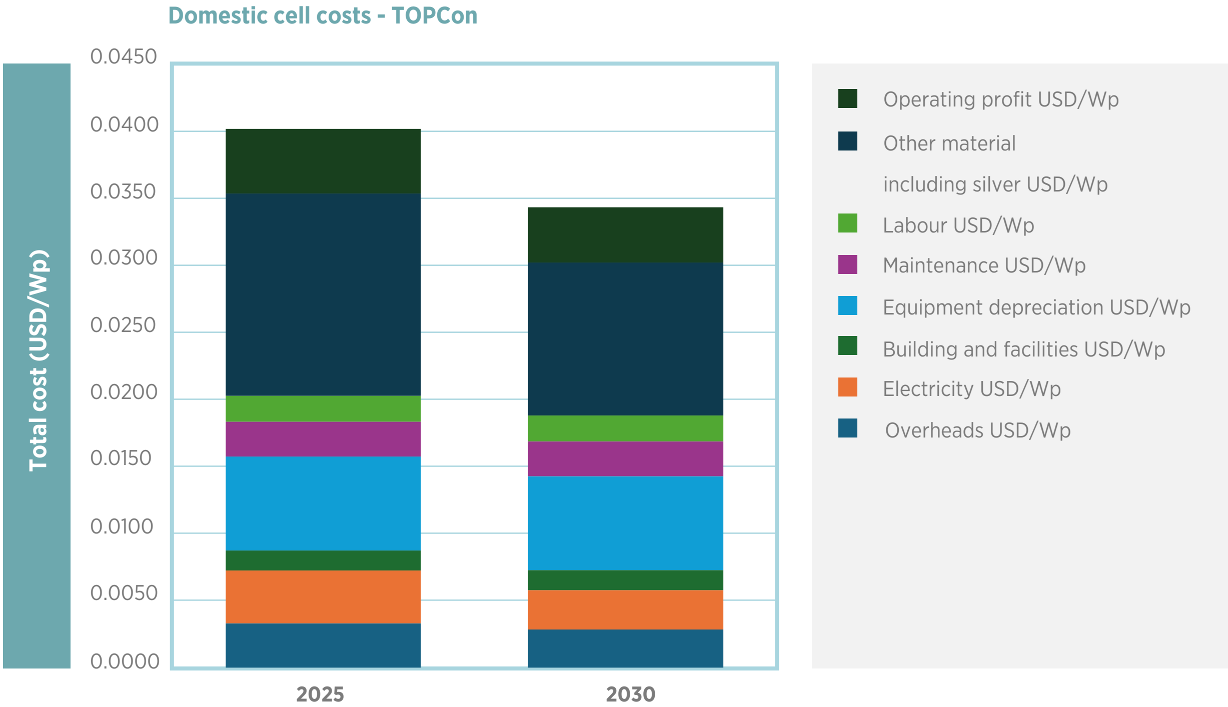
Notes: USD = United States dollar; Wp = watt peak.

- **Solar cells**

The chart in Figure 12 highlights that while TOPCon cell production remains materials-intensive, overall cost efficiency is improving, with the biggest savings coming from materials, depreciation and electricity. This supports a trend towards more affordable and competitive domestic solar manufacturing by 2030.

The chart excludes wafer material costs and includes only other inputs, with silver paste representing the largest material expense. Equipment and electricity also remain major cost components in solar cell production, requiring capital expenditure similar to those for wafer production. Due to rapid technological advancements, solar cell equipment typically has an even shorter operational lifespan of five to six years, often leading to earlier-than-planned replacement (NREL, 2025).

Figure 12 Results for domestic cell production in Viet Nam



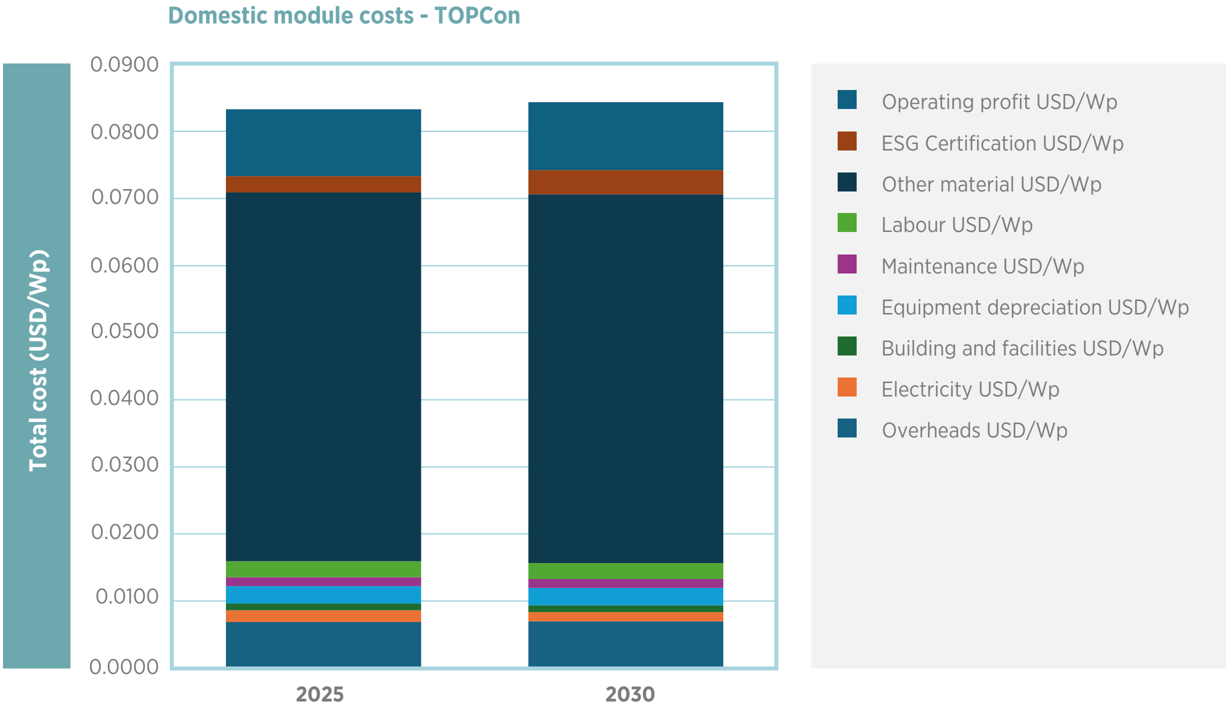
Notes: USD = United States dollar; Wp = watt peak.

- **PV module assembly**

The chart in Figure 13 excludes solar cell material costs and includes only other materials such as aluminium frames, glass and junction boxes, which represent the largest cost items in module assembly. Compared to other segments of the PV value chain, module assembly requires the least capital, labour and electricity, making it the most attractive stage for local manufacturing.

As total production costs decline due to economies of scale and technological improvements, the relative share of fixed or semi-fixed expenses – such as those related to ESG compliance – may increase with added capacity, but these costs will be amortised as a larger number of panel is produced. The tool does not project a decrease in the cost of other materials due to limited industry data and persistent price volatility.

Figure 13 Results for domestically assembled PV module in Viet Nam



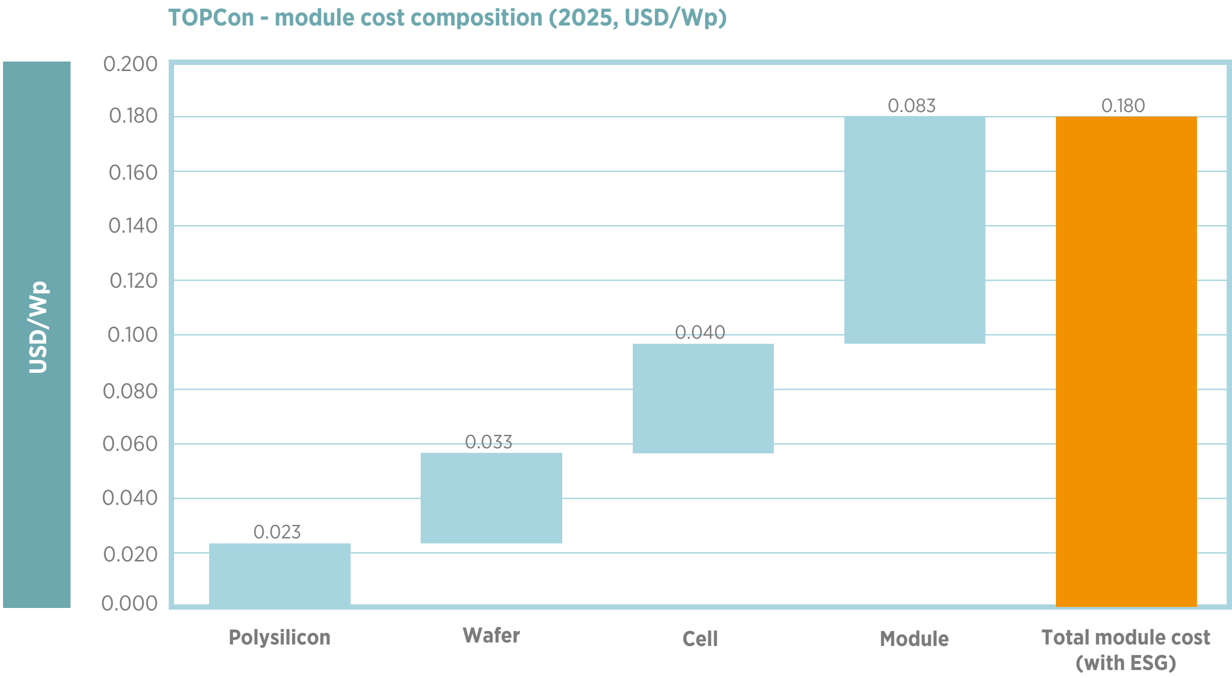
Notes: USD = United States dollar; Wp = watt peak.

5.1.3 Module cost composition (waterfall charts)

For fully domestic module manufacturing in Viet Nam, the total cost is USD 0.180/Wp (Figure 14). Importing wafers from China reduces the cost to USD 0.146/Wp – a 19% decrease (Figure 15). If solar cells are imported instead, the total module cost drops further to USD 0.124/Wp, representing a 31% reduction compared to full domestic production (Figure 16).

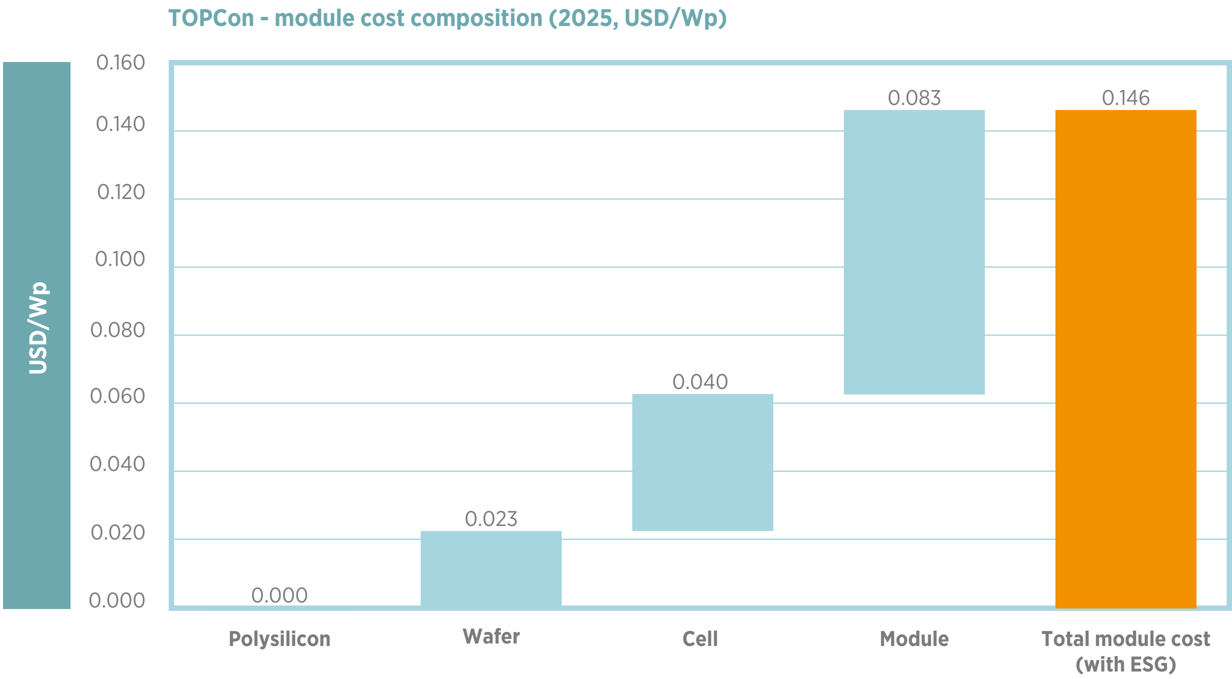
This cost difference highlights the significant impact of upstream manufacturing stages on overall module pricing. Domestic production faces higher costs primarily due to capital intensity, labour and electricity expenses. In contrast, importing wafers or cells from China leverages established supply chains and economies of scale, which help lower prices substantially.

Figure 14 Results for domestic TOPCon module production in Viet Nam



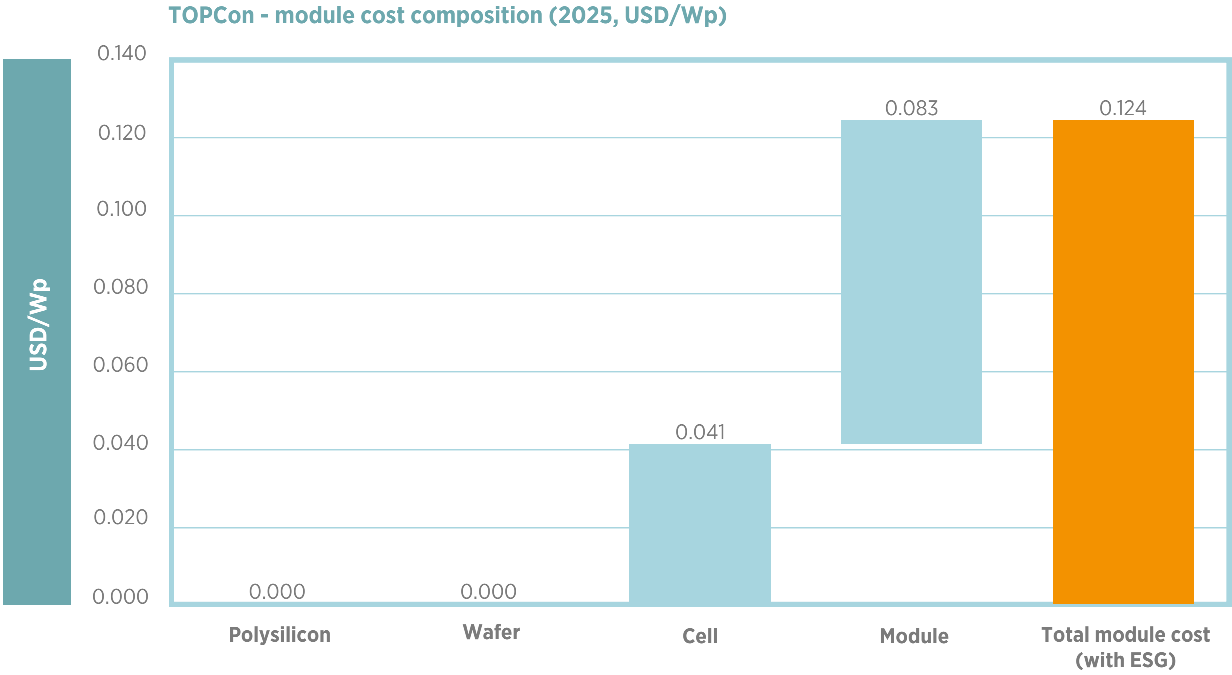
Notes: ESG = environmental, social and governance; USD = United States dollar; Wp = watt peak;

Figure 15 Results for TOPCon module production in Viet Nam, importing wafers from China



Notes: ESG = environmental, social and governance; USD = United States dollar; Wp = watt peak; polysilicon costs are excluded here, as they are already incorporated in the price of imported wafers; total module costs include ESG certification costs.

Figure 16 Results for TOPCon module production in Viet Nam, importing cells from China



Notes: ESG = environmental, social and governance; USD = United States dollar; Wp = watt peak; polysilicon and wafer costs are excluded here, as they are already incorporated in the price of imported solar cell; total module costs include ESG certification costs.

5.2 Comparative scenario analysis for the major markets

To better assess the impact of various factors such as trade policies and regional cost differences, this section compares domestic PV module production across the countries for which data are available in the cost tool: the United States, Germany, India, Australia, Viet Nam and China. These countries were selected due to their active policy support for local PV manufacturing (see example in Box 1). However, the list is not exhaustive; additional countries could have been included if data were available. For this comparison, the tool assumes a manufacturing capacity of 50 tonnes for polysilicon and 4 GW for wafers, cells and modules across all markets.

Box 1: Solar Manufacturing support in Australia

According to the recently published report from APVI, Australia's renewable energy resources, quality quartz, and high safety standards give it a competitive edge in establishing a local manufacturing. Polysilicon, despite high capital costs, presents strong export potential to premium markets due to trade barriers on Chinese products. Ingot/wafer manufacturing could benefit from Australia's established collaboration with the Chinese PV industry. While for cells production and module assembly, Australia can leverage its large upcoming local demand and high-skilled labor needed for innovation and other increased productivity benefits (APVI, 2023).

The Australian Government is actively working to reduce manufacturing costs through a set of policies aimed at promoting domestic production and diversifying solar PV supply chains in the region. The $AUD 1 billion Solar Sunshot program promotes the development of Australia's solar manufacturing capabilities and improves the industry's supply chain resilience through production incentives and other forms of support. The program supports the manufacturing of solar PV modules, cells and other components such as solar glass and framing. Advanced deployment technologies - including racking, tracking, and mounting structures - are also supported to enhance efficiency and scalability. The Australian Government is also supporting the development and diversification of clean energy supply chains through the Quad Clean Energy Supply Chains through Diversification Program.

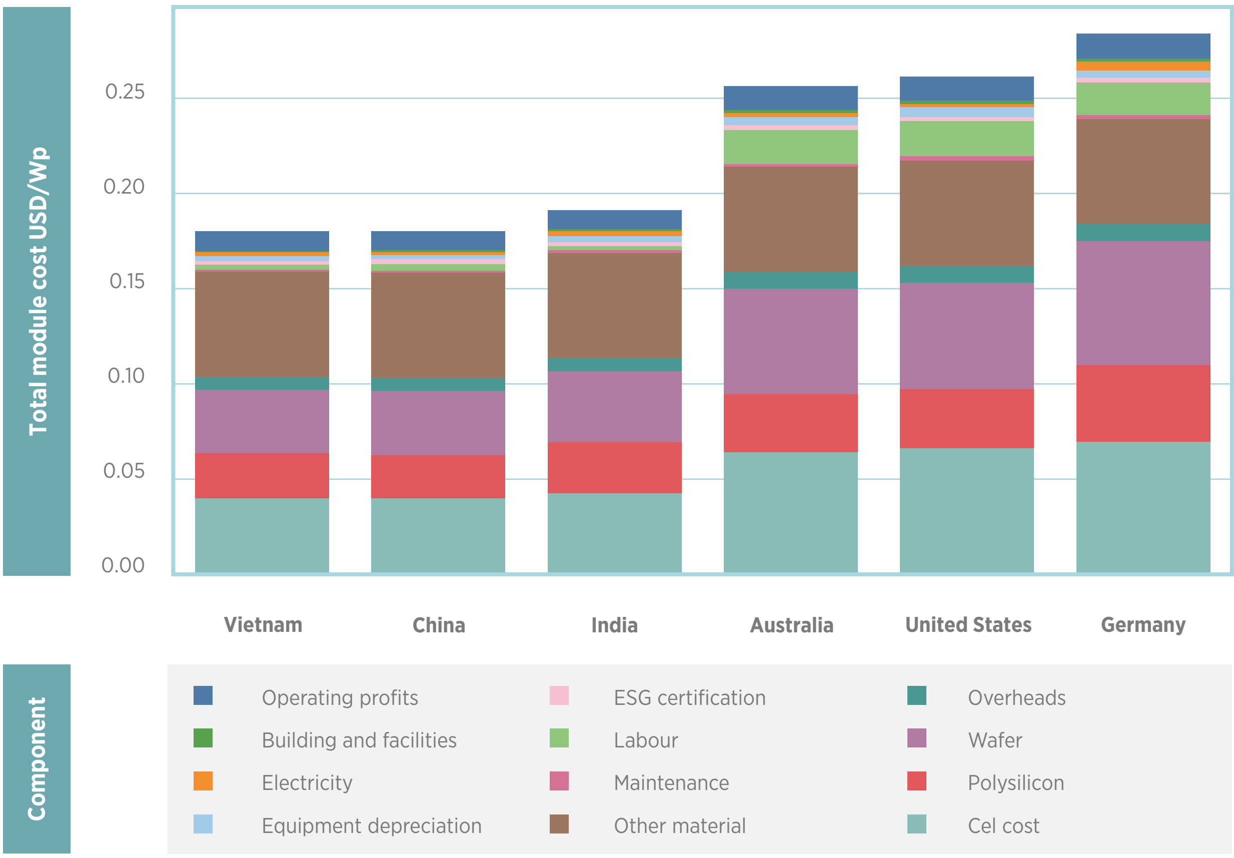
5.2.1 Fully domestic solar PV manufacturing

The tool confirms that regional cost factors – primarily industrial electricity tariffs and labour rates – are the primary determinants of baseline production cost differentials.

Asian markets demonstrate the most competitive cost structures due to these factors. In contrast, Germany's higher manufacturing cost is driven almost entirely by electricity expenses, which significantly affect the cost structure of energy-intensive upstream segments like polysilicon production.

Figure 17 shows the aggregated total cost of polysilicon, wafer and cell, while the breakdown cost components correspond only to the module assembly.

Figure 17 Domestic PV manufacturing costs for all components



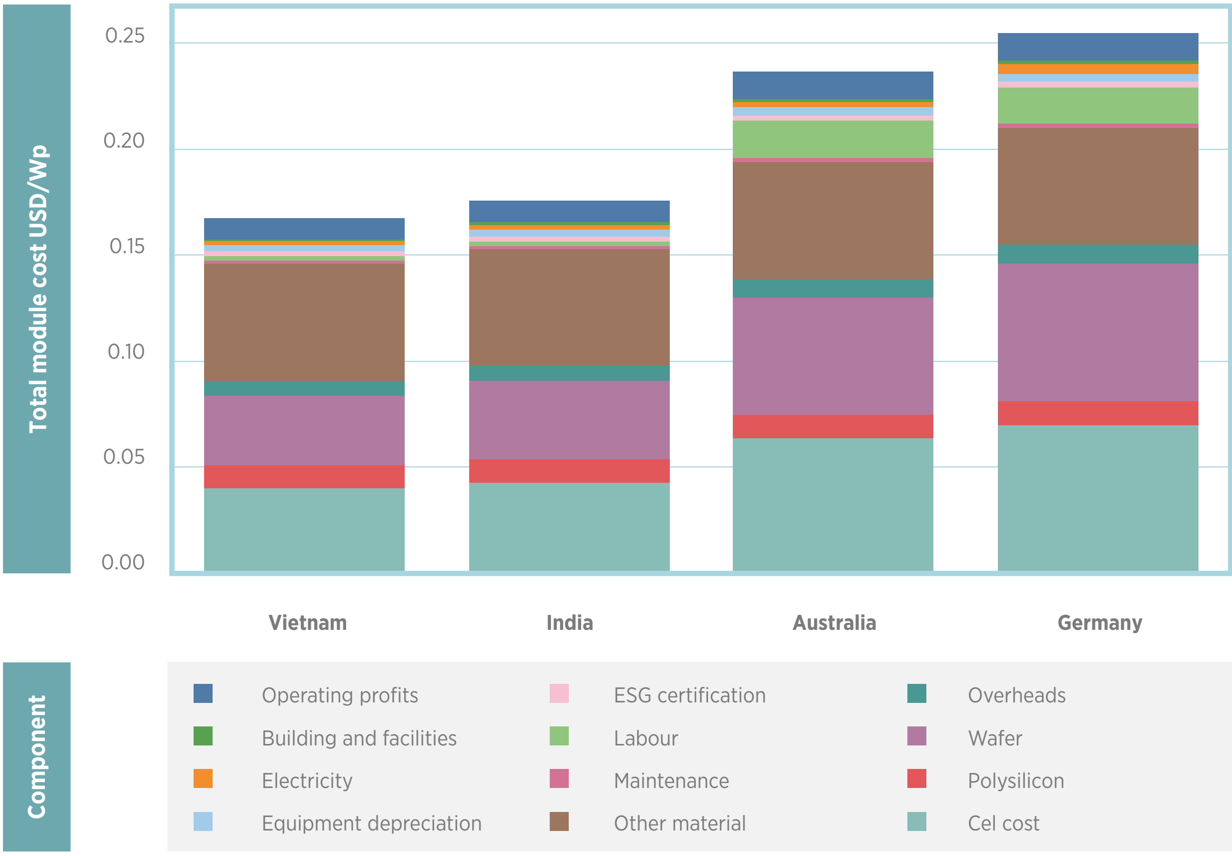
Notes: USD = United States dollar; Wp = watt peak; total module costs include ESG certification costs.

5.2.2 Importing polysilicon from China

Importing polysilicon leads to cost reduction when compared with full domestic manufacturing. Since wafer, cell and module manufacturing still need to occur locally, the associated costs remain substantial.

For the markets shown in Figure 18, total module costs, including imported polysilicon, fall by 7% in Viet Nam and as much as 10% in Germany when compared to all-domestic manufacturing.

Figure 18 Domestic PV manufacturing with imported polysilicon from China



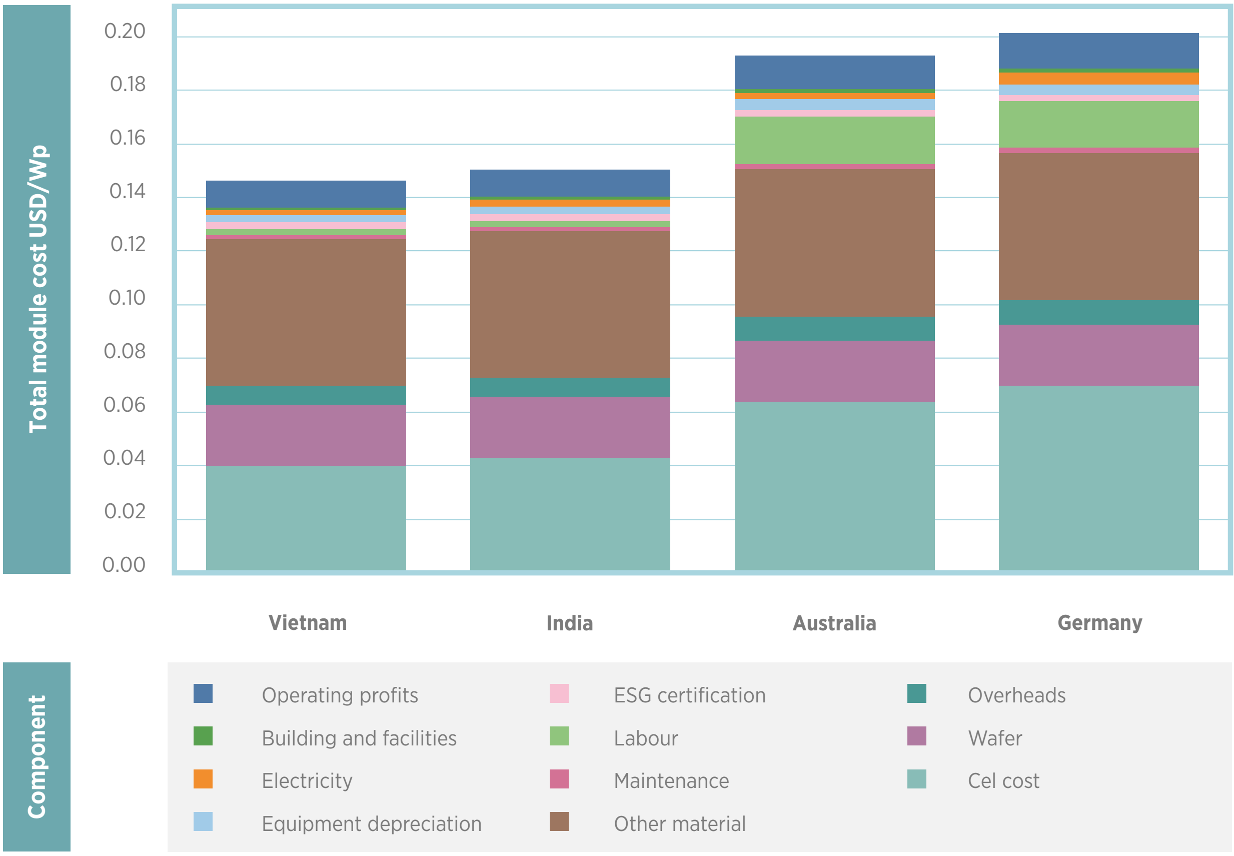
Notes: USD = United States dollar; Wp = watt peak; total module costs include ESG certification costs.

5.2.3 Importing wafers from China

Importing wafers leads to moderate cost reductions, but not as significant as importing cells. Since cell and module manufacturing still need to occur locally, the associated costs remain substantial.

For the markets shown in Figure 19, total module costs, including imported wafers, fall by 19% in Viet Nam and as much as 29% in Germany when compared to all-domestic manufacturing.

Figure 19 Domestic PV manufacturing with imported wafers from China



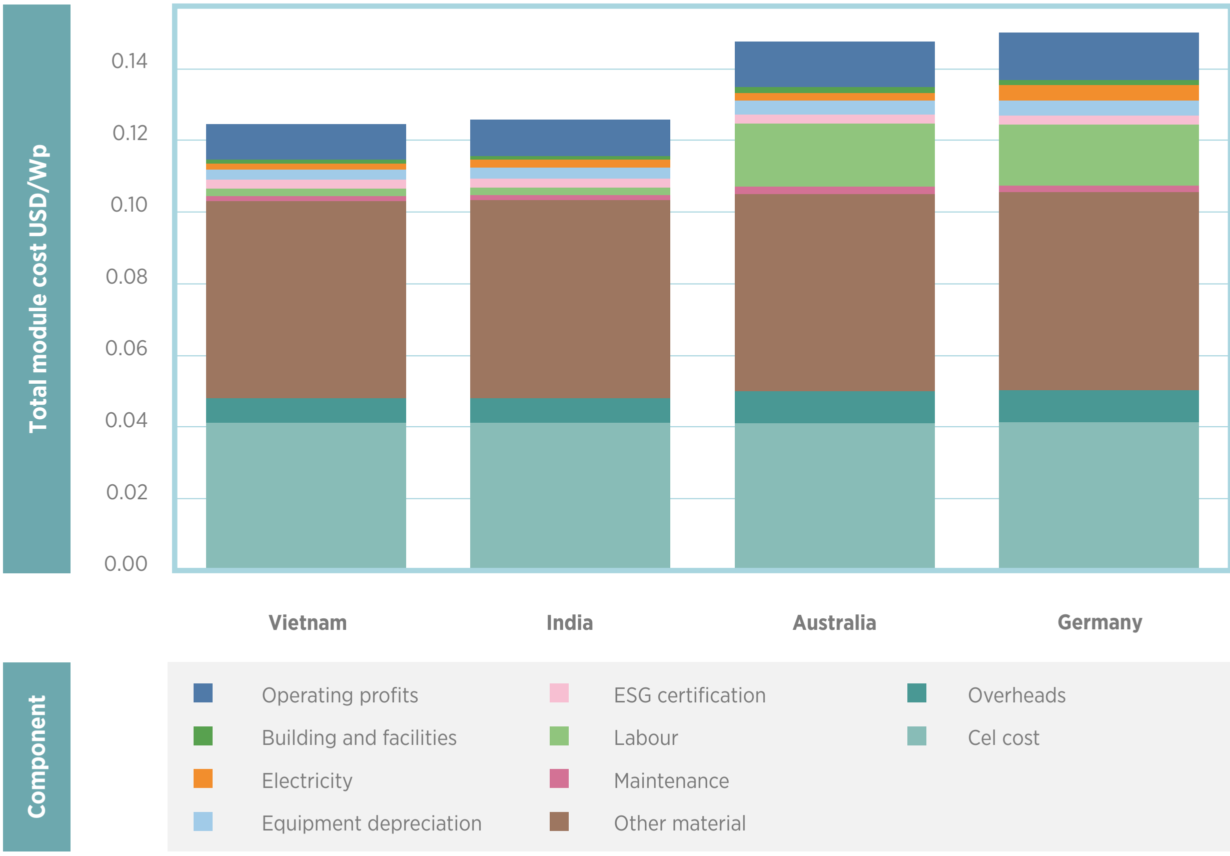
Notes: USD = United States dollar; Wp = watt peak; total module costs include ESG certification costs.

5.2.4 Importing cells from China

Importing cells from China results in the lowest total module cost compared to other scenarios. It eliminates the need for local cell production, which is typically cost-intensive, while still allowing final module assembly to be done domestically. The main difference between Asian and other markets is the labour cost.

For the markets shown in Figure 20, total module costs, including imported cells, falls by 31% in Viet Nam and as much as 47% in Germany when compared to all-domestic manufacturing.

Figure 20 Domestic PV manufacturing with imported cells from China



Notes: USD = United States dollar; Wp = watt peak; total module costs include ESG certification costs.

Table 10 presents the total module cost overview per country according to the different scenarios described above.

Table 10 Total module cost per country according to different scenarios

	Manufacturing scenario	Viet Nam	India	Australia	Germany
Total module cost in USD/Wp	All-domestic	0.180	0.191	0.256	0.284
	Imported polysilicon	0.167	0.176	0.236	0.255
	Imported wafers	0.146	0.150	0.193	0.201
	Imported cells	0.124	0.126	0.148	0.150

Notes: USD = United States dollar; Wp = watt peak.

Our analysis of the total module costs reveals that the overall price is highly dependent on the stage at which components are imported versus domestically manufactured:

- **Domestic manufacturing**: When all components (polysilicon, wafers, cells and modules) are produced domestically, the total module cost remains relatively high due to accumulated manufacturing expenses and possibly higher input costs.

- **Importing advanced components**: A notable decrease in total module cost is observed when more advanced components are imported, especially considering current market prices.

6. Conclusion

The PV supply chain cost tool is a flexible instrument designed to help users better assess the costs associated with each production component: polysilicon, wafers, cells, and panel assembly. By allowing users to choose whether to import or produce each component domestically, the tool highlights the key cost drivers at each stage.

The analysis shows that domestic manufacturing in most cases demonstrates higher costs, particularly when compared with importing components from lower-cost markets. The biggest cost reduction is observed when importing solar cells for local PV assembly, highlighting the current price advantages of established manufacturing centres.

When comparing costs across countries, Viet Nam shows the lowest manufacturing costs—comparable to China, due to its lower-cost labour and electricity tariffs. India is less competitive than Viet Nam, mainly because of its higher average electricity prices, while also benefiting from low labour costs.

In contrast, higher costs are observed for manufacturers in Australia, the United States and Germany. Compared with Asian countries, Australia has a higher manufacturing cost, driven mainly by higher electricity, labour, and building and facilities costs. In the United States, elevated labour and construction costs are key drivers, although electricity prices are relatively low, depending on the region. German manufacturers have the highest manufacturing costs observed, driven by a combination of high electricity rates, elevated labour and construction costs, and smaller economies of scale.

The tool clearly highlights the problematic relationship between short-term market dynamics and long-term industry sustainability. While low-cost imports from China enabled a rapid solar deployment by making PV systems more affordable for installers and end users, these prices are significantly lower than what is required to maintain sustainable production levels. Financial data from major manufacturers confirm that current price levels are below production costs, leading to financial strain across the value chain.

Thus, there is a need for a balanced approach: maintaining affordability to support solar adoption, but also ensuring fair market conditions for manufacturers – both domestic and international. Without some corrective action, there is a risk of deepening market distortions within the solar industry.

Several countries that have successfully developed local PV manufacturing have implemented targeted policies, which can serve as valuable examples:

- **Lowering electricity costs:** Electricity is a major operational cost for PV manufacturing, particularly for energy-intensive upstream segments, such as polysilicon and wafer production. Governments should consider measures to reduce electricity costs for the industry, such as providing preferential tariffs, incentivising onsite renewable energy generation, or supporting access to low-cost clean energy through power purchase agreements.

- **Manufacturer certification and access to low-cost finance:** Establishing clear national quality standards and a certified manufacturer list can help domestic producers access low-cost financing and build buyer confidence. The production linked incentive (PLI) scheme, adopted in India, is a good example of certification, which requires companies to meet quality benchmarks to qualify for incentives. Certification helps reduce investment risk, attract financing from banks and development agencies, and promote exports by ensuring product reliability.

- **Long-term industry strategy focused on innovation:** To build a sustainable competitive industry market, countries should invest in R&D and focus on emerging technologies where global markets are not yet dominated. This could include next-generation solar cell technologies, advanced manufacturing techniques, or specialised materials. Leveraging local strengths, such as unique resources, research institutions and skilled labour, can position the country as a leader in niche segments or technologies.

Countries can adopt hybrid strategies that combine importing of key upstream components (such as wafers or cells) with a focus on domestic assembly and module manufacturing. This approach helps balance cost competitiveness, job creation and ensure some level of security, especially where full domestic production remains uncompetitive. Since cost structures and resource endowments differ widely, policies should be carefully tailored to local economic contexts and strategic priorities. The cost tool presented here can serve as a tool to guide such strategies, helping policy makers identify which parts of the value chain to prioritise for local development.

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8. Appendices

8.1 Country index

The **country index data** provide an overview of input values used to calculate country-specific cost data. This index aggregates data from multiple sources to offer a holistic view of each country's cost difference.

Technology type: **TOPCon**

Key inputs: **Polysilicon**

Parameter	Unit	Viet Nam	Australia	China	Germany	India	United States
Installed capacity in 2025	kg	50 000	50 000	60 000	50 000	50 000	50 000
Projected installed capacity through to 2030	kg	70 000	70 000	80 000	70 000	70 000	70 000
Electricity price	USD/kWh	0.07	0.09	0.065	0.18	0.095	0.068
Average engineer salary	USD/year	9 000	67 000	14 500	65 000	8 500	69 000
Equipment costs	USD/kg	15	20	13	20	16	25
Total building and facilities costs	USD/kg	5	7	3	7	6	10

Notes: USD = United States dollar; kg = kilogramme; kWh = kilowatt hour.

Key inputs: **Wafers, cells and modules**

Parameter	Unit	Viet Nam	Australia	China	Germany	India	United States
Installed capacity in 2025	Wp	4 billion	4 billion	5 billion	200 million	4 billion	2 billion
Projected installed capacity through to 2030	Wp	6 billion	6 billion	10 billion	2 billion	10 billion	5 billion
Equipment costs for wafer	USD/kW	40	45	35	45	40	55
Equipment costs for cell	USD/kW	35	50	30	50	35	60
Equipment costs for module	USD/kW	13	20	10	20	15	25
Electricity price	USD/kWh	0.07	0.09	0.08	0.18	0.095	0.068
Average engineer salary	USD/year	9 000	67 000	14 500	65 000	8 500	69 000
Total building and facilities costs for wafer manufacturing	USD/kWp	30	55	25	55	40	60
Total building and facilities costs for cell manufacturing	USD/kWp	30	50	25	50	40	50
Total building and facilities costs for module manufacturing	USD/kWp	20	30	15	30	22	35

Notes: USD = United States dollar; kWh = kilowatt hour; kWp = kilowatt peak; Wp = watt peak.

Technology type: **Monocrystalline**

Key inputs: **Polysilicon**

Parameter	Unit	Viet Nam	Australia	China	Germany	India	United States
Installed capacity in 2025	kg	50 000	50 000	60 000	50 000	50 000	50 000
Projected installed capacity through to 2030	kg	70 000	70 000	80 000	70 000	70 000	70 000
Electricity price	USD/kWh	0.07	0.09	0.08	0.18	0.095	0.068
Average engineer salary	USD/year	9 000	67 000	14 500	65 000	8 500	69 000
Equipment costs	USD/kg	15	20	13	20	16	25
Total building and facilities costs	USD/kg	5	7	3	7	6	10

Notes: USD = United States dollar; kg = kilogramme; kWh = kilowatt hour.

Key inputs: **Wafers, cells and modules**

Parameter	Unit	Viet Nam	Australia	China	Germany	India	United States
Installed capacity in 2025	Wp	4 billion	4 billion	5 billion	200 million	4 billion	2 billion
Projected installed capacity through to 2030	Wp	6 billion	6 billion	10 billion	2 billion	10 billion	5 billion
Equipment costs for wafer	USD/kW	40	45	35	45	40	55
Equipment costs for cell	USD/kW	35	50	30	50	35	60
Equipment costs for module	USD/kW	13	20	10	20	15	25
Electricity price	USD/kWh	0.07	0.09	0.08	0.18	0.095	0.068
Average engineer salary	USD/year	9 000	67 000	14 500	65 000	8 500	69 000
Total building and facilities costs for wafer manufacturing	USD/kWp	30	55	25	55	40	60
Total building and facilities costs for cell manufacturing	USD/kWp	30	50	25	50	40	50
Total building and facilities costs for module manufacturing	USD/kWp	20	30	15	30	22	35

Notes: USD = United States dollar; kg = kilogramme; kWh = kilowatt hour; kWp = kilowatt peak.

8.2 Import costs based on the country of origin and destination

The **import costs** provide an overview of projected imported costs from China or Viet Nam to a specific destination country through to 2030. Costs were calculated by IRENA based on Woodmac projections (Wood Mackenzie, 2025).

Polysilicon in USD/Wp

Country of origin	Destination country	2025	2026	2027	2028	2029	2030
China	Viet Nam	0.011	0.020	0.022	0.022	0.021	0.021
China	India	0.011	0.020	0.022	0.022	0.021	0.021
China	Australia	0.011	0.021	0.022	0.022	0.022	0.021
China	Germany	0.011	0.021	0.023	0.023	0.022	0.022
Viet Nam	United States	0.088	0.084	0.084	0.081	0.079	0.079

Technology type: **TOPCon**

Wafers and ingots in USD/Wp

Country of origin	Destination country	2025	2026	2027	2028	2029	2030
China	Viet Nam	0.023	0.036	0.039	0.038	0.038	0.037
China	India	0.023	0.036	0.039	0.039	0.038	0.038
China	Australia	0.023	0.036	0.039	0.039	0.038	0.038
China	Germany	0.023	0.036	0.039	0.039	0.038	0.038
Viet Nam	United States	0.104	0.131	0.137	0.136	0.135	0.134

Notes: USD = United States dollar; Wp = watt peak.

Solar cells in USD/Wp							
Country of origin	**Destination country**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
China	Viet Nam	0.041	0.054	0.053	0.052	0.051	0.051
China	India	0.041	0.055	0.054	0.053	0.052	0.051
China	Australia	0.041	0.055	0.054	0.053	0.052	0.051
China	Germany	0.041	0.055	0.054	0.053	0.052	0.051
Viet Nam	United States	0.182	0.173	0.171	0.169	0.167	0.166

Notes: USD = United States dollar; Wp = watt peak.

Technology type: **Monocrystalline**

Wafers and ingots in USD/Wp							
Country of origin	**Destination country**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
China	Viet Nam	0.020	0.034	0.037	0.036	0.036	0.035
China	India	0.020	0.034	0.037	0.036	0.036	0.035
China	Australia	0.021	0.034	0.037	0.036	0.036	0.035
China	Germany	0.021	0.034	0.037	0.037	0.036	0.036
Viet Nam	United States	0.098	0.125	0.131	0.130	0.129	0.128

Solar cells in USD/Wp							
Country of origin	**Destination country**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
China	Viet Nam	0.032	0.027	0.026	0.025	0.024	0.023
China	India	0.032	0.027	0.026	0.025	0.024	0.023
China	Australia	0.032	0.027	0.026	0.025	0.024	0.023
China	Germany	0.032	0.027	0.026	0.025	0.024	0.023
Viet Nam	United States	0.146	0.138	0.133	0.129	0.124	0.122

Notes: USD = United States dollar; Wp = watt peak.

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