Building a regional solar PV value chain in East Africa

——Insights from China

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TUDelft

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By

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Executive Summary

As East African countries seek to address persistent energy poverty while positioning themselves within the global green economy, solar photovoltaics (PV) has emerged as a promising technological and industrial pathway. However, current patterns of adoption in the region remain heavily dependent on imported components, particularly from China, and are largely limited to deployment and distribution stages. This dependency not only undermines long-term energy security but also constrains the region's ability to capture industrial and employment benefits associated with the clean energy transition.

This thesis investigates the potential for East African countries to collectively establish a regional solar PV manufacturing value chain (RVC), drawing strategic insights from China's rise as the world's leading solar PV producer. It addresses the core research question: To what extent can regional cooperation help East African countries build a sustainable solar PV value chain, and how can China's experience inform this process?

The study adopts a multi-framework analytical approach, integrating the Technological Innovation System (TIS) framework, a regional integration into global value chains (GVCs) perspective informed by Bamber et al.'s competitiveness framework, and the developmental regionalism approach. These frameworks are applied sequentially across three empirical chapters.

First, through a TIS analysis of twelve East African countries, the study identifies systemic bottlenecks in the region's solar PV innovation systems. While downstream deployment is gaining momentum—especially through off-grid solutions—upstream and midstream industrial development remains limited. Functions such as knowledge development, entrepreneurial experimentation, and resource mobilization are weakly fulfilled. Kenya and Ethiopia are the only countries showing nascent manufacturing activities: Kenya through local module assembly (Solinc), and Ethiopia through foreign direct investment in cell production. Most other countries lack the institutional coordination, industrial capabilities, and policy direction needed to support solar PV manufacturing.

Second, the study applies a regional value chain lens grounded in regional integration theory and developmental regionalism to explore the feasibility of task-sharing across countries. No single East African country possesses the full set of capabilities required for a vertically integrated solar PV industry. However, several countries demonstrate complementary strengths: Rwanda, Tanzania, and Uganda possess critical mineral reserves such as tin and copper; Ethiopia offers abundant low-cost hydropower for energy-intensive processing; Kenya has the most advanced industrial infrastructure and logistics connectivity. This uneven distribution of capabilities provides a strong rationale for a coordinated regional manufacturing strategy based on functional specialization.

To operationalize this vision, the thesis proposes a regional specialization model in which upstream resource processing is concentrated in mineral-rich countries, midstream activities are sited in energy-abundant zones, and downstream module assembly and system integration is anchored in Kenya. Countries like Rwanda may also serve in support roles for certification and trade facilitation. This model not only addresses structural asymmetries but also aligns with the principles of developmental regionalism that emphasize state-led industrial cooperation and regional complementarity.

Third, the study turns to China's experience in developing a world-leading solar PV industry as a latecomer. Through catch-up theory and policy transfer analysis, the research identifies both the mechanisms behind China's success—such as sequenced industrial policy, vertical coordination, and innovation investment—and the structural differences that constrain direct replication in East Africa. Instead of wholesale policy borrowing, the thesis identifies a selective set of transferable lessons: gradual policy layering, clustering and SEZ development, quality certification systems, public-private-academic collaboration, and performance-linked incentives.

The study concludes that while East Africa faces formidable constraints—ranging from fragmented markets to underdeveloped industrial ecosystems—strategic regional cooperation presents a viable path forward. By aligning national comparative advantages and adapting selected lessons from China's experience, East African countries can collectively enter higher-value segments of the global solar PV supply chain. This will require not only targeted investment and institutional innovation, but also robust regional mechanisms to coordinate infrastructure, standards, and industrial policy.

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Acknowledgments

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This thesis also gave me the precious opportunity to explore a topic that aligns closely with my intellectual curiosity and passion for global development, sustainability, and industrial transformation. I sincerely thank the TPM faculty and MOT program staff for fostering an environment that encourages independent thinking and academic rigor.

To my family and friends, thank you for your unwavering support, encouragement, and belief in me during every step of this journey.

1 Introduction

The global energy landscape is undergoing a profound transformation, driven by the accelerated deployment of renewable energy technologies such as solar photovoltaics (PV) and wind power. These technologies are not only redefining the ways electricity is produced and consumed but are also prompting countries to reimagine the strategic implications of energy systems in the post-fossil fuel era. Beyond their potential to improve access and reliability for end users, the rise of renewables has added a new dimension to long-standing concerns around energy security.

In the past, geopolitical power in the energy domain was concentrated in the hands of fossil fuel exporters such as OPEC member states, US and Russia, who controlled the global supply of oil and gas. Today, a similar form of concentration is emerging in clean energy supply chains. Unlike fossil fuels, solar and wind energy draw from widely distributed natural forces that are inherently less susceptible to direct geopolitical manipulation. However, the technologies that enable this transition—especially solar PV—are deeply embedded in globalized manufacturing supply chains. In the case of solar PV, China has become the dominant manufacturer of key components—from polysilicon to wafers and cells—accounting for over 80% of global production (SAPVIA, 2024). On the one hand, China's industrial scale and cost efficiencies have played a pivotal role in driving down PV system prices, making solar electricity more affordable worldwide (IEA, 2022b). On the other hand, this concentration has raised concerns in the rest of the world about excessive reliance on Chinese imports for their clean energy ambitions, sparking debates over supply chain diversification, domestic manufacturing, and industrial sovereignty (IEA, 2022b; SAPVIA, 2024).

East Africa is one of the regions most heavily dependent on imported solar PV modules. In recent years, countries across the region have increasingly adopted distributed solar PV systems to meet rural electrification needs, significantly boosting demand for solar modules and driving a surge in imports (Cross et al., 2021). While this growth has improved energy access, the sector's reliance on foreign components exposes it to external risks such as supply chain disruptions and price volatility (IEA, 2022b). These vulnerabilities highlight the strategic importance of strengthening local production capacity.

Developing a localized regional value chain could mitigate these risks by reducing exposure to global market shocks and ensuring a more stable, resilient supply of solar products to meet long-term electrification goals. Beyond energy security, local production could also directly address the region's acute energy poverty. According to the IEA (2022a), over 600 million people in Africa—43% of the population—still lack access to electricity. Locally manufactured solar systems can accelerate rural electrification by reducing dependence on imports and enabling faster deployment of off-grid solutions.

Furthermore, local solar manufacturing offers a pathway to alleviate unemployment. World Bank data show that East African countries such as Kenya, Rwanda, and Somalia face unemployment rates exceeding 10%, with youth unemployment even higher (World Bank, 2025). As a labor-intensive segment of the clean energy sector, solar PV manufacturing presents considerable potential for job creation—particularly for low- and medium-skilled workers. Industrial assessments suggest that building 1 GW of crystalline silicon (c-Si) solar module capacity per year could generate up to 1,300 full-time manufacturing jobs—spanning activities from polysilicon and ingot production to module assembly and auxiliary materials like glass, back sheet, and EVA (IEA, 2022b).

In sum, promoting domestic solar PV manufacturing in East Africa is not merely an energy strategy. It represents a triple-win solution—enhancing supply chain resilience, expanding electricity access, and generating employment. With targeted investment, the region can unlock the full economic and social potential of its solar resources.

However, given the technical complexity and high capital acquirements across the solar PV value chain (Basore, 2022), it is difficult for any single East African country to establish complete vertical integration from beginning. A more feasible approach may involve regional cooperation, where countries implement mutually beneficial policies to support one another, leverage their respective strengths, and enhance intra-regional trade and knowledge sharing.

This thesis explores whether such regional cooperation could enable East African countries to specialize in specific segments of the solar PV value chain, thereby collectively building a more resilient and competitive regional solar PV industry. Given China's achievements in developing its solar PV industry as a late-comer, this study will also examine China's successful practices and critically assess their transferability and potential adaptation for East

Africa's solar sector development with special consideration to this region's skills base and infrastructure constraints.

1.1 Contextual Background

To understand the feasibility and strategic rationale for building a regional solar PV value chain in East Africa, it is essential to first situate the region within the broader global context. This section provides the necessary background by outlining the current structure of the global solar PV value chain, identifying the key enabling conditions required to compete across its major manufacturing segments, and assessing the current state of solar PV development in East Africa. Together, these subsections establish the contextual foundation for the subsequent analysis in Chapters 2 through 7.

1.1.1 Current Solar PV Global Value Chain

Solar PV technology is increasingly viewed as a cornerstone of global decarbonization efforts, offering a low-cost, modular solution to rising electricity demand and climate mitigation goals. There are two mainstream technologies in the global solar PV market, namely crystalline silicon (c-Si) modules and thin-film PV technology. Currently, c-Si PV dominates the market with a 95% share compared to thin-film's 5% (IEA, 2022b). Given c-Si PV's market predominance and well-established supply chain, this thesis will primarily focus on it.

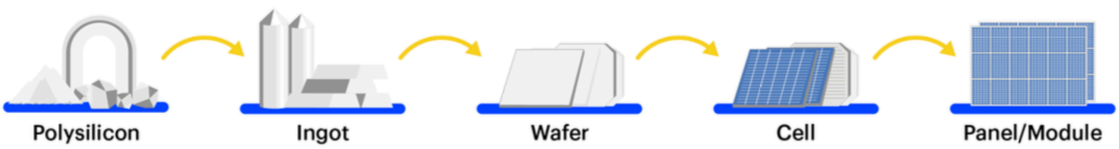


Figure 1 – Key Stages in the Main Manufacturing Process for solar PV
Source: IEA, 2022b

The simplified key stages in the main manufacturing process for c-Si solar PV are illustrated in Figure 1. The primary input material for polysilicon is metallurgical-grade silicon (MGS), a commodity material produced from high-grade quartz. About 12% of the world's MGS is refined to make high-purity polysilicon for the solar supply chain (Basore, 2022). Among the many techniques for producing polysilicon, the Siemens process leads the market with over 90% share, followed by the fluidized bed reactor (FBR) method with approximately 3% to 5%.

The polysilicon is melted at 1410°C in a crucible designed to minimize contamination, then solidified to grow a rectangular-block ingot comprised of centimeter-sized crystals or a single-crystal cylindrical ingot (Basore, 2022). There are two primary methods for manufacturing PV wafers from polysilicon: the continuous-Czochralski (Cz) process for monocrystalline wafers and the directional solidification (DS) process for multicrystalline wafers (as shown in Figure 2 and Figure 3).

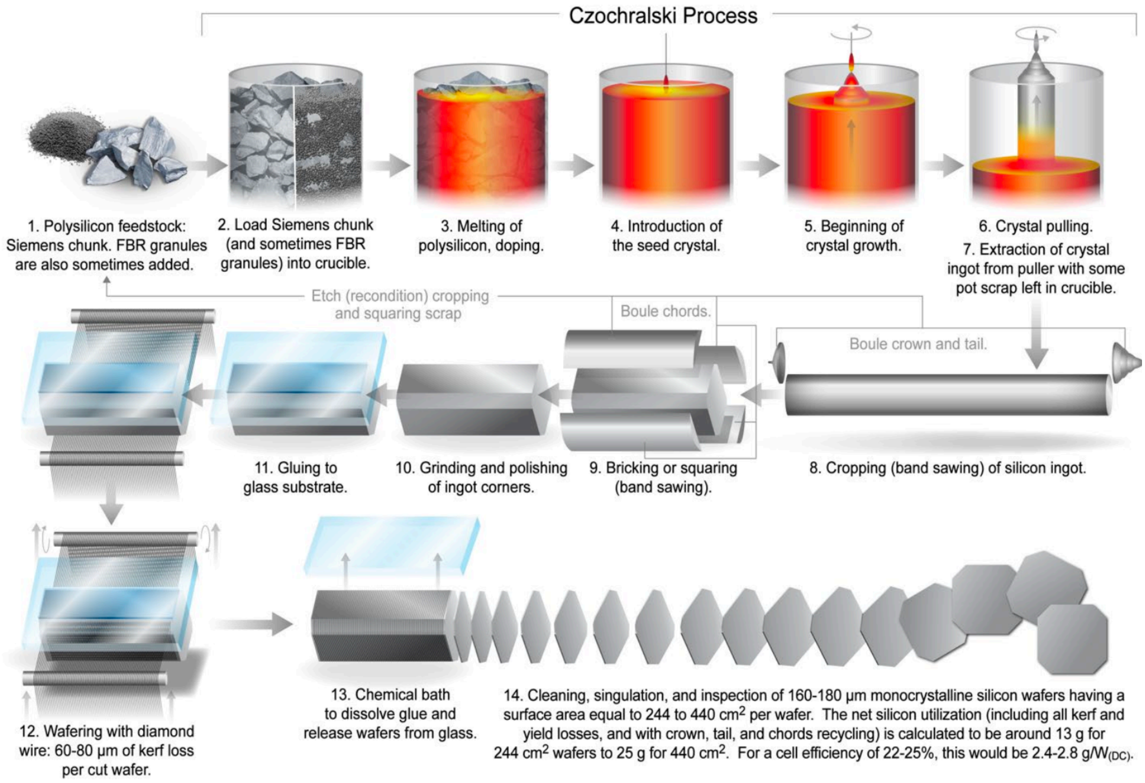


Figure 2 - Process flow for making monocrystalline-silicon wafers via Cz crystal growth
Source: US NREL

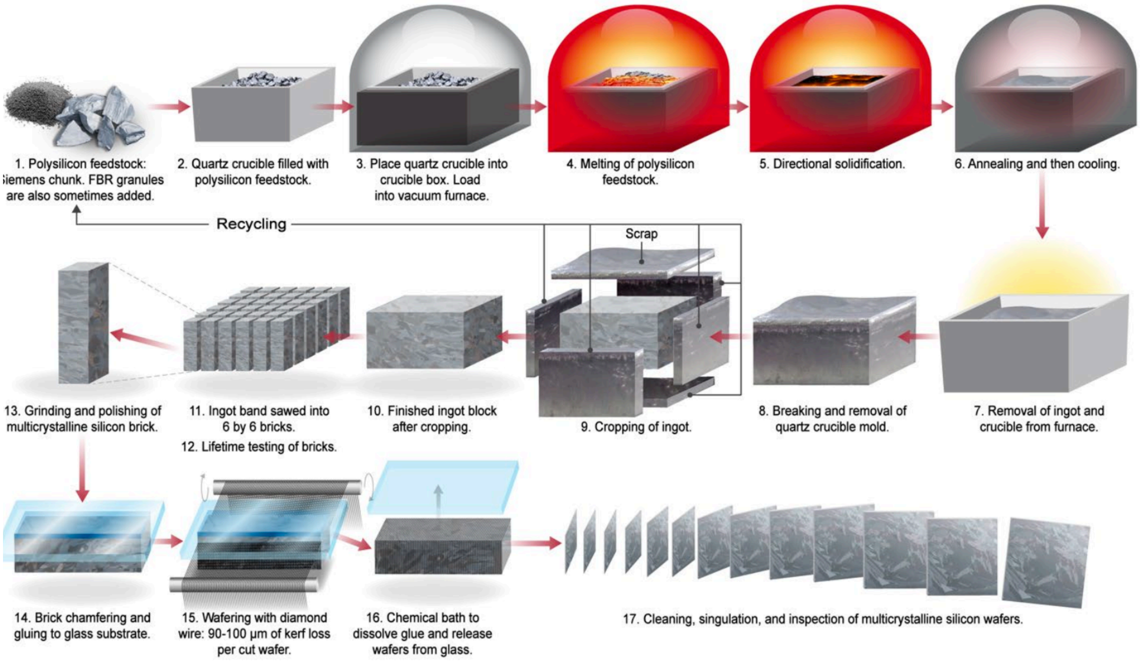


Figure 3 - Process flow for making multi-crystalline-silicon wafers via directional solidification
Source: US NREL

Wafers are converted into solar cells through a series of wet chemical treatments, high-temperature gaseous diffusion, coating depositions, and metallization steps. The steps and the tools used vary based on the cell architecture. In 2018, the passivated emitter and rear cell (PERC) took place of the full-area aluminum back surface field (AL-BSF) as the dominant cell structure in the market due to its efficiency advantage (Basore, 2022; IEA, 2022b).

Module assembly involves connecting individual solar cells into series (strings), combining multiple strings in parallel to form an array, and linking them with metallic ribbons. This array is placed on a layer of encapsulant over a sheet of glass or a backsheet. Another encapsulant layer and a front glass sheet are then laminated on top, sealing the entire structure. The encapsulant, typically a thermoplastic, melts during lamination to bond and protect the components. The metallic ribbons are routed through an opening in the backsheet or rear glass and connected within a junction box, which includes bypass diodes to manage cell mismatch and serves as the system's external connection point. Finally, an aluminum frame is installed around the module's edges for structural support (Basore, 2022). This process is shown in Figure 4.

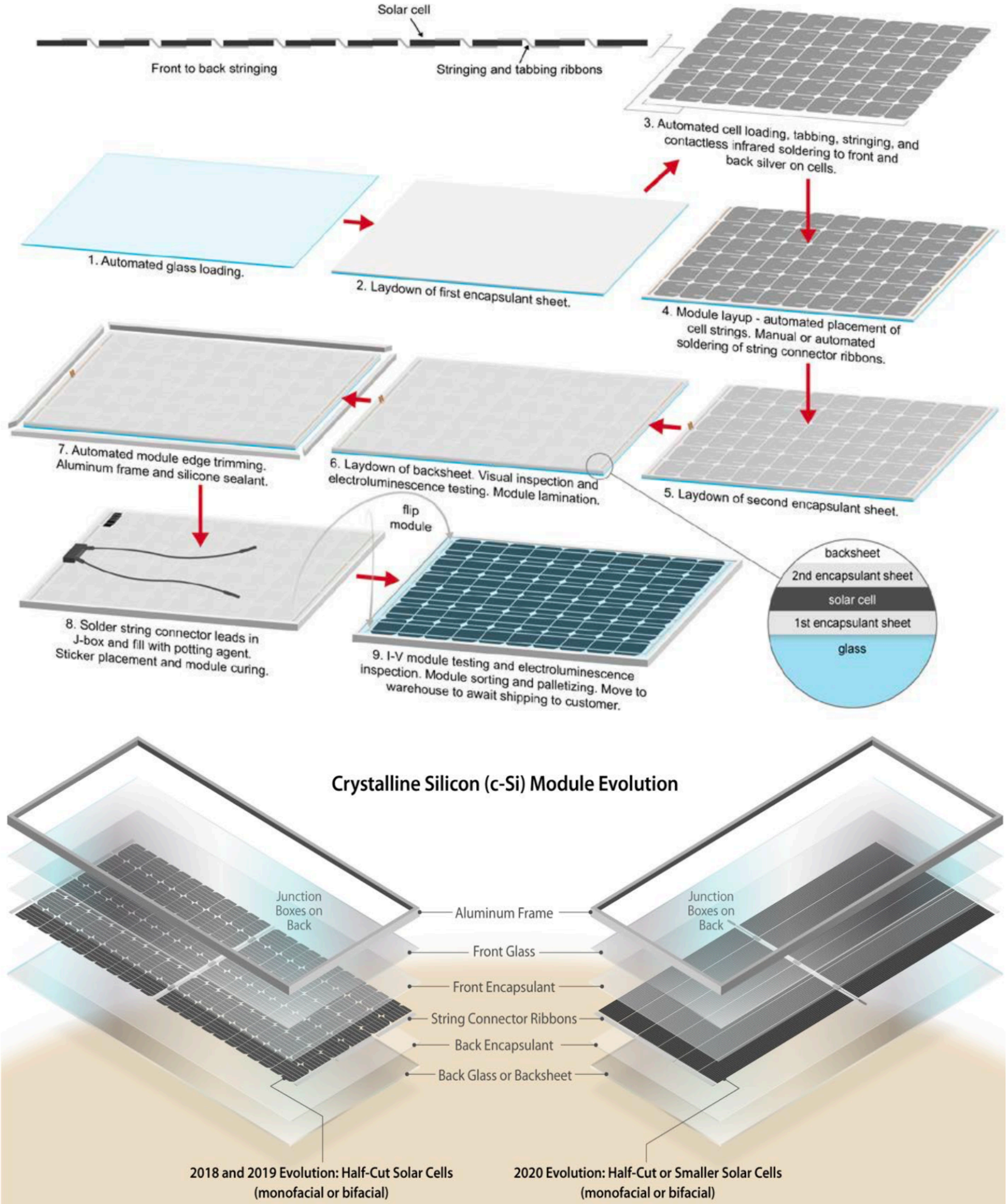


Figure 4 - Process flow (top) and finished product (bottom) for standard 60-cell monocrystalline-silicon module assembly
Source: US NREL

IEA report (2022b) estimates indicate that raw materials account for approximately 35% to 50% of the total cost of a solar PV module (as of 2021). Although glass, aluminum, and polymer-based materials dominate in terms of module weight, it is the small quantities of critical minerals—particularly silver and polysilicon in crystalline silicon (c-Si) modules—that drive the bulk of material costs. For example, as shown in Figure 5, despite comprising less than 5%

of a module's weight, silver paste and monocrystalline silicon wafers can represent nearly two-thirds of the raw material costs (IEA, 2022b).

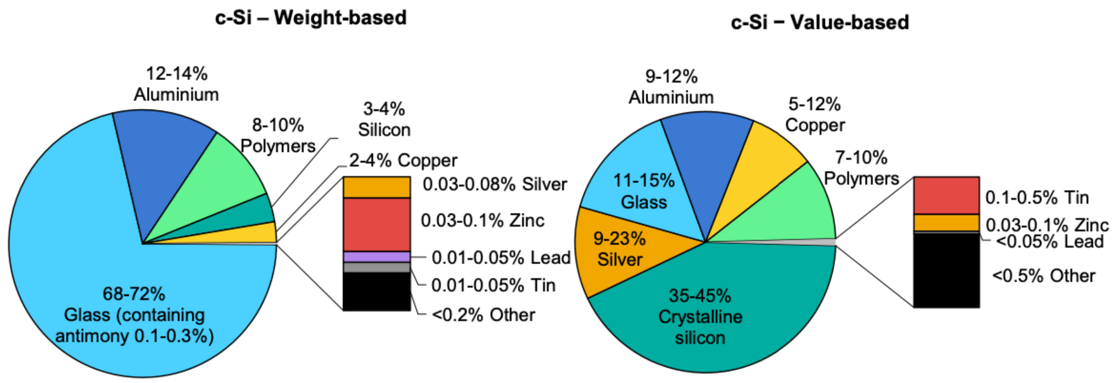


Figure 5 – Material composition shares of crystalline silicon solar PV modules by weight and average value, 2021
source: IEA, 2022b

The following table outlines the main raw materials used in crystalline silicon (c-Si), along with their respective main uses.

Table 1 – The Uses of Main Materials in c-Si solar PV Manufacturing

Material	Main uses
Aluminum	Module frame; mounting structure; connectors; back contact; inverters
Antimony	Solar-grade glass (used to reduce the long-term impact of ultraviolet radiation on the solar performance of glass) and encapsulant (used as a polymerization catalyst)
Copper	Cables, wires, ribbons, inverters
Glass	Module cover
Indium	Transparent conducting layer (indium tin oxide [ITO]) in silicon heterojunction (SHJ)
Lead	Soldering paste and ribbon coating in c-Si modules
Silicon	c-Si wafers; in the form of high-purity quartz (HPQ), for crucibles to grow monocrystalline silicone ingots via the Czochralski process
Silver	Electronic contacts: silver paste, busbars and soldering
Tin	Solder, ribbon coating in c-Si modules
Zinc	Galvanized steel in mounting structures

Source: IEA (2022b)

Apart from raw materials, each stage of the solar PV value chain also requires initial capital expenditure. According to the U.S. National Renewable Energy Laboratory (NREL), the polysilicon segment in the c-Si value chain has the highest upfront cost, ranging from $110-140M per GW. This includes equipment and the factory's balance-of-plant, which encompasses all auxiliary systems and infrastructure needed to support the core power generation equipment such as inverters, transformers, and control systems. It typically takes 3 to 4 years to build a polysilicon plant. Other segments in c-Si value chain usually requires less than $ 100M in initial investment, with construction times between 1 and 3 years (as shown in Table 2). Specific costs and time-to-build vary depending on factors such as land rent, building material costs, energy costs, policy incentives, labor costs and workforce productivity in the chosen location (Basore, 2022).

Table 2 - Fixed Cost Drivers Across the c-Si and CdTe Supply Chain

Fixed Cost Drivers	c-Si Supply Chain				CdTe Module Production
	Polysilicon	Ingot and Wafer	Cell Conversion	Module Assembly	
Initial Capital Expenditure ($USD per Watt of annual capacity)	$0.11-0.14/W ($40—50/kg, 2.8 g/W)	$0.08-0.10/W ($0.54/wafer, 6.0 W for M6)	$0.05-0.13/W (PERC to Advanced technology)	$0.05-0.08/W (Standard to Busbarless)	$0.28-0.36/W (430-W series)
for equipment:	$0.06—0.08/W	$0.06—0.07/W	$0.03—0.10/W	$0.03—0.05/W	$0.25—0.30W
for balance-of-plant or factory	$0.04—0.06/W	$0.02—0.03/W	$0.02—0.03/W	$0.02—0.03/W	$0.03—0.06/W
1 GW_{dc} Investment	$110—140M	$80—100M	$50—130M	$50—80M	$280—360M
for equipment:	$65—80 M	$60—70 M	$30—100M	$30—50M	$250—300M
for balance-of-plant or factory	$45—60 M	$20—30 M	$20—30M	$20—30M	$30—60M
Time to Build (Engineering to production)	3—4 years (All-new, not retrofit)	1—3 years	1—3 years	1—3 years	1—3 years

Source: US NREL

Besides the benefit of supporting energy system upgrades, the solar PV industry also creates significant employment opportunities. According to IEA (2022b), the number of jobs per GW of manufacturing capacity varies across the c-Si supply chain. As shown in the Figure 6, job intensity increases from upstream to downstream stages. Upstream segments like polysilicon and wafer/ingot production, which are more standardized and highly automated, create fewer than 300 jobs per GW. In contrast, cell production and module assembly have greater job creation potential, accounting for 32% and 44% of employment in the existing supply chain, respectively.

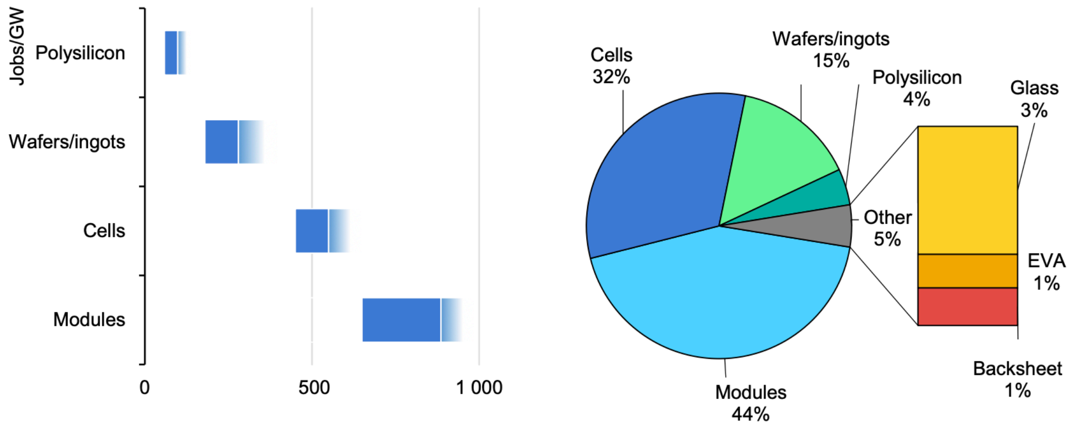


Figure 6 – Jobs per GW of Manufacturing Capacity and Share of Jobs per Supply Chain Segment
Source: IEA, 2022b

Currently, two major barriers limit other countries from entering the solar PV value chain. The first is China's market dominance, and the second is the vertically integrated nature of the cell industry, which makes it difficult to develop isolated segments without the benefits of a local industrial cluster (Basore, 2022). Nowadays, China holds more than 80% of global capacity across all major stages of production. In particular, it accounts for 97% of ingot and wafer manufacturing, which is achieved through economies of scale, supply chain integration, continuous innovation, and strong government support (IEA, 2022b). This concentration has left little room for other players to gain a meaningful share of the market.

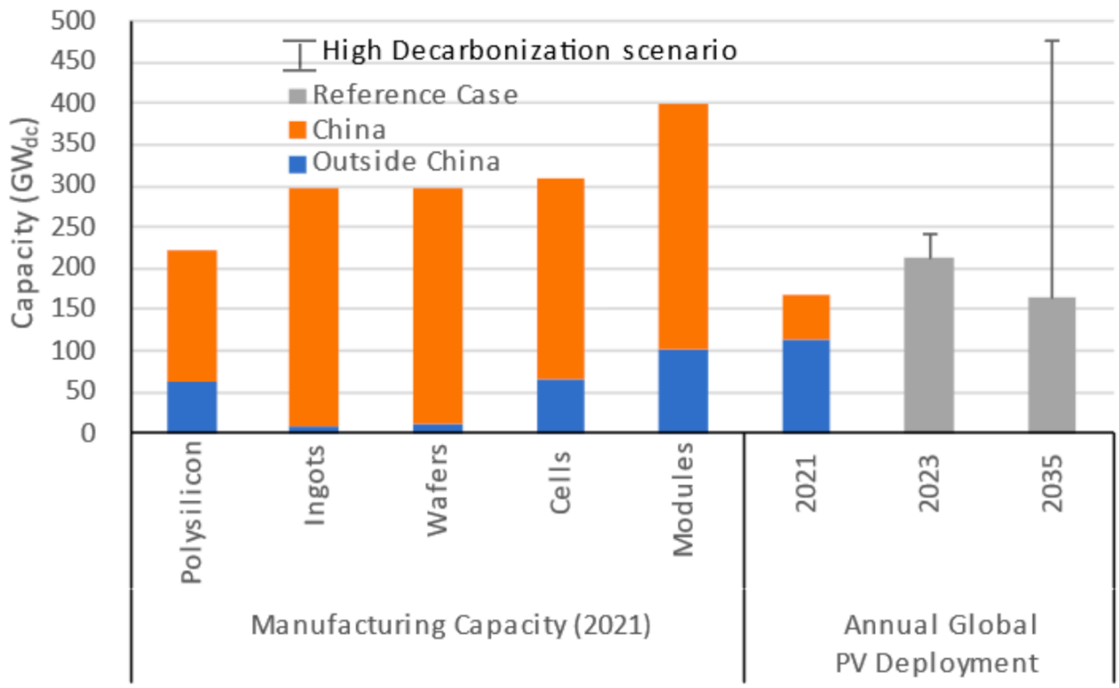


Figure 7 -PV Manufacturing Capacity and Deployment, inside and outside China
Source: Basore, 2022

In contrast, module assembly is more geographically dispersed (as shown in Figure 7 and Figure 8). This segment has the largest global manufacturing capacity but also the lowest plant utilization rates among all parts of the supply chain. The reasons are that module assembly requires only moderate capital investment and relatively low technological complexity. Additionally, low cell prices, the possibility of sourcing components such as frames, glass, and wiring locally, along with trade restrictions and policy incentives, have encouraged many countries to develop local assembly lines (IEA, 2022b). As a result, 38 countries had some module assembly capacity by 2021, the highest number across all stages of PV manufacturing. However, in many cases, these investments were limited in scale or remained at a pilot level, with only 19 countries achieving an annual capacity of at lEast 1GW (IEA, 2022b).

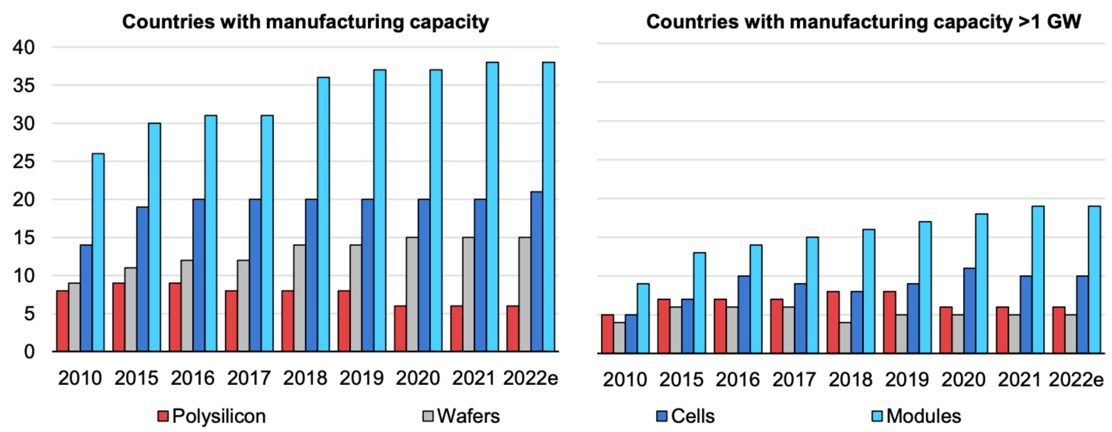


Figure 8 – Number of Countries with Manufacturing Capacity across the PV Value Chain
Source: IEA, 2022b

The other reason other countries struggle to enter the solar PV value chain is the strong advantage created by vertical integration in existing manufacturing hubs, particularly in China. Solar cell production is often collocated with wafer and module manufacturing (as shown in Figure 9), allowing firms to capture synergies in production, reduce logistics costs, and benefit from captive demand and economies of scale (Basore, 2022). According to BloombergNEF, as of July 2021, 27% of global cell manufacturing capacity was collocated with wafer production, and 61% with module production (BloombergNEF, 2021). This level of integration significantly reduces marginal costs and improves supply chain efficiency, which gives established manufacturers a strong competitive edge, making it difficult for new entrants to succeed by building just a single segment in isolation.

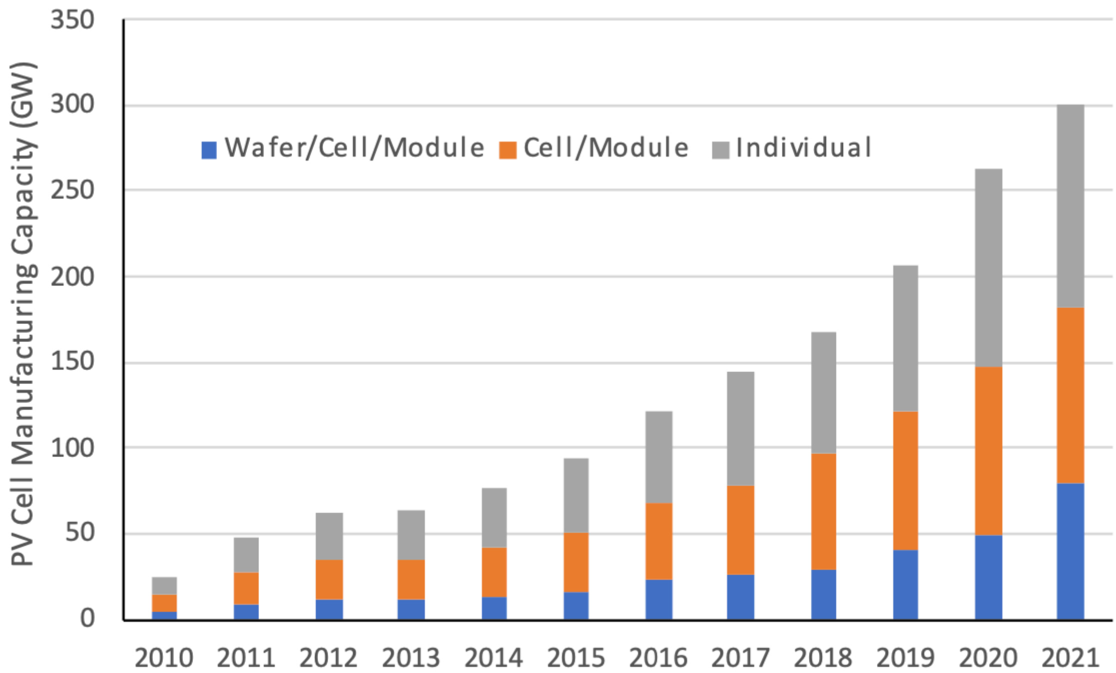


Figure 9-Co-location of Cell Manufacturing with Wafer and Module Manufacturing
Source: BloombergNEF, 2021

1.1.2 Key Enablers for Solar PV Manufacturing by Segment

Countries seeking to build competitive solar PV industries must consider the unique resource requirements, cost structures, and entry barriers across each segment of the manufacturing value chain. Drawing on the IEA's and US DOE's in-depth supply chain assessments (IEA, 2022b; Basore, 2022), this section identifies the key comparative advantages needed for each stage of production—from raw material extraction to module assembly.

Raw Materials: Competitive Access to High-Purity Quartz and Low-Cost Energy

The initial stage of the solar PV value chain begins with the production of metallurgical-grade silicon (MG-Si) from high-purity quartz (as shown in Figure 10). This segment relies heavily on natural endowments—specifically, accessible quartz deposits with high-purity levels—as well as cheap and reliable electricity due to the energy-intensive nature of silicon smelting. Figure 11 maps the world's major producers of Silicon as of 2022, with China overwhelmingly leading global output, followed by Russia, Brazil, and the US. The carbothermic reduction process requires 10–15 MWh of electricity per ton of MG-Si produced (Basore, 2022). Consequently, countries with abundant low-cost energy sources possess an advantage.

Additionally, the availability of supporting inputs like low-ash coal or charcoal (Basore, 2022), and domestic refining capacity, may further reduce dependence on global supply routes. In this segment, infrastructure and services (particularly energy and logistics) and natural resource endowments play a dominant role in shaping competitiveness.

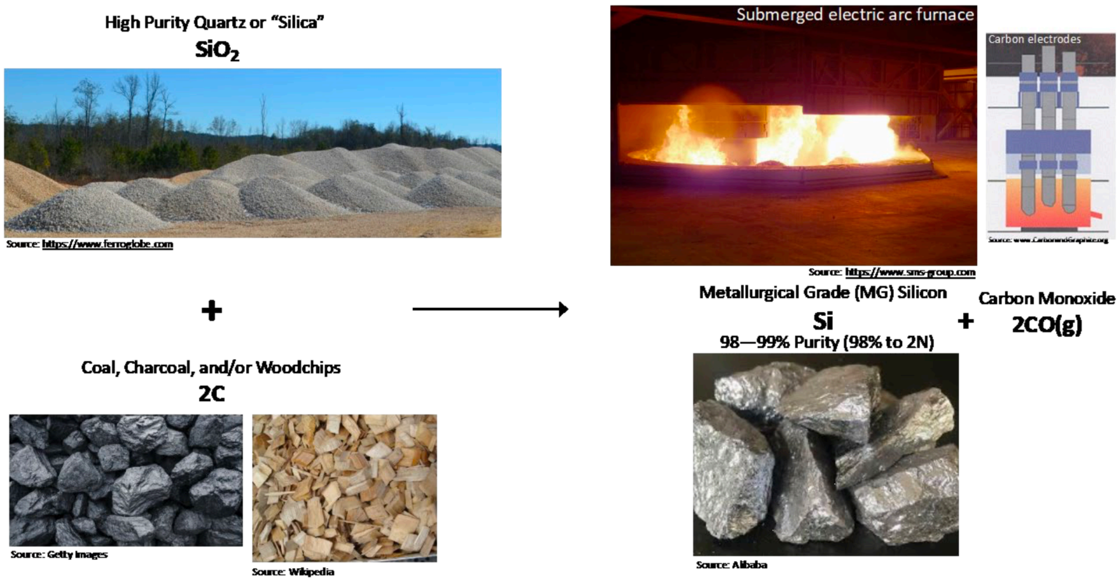


Figure 10 - Principal input materials and process for MGS production
Source: US NREL

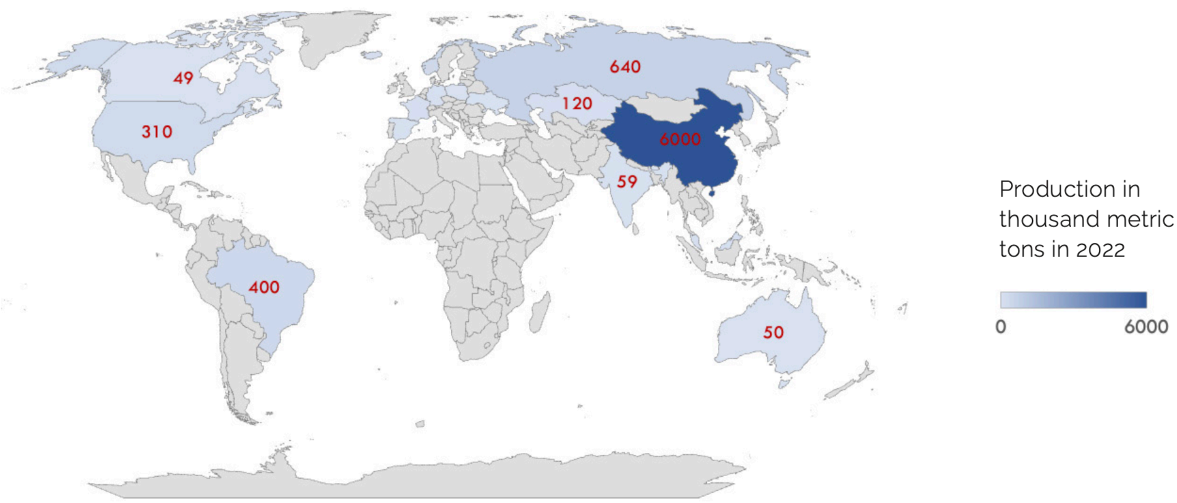
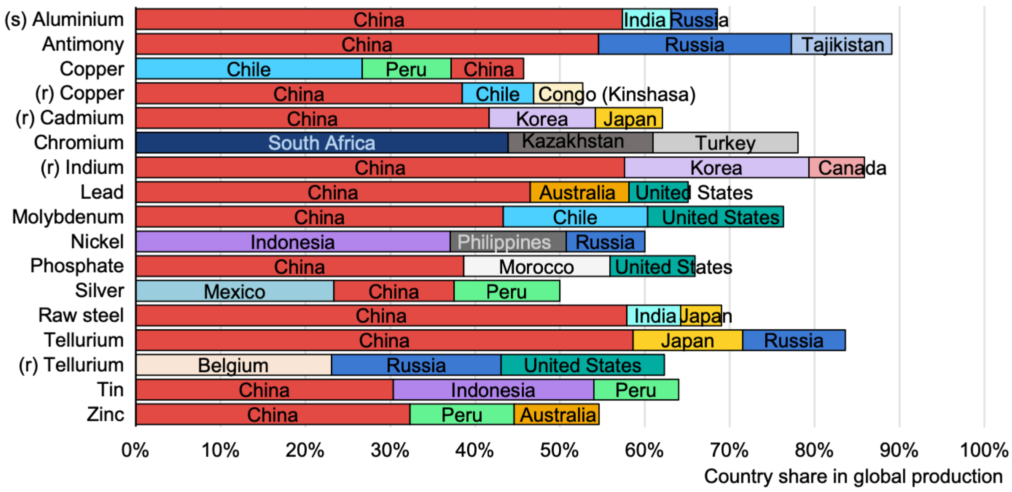


Figure 11 – Major silicon producers in 2022
Source: Ndubuisi and Avenyo, 2024

In addition to high-purity quartz, the broader solar PV manufacturing chain relies on a range of mineral inputs—such as copper, silver, aluminum, tin, and indium—for wiring, soldering, frames, and transparent conductive layers. However, global production of these minerals is highly concentrated, often dominated by a handful of countries. As illustrated in Table 3 and Figure 12, China alone is the leading producer of more than half of the critical minerals used in solar PV manufacturing, including antimony, indium, lead, aluminum, and raw steel. In some cases, its share exceeds 60–70% of global output.



Notes: (s) = smelter production. (r) = refinery production. Other values correspond to mine production.

Figure 12 -Top three producing countries' shares in global production of selected minerals used for solar PV manufacturing, 2021
Source: USGS, 2022

Table 3 – Top three producing countries in global production of Main Materials in c-Si solar PV Manufacturing

Material	Top three producing countries
Aluminum	China, India, Russia
Antimony	China, Russia, Tajikistan
Copper	Chile, Peru, China
Copper (refined)	China, Chile, Congo (Kinshasa)
Indium	China, Korea, Canada
Lead	China, Australia, United States
Silicon	China, Russia, United States
Silver	Mexico, China, Peru
Tin	China, Indonesia, Peru
Zinc	China, Peru, Australia

Polysilicon: Energy Efficiency, Electricity Costs, and Exposure to Price Volatility

The purification of polysilicon via the Siemens process is the most energy-intensive stage of the entire solar PV manufacturing chain (as shown in Figure 13 and Figure 14). According to IEA (2022b), electricity accounts for approximately 41% of total production costs in this segment, with energy demand exceeding 100 MWh per ton of output (Basore, 2022). Thus, low-cost, stable electricity—preferably with low carbon intensity—is an indispensable comparative advantage. This makes infrastructure & services, particularly stable and low-cost electricity, the single most important enabling factor at this stage.

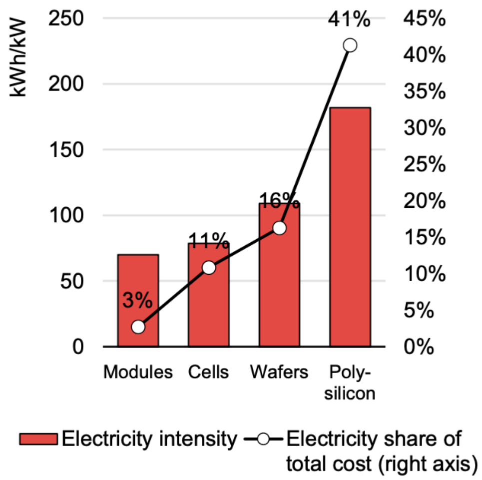
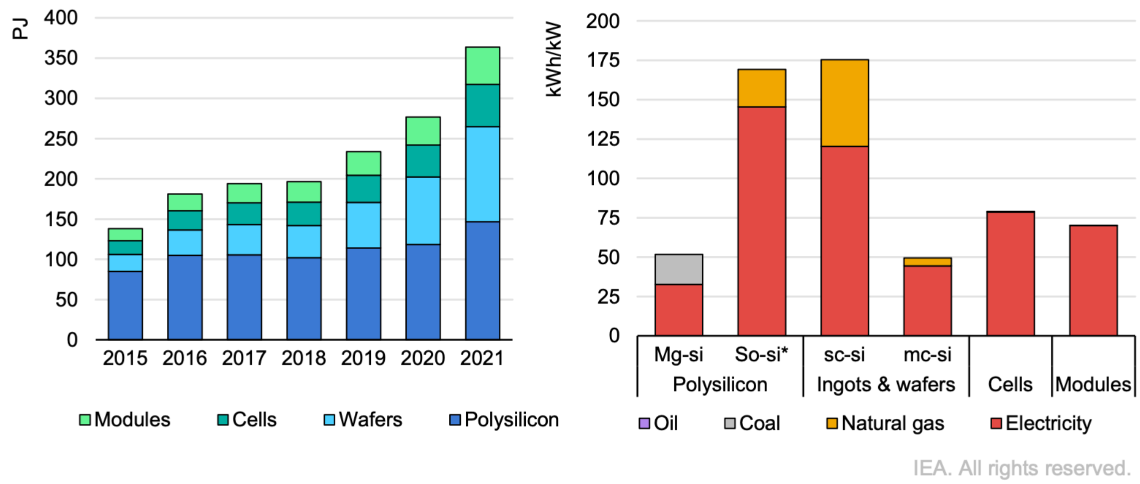


Figure 13 - Electricity Intensity and Share of Electricity in Production Costs by Segment
Source: IEA, 2022b



Notes: Mg-si = metallurgical-grade silicon. So-si* = solar-grade silicon using the Siemens process. sc-si = monocrystalline wafers. mc-si = multicrystalline wafers.

Figure 14 - Energy consumption of solar PV manufacturing by segment, 2015-2021 and energy intensity per segment
Source: IEA, 2022b

Polysilicon markets have also experienced extreme price volatility. Notably, between 2020 and 2021, prices quadrupled, rising from below $10/kg to over $35/kg (IEA, 2022b). For countries reliant on imported polysilicon, this creates strong sensitivity to import tariffs and other trade-related costs. Therefore, trade policy (tariff regimes, local content rules) becomes highly consequential. In sum, this stage requires competitive infrastructure and services (energy), favorable trade and investment policy, and macroeconomic stability to attract long-term capital.

Ingots and Wafers: Scale, Co-location, and Infrastructure Synergies

The production of silicon ingots and wafers is also energy- and capital-intensive. Ingot crystallization using the Czochralski method requires continuous high-temperature operation lasting over 100 hours per ingot, while wafering involves high-precision sawing with diamond wire and generates substantial material loss (Basore, 2022). Electricity accounts for roughly 20% of production costs at this stage, making energy pricing and reliability critical (IEA, 2022b).

Moreover, cost competitiveness is also strongly influenced by economies of scale and infrastructure connectivity. China's near-total dominance in this segment—accounting for 97% of global wafer production—is partly attributed to its ability to co-locate wafer plants with upstream (polysilicon) and downstream (cell) facilities, minimizing transport costs and transaction frictions (Basore, 2022; IEA, 2022b). Efficient transportation logistics, access to specialized machinery, and timely delivery of consumables such as diamond wire are essential. Furthermore, establishing such facilities demands long-term financing, robust industrial infrastructure, and policy coherence.T

Solar Cells: Skilled Workforce, Process Stability, and Innovation Absorption

Solar cell manufacturing is moderately capital- and technology-intensive. It involves a series of precision steps such as doping, diffusion, passivation, and metallization—each requiring cleanroom environments, advanced automation, and tight process control (Basore, 2022). While production costs per watt have declined due to improved throughput and line standardization (e.g., PERC cell lines), successful operation still relies on technically skilled labor and stable industrial infrastructure.

Unlike earlier segments that are driven primarily by energy and materials cost, competitiveness in cell manufacturing is more dependent on productive capacity, particularly in the form of human capital and absorptive capacity for foreign technology. As noted by the IEA (2022a), developing economies seeking to localize this stage must be able to adopt turnkey cell production lines and rapidly build technical competencies through training programs, partnerships, or joint ventures.

Module Assembly: Labor Availability, Policy Incentives, and Market Access

Module assembly represents the most accessible manufacturing segment within the solar PV value chain in terms of capital and technical complexity. While it does not require cleanroom environments or high-precision equipment, success in this stage depends heavily on the availability of semi-skilled labor, stable policy incentives, and access to regional demand hubs (IEA, 2022b).

Labor intensity is a key feature: every gigawatt of module assembly capacity can create 500–700 direct jobs—more than any other manufacturing segment (IEA, 2022b). Therefore, productive capacity, particularly in the form of scalable human capital and basic factory training, plays a central role. Moreover, since most upstream materials (cells, EVA, glass, frames) are imported in many countries, the viability of module production is also strongly shaped by trade and investment policies, including import duties, VAT exemptions, and local content requirements (Basore, 2022).

1.1.3 Solar PV in East Africa

Since its emergence in the mid-20th century, solar PV technology has played an increasingly important role in global energy transitions. In many parts of the world, it has contributed not only to cleaner and low-carbon electricity supply on the consumption side, but also new opportunities for value creation through manufacturing and industrial development. While the potential of solar energy is vast and geographically widespread, the ability to capture its benefits remains uneven across regions. East Africa is a case in point.

This study adopts the African Development Bank's (AfDB) classification of East Africa, which includes twelve countries: Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Seychelles, Somalia, South Sudan, Tanzania, and Uganda. Their geographic locations are shown in the map below.

Figure 15 – Geographic Distribution of East African Countries as Defined by the AfDB

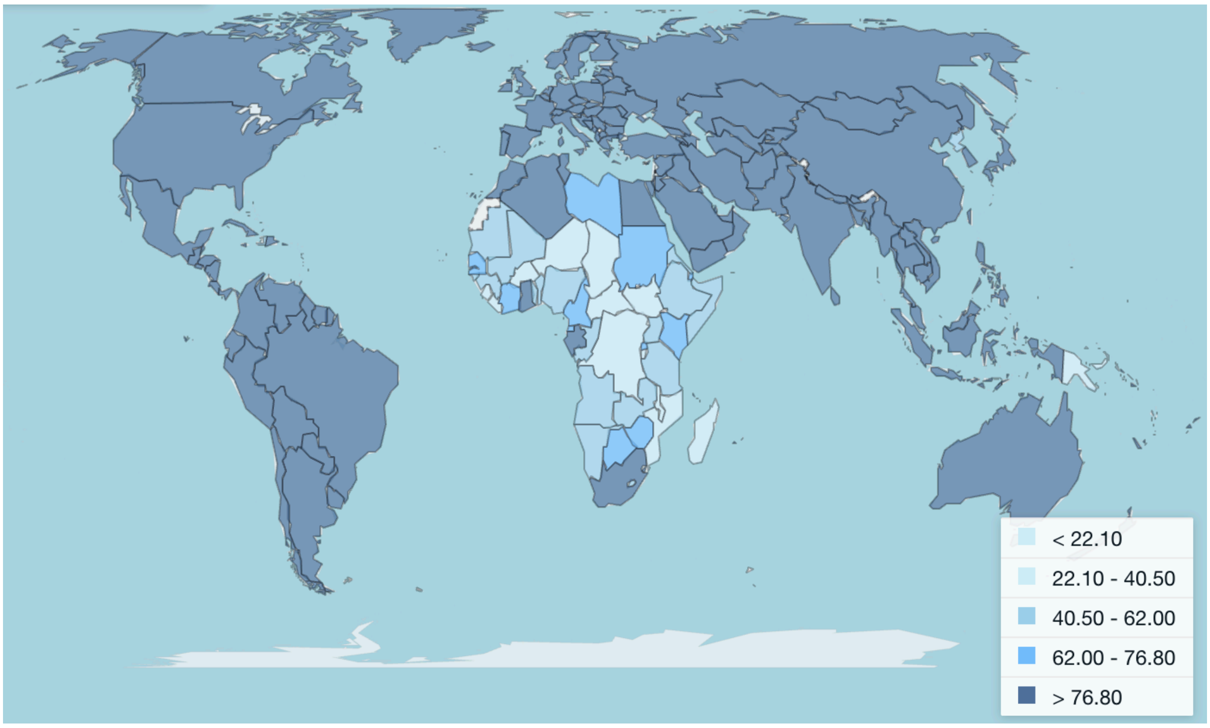


Figure 16 – Global access to electricity (% of population)
Source: World Bank, 2023

Access to electricity remains a persistent challenge across East Africa (as shown in Figure 16 with the comparison to the rest of the world). In many rural areas, households are not connected to the national grid, and even in urban centers, power supply is often unreliable and costly (LightingGlobal, 2020). At the same time, the region benefits from abundant solar irradiation, typically ranging from 2000 to 2500 kWh/m^2 per day (IEA, 2024), making it one of the most solar-rich areas in the world (as shown in Figure 17) and suited for solar energy applications. In this context, off-grid solar PV systems have emerged as a relevant option for improving electricity access, particularly in areas where grid infrastructure remains limited or underdeveloped (LightingGlobal, 2020).

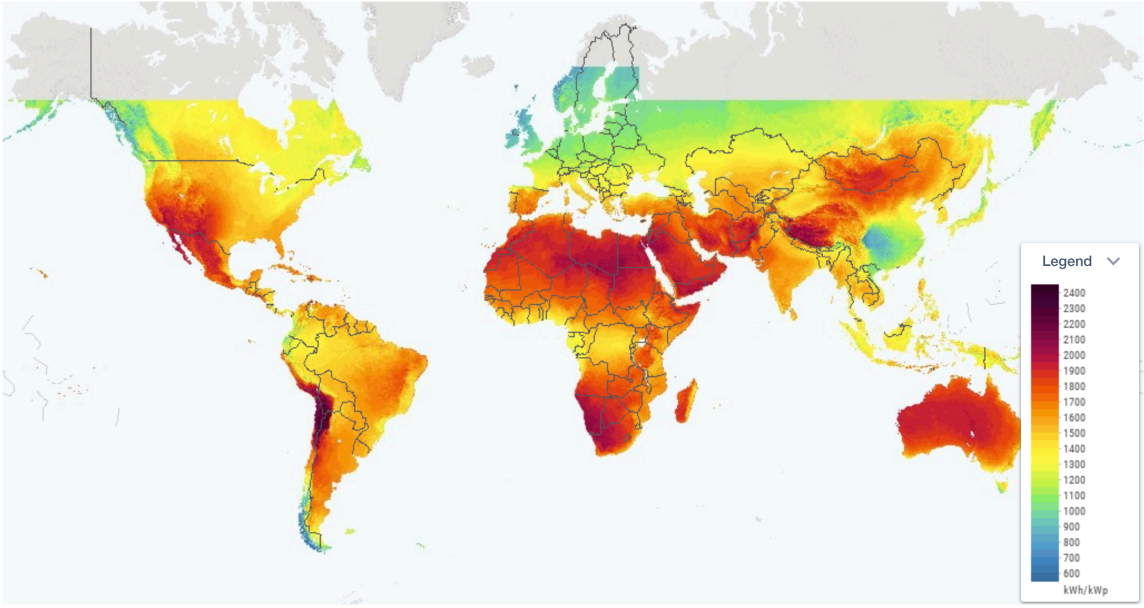


Figure 17 - Global Solar Radiation Map
Source: Global Solar Atlas

From the perspective of energy consumption, the current deployment of solar PV in East Africa remains limited despite the region's favorable solar irradiation. While solar energy offers a clear solution to the region's electricity access challenges, actual adoption levels are still far from sufficient. According to data from the International Renewable Energy Agency (IRENA), the African continent as a whole accounted for just 0.8% of global installed solar PV capacity in 2025 (as shown in Figure 18). Given that most of this capacity is concentrated in North and Southern Africa, East Africa's share is even smaller.

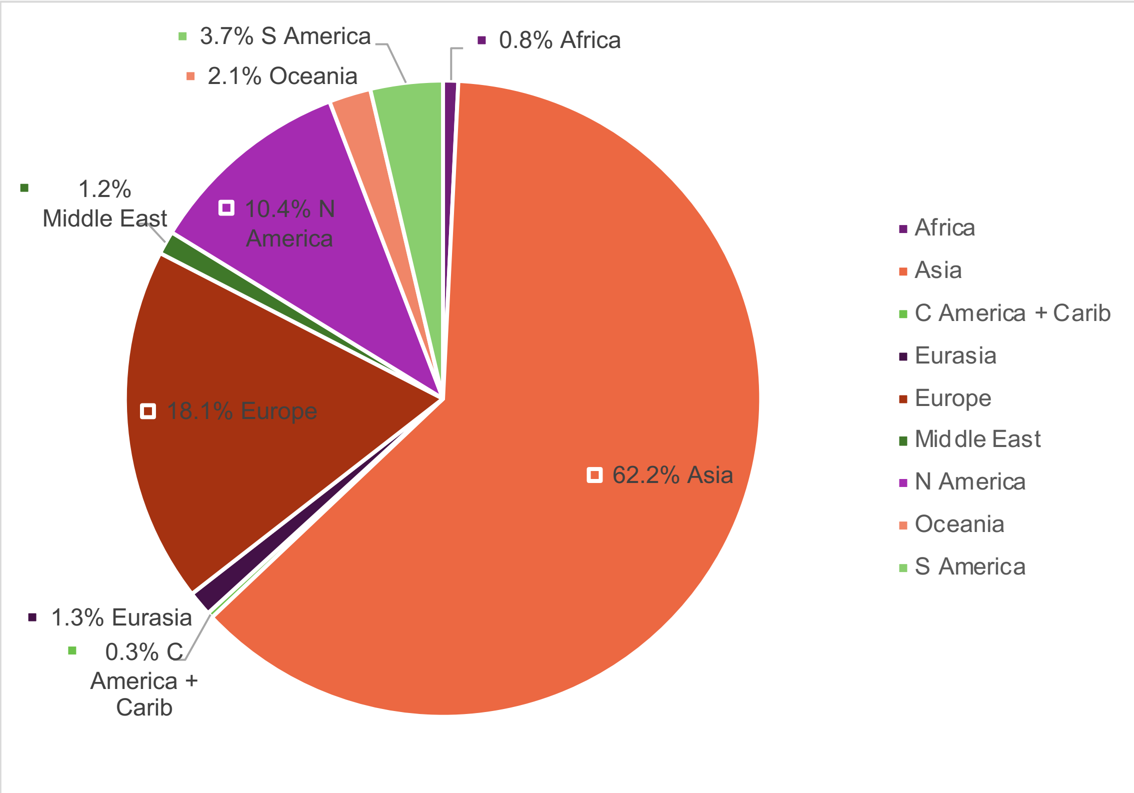


Figure 18 – Global Solar PV Installed Capacity
Source: IRENA, 2025

This disconnect between high solar potential and limited deployment points to deeper structural challenges. The region's growing demand for solar energy is not matched by its capacity to supply the necessary technologies. At present, nearly all PV hardware is imported, mostly from Asia (Development Reimagined, 2024). A set of downstream activities-such as distributing, installing and maintaining solar systems-has gradually taken shape, but local manufacturing is limited to a few module assembly operations, such as Solinc in Kenya (Davy *et al.*, 2024). These activities capture only a small portion of total value. This import dependency leaves the region exposed to global supply fluctuations and restricts its ability to retain value domestically.

As demand for solar solutions grows, the absence of a domestic production base becoming a critical bottleneck. Developing local manufacturing capacity is therefore not only about industrial upgrading, but also ensuring long-term energy access and reducing supply vulnerabilities. This study focuses on the supply side of the solar PV value chain, particularly the manufacturing segment. It follows the industry structure from polysilicon, ingot, and wafer production to cell and module assembly. A more detailed analysis of East Africa's current participation in this value chain in lens of Technological Innovation System (TIS) is presented in Chapter 4.

1.2 Problem Statement

Although solar energy deployment in East Africa has grown in recent years (as shown in Figure 19, the region's participation in the solar PV value chain remains largely superficial. Prior efforts have focused on expanding access through off-grid systems, yet less progress has been made toward building upstream or midstream manufacturing capacity. This limits not only local value creation and job opportunities, but also undermines energy security by creating continued dependence on imported technologies.

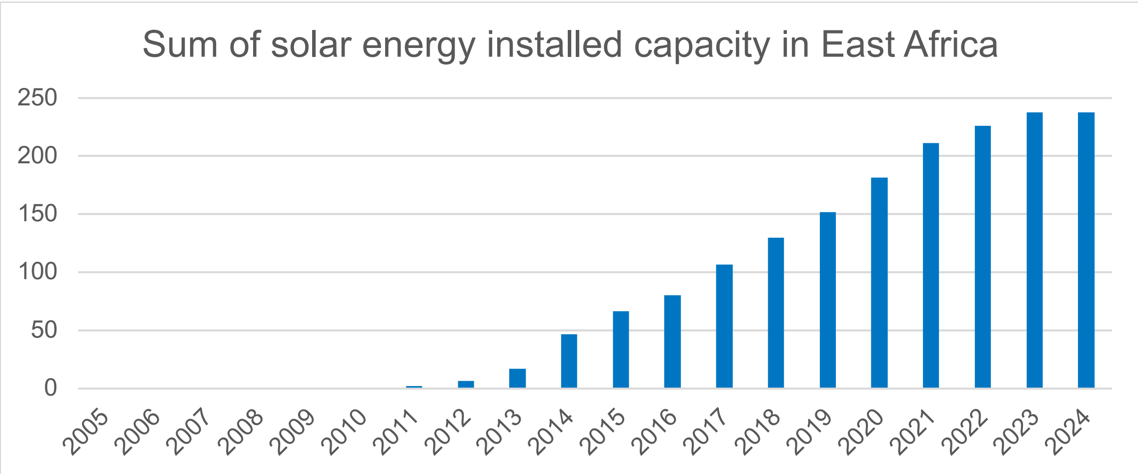


Figure 19 – Sum of solar energy installed capacity in East Africa, 2005-2024
Source: IRENA, 2025

Meanwhile, growing concerns over energy security and supply chain risks are driving urgent calls for solar PV production diversification. As noted by IEA, concentration in the solar PV supply chain represents a considerable vulnerability (IEA, 2022b). Countries seeking to reduce this risk are increasingly looking to diversify both their import and manufacturing locations (WTO et al., 2023). This shift opens up opportunities for emerging regions to position themselves as viable alternative hubs for solar PV production.

To take advantage of this window, East African countries must first develop a clear understanding of their own development potential and existing constraints. This involves identifying structural barriers such as inadequate infrastructure, absence of related institutions, and limited technical capacity, all of which may hinder their ability to attract investment in solar manufacturing. A realistic assessment of these limitations is essential for designing targeted strategies that improve the region's readiness to participate in the solar PV value chain.

Crucially, many of these constraints—such as high capital requirements and lack of industrial depth—are systemic and not easily addressed at the national level.

In this context, the challenge lies not only in scaling solar deployment but also in developing a locally embedded and resilient solar PV value chain. Given the capital- and knowledge-intensive nature of the PV industry, as well as the global market concentration as mentioned previously, it is difficult for any single East African country to independently build a full-scale PV manufacturing base. Fragmented national efforts are unlikely to compete with the economies of scale and integration achieved by established players.

This situation calls for a shift in perspective: instead of focusing on national self-sufficiency, it may be more actionable to explore regional strategies that pool resources and capabilities. This raised the question of whether regional cooperation can offer a more viable option. By coordinating their efforts and leveraging complementary national strengths, East African countries may be able to collectively enter the value chain in a more competitive manner. For example, resource-endowed countries could focus on upstream material supply by building refining industry, while more industrialized countries like Kenya could concentrate on module assembly and system integration. Such task-sharing could enable the region to overcome scale-related constraints, reduce production costs, and develop competitive advantages that would be unattainable through isolated national strategies.

In summary, the development of a regional solar PV value chain in East Africa is both necessary and potentially beneficial for several reasons:

Reducing import dependency and enhancing energy security: The region’s current reliance on imported PV technologies makes it vulnerable to global supply disruptions and price volatility. Localizing production through regional collaboration can improve resilience.

1. **Addressing structural constraints through collective action**: No single East African country currently possess the full set of capabilities needed to build a competitive solar manufacturing sector. Regional cooperation allows countries to specialize based on comparative advantage, helping to overcome individual limitations.

2. **Achieving economies of scale**: By pooling demand and coordinating production, East African countries can lower unit costs, improve efficiency, and attract larger-scale investment, which is difficult for individual countries.

3. **Enhancing industrial development and local value creation**: A more integrated regional value chain can support job creation, skills development, and technology transfer, contributing to broader economic improvement across the region through spillover effect.

4. **Aligning with global trends toward supply chain diversification**: As international actors seek to reduce their dependence on concentrated supply sources (China), East Africa has an opportunity to position itself as an emerging node in the global PV supply network, but only if it can improve its investment climate and regional coordination mechanisms.

To explore this possibility, it is also essential to examine cases where latecomers have successfully established a presence in global PV value chains. China's experience is particularly relevant. Within two decades, China transitioned from a marginal player to the world's dominant solar PV manufacturer and exporter. This success was not solely market-driven, but supported by targeted industrial policies, strategic public investments, and infrastructure and skills development (Zhao *et al.*, 2013). While the political and economic context of East Africa differs significantly, elements of China's approach may offer useful lessons for building context-appropriate strategies for regional cooperation and industrial upgrading.

What remains unclear, and what this study aims to investigate, is whether and how East African countries can develop such a coordinated regional approach to solar PV industrialization. It also asks whether lessons from China's trajectory in the global PV industry—particularly its experience in technology upgrading and supply chain integration—might be meaningfully adapted to the East African context, despite differences in institutional capacity, market size, and industrial maturity.

1.3 Research Objectives and Questions

Despite the growing recognition of Africa's potential in solar PV development, there remains a research gap in understanding whether and how regional cooperation—particularly through a developmental regionalism approach—can be effectively leveraged to foster a sustainable and inclusive solar PV Regional Value Chain (RVC). Additionally, while China's rise in the solar PV industry has been extensively studied, there is limited research on how African can adapt China's experience to its unique context, particularly in the face of today's highly consolidated global market. Along these lines, this thesis broad objective is threefold. First, it seeks to evaluate the feasibility of Developmental Regionalism as a viable solution for Africa to develop a sustainable solar PV industry, considering the continent's unique challenges and opportunities. Second, it aims to analyze the lessons from China's solar PV industry development and assess their applicability to East Africa's context, particularly in the framework of catchup and policy transfer theory. Third, it intends to provide actionable policy recommendations for East African countries to strategically position themselves within the global solar PV market, leveraging regional cooperation and foreign investment to overcome existing barriers.

To address these research objectives, the main research question of the thesis is as follow:

To what extent can regional cooperation help East African countries build a sustainable solar PV value chain, and how can China's experience inform this process?

To address the main research question, this thesis breaks it down into five interrelated sub-questions:

1. What is the current state of solar PV value chain development in East Africa?
2. What are the main constraints preventing Eastern African countries from developing competitive solar PV industries individually?
3. What enabling factors exist for building regional solar PV value chains in East Africa?
4. How can Eastern African countries position themselves within different segments of the solar PV value chain through regional specialization?
5. How can China's solar PV industry development experience inform the establishment of a competitive and context-adapted regional value chain (RVC) for East Africa under current global market dynamics?

By addressing these questions, this thesis aims to contribute to the growing body of literature on Africa's renewable energy development while providing practical insights for policymakers, industry stakeholders, and international partners.

1.4 Thesis Structure

This thesis is organized into six chapters. Chapter 2 presents a literature review that situates the study within existing academic debates on solar PV industrialization, value chain development, and regional cooperation in Africa. It identifies key empirical and theoretical gaps that motivate this research, particularly the underexplored potential of regional solar PV manufacturing in East Africa. Chapter 3 outlines the research methodology, detailing the application of three theoretical frameworks—Technological Innovation System (TIS), Developmental Regionalism, and Catch-up & Policy Transfer Theory—and describes the data sources and analytical strategies used. Chapter 4 applies the TIS framework to assess the current state of solar PV innovation systems in East African countries, with a focus on actors, institutions, networks, and functional performance. Chapter 5 draws on the Developmental Regionalism perspective to explore the feasibility of building a coordinated regional solar PV value chain, highlighting opportunities for specialization based on country-level comparative advantages. Chapter 6 examines the trajectory of China's solar PV industry through the lens of catch-up theory and policy transfer, evaluating the relevance and limitations of China's experience for East African contexts. Chapter 7 concludes the thesis by synthesizing the key findings, answering the research questions, reflecting on their policy implications, and proposing directions for future research.

2 Literature Review

2.1 Global Value Chain (GVC) of Solar PV System

The concept of Value Chain was first introduced by Porter as a framework to analyze how businesses create value through a series of interconnected activities. It refers to the full range of activities involved in the design, production, marketing, distribution, and support of a product or service (Porter, 2001). The Global Value Chain (GVC) theory later developed by Gereffi *et al.*, expands this concept to an international context, emphasizing how different stages of production are geographically dispersed across multiple countries (Gereffi, 2011).

Global value chains (GVC) have become a defining feature of 21st century trade, enabling countries and firms to specialize in specific tasks such as R&D, manufacturing, or assembly rather than producing whole products domestically (Kowalski et al., 2015). This division of task, driven largely by multinational enterprises and supported by trade liberalization, logistics improvements, and foreign direct investment (FDI), has created new pathways for developing countries to integrate into the global economy without the need to build a full industrial base for the whole value chain from scratch (Kowalski et al., 2015). As Kaplinsky and Morris (2000) explain, GVCs are not neutral configuration of trade, but systems governed by power asymmetries, technological standards, and strategic control over high-value segments. Participation in such chains offers development opportunities, but capturing value depends on a country's ability to enter the value chain at viable points and to upgrade overtime. As one OECD study points out, countries with limited industrial bases and structural disadvantages, such as small markets or distance from major production hubs, face persistent barriers to upgrading within GVCs (Kowalski et al., 2015). This is particularly relevant for East African countries, many of which struggle with fragmented markets, underdeveloped infrastructure, and limited technological capabilities. For these countries, policy reforms alone may be insufficient. Regionalized strategies are increasingly seen as critical enablers of more meaningful participation (Ndubuisi, 2024).

The emergence of global value chains (GVCs) has created important development opportunities for many developing countries by enabling their integration into segments of international production. However, for countries that have not successfully capitalized on these waves of globalization, understanding the conditions for competitiveness becomes crucial. In response to this, Bamber *et al.* (2014) proposed a comprehensive analytical framework to identify the key determinants that shape a country's ability to enter, remain in, and upgrade within GVCs. Their framework also distinguishes the varying competitiveness drivers across different sectors, including extractive industries, manufacturing, agriculture, and offshore services, recognizing that each domain requires a different strategic focus.

In practice, many so-called GVCs are in fact regionally concentrated and operate as Regional Value Chains (RVCs), where production steps are coordinated among neighboring countries, often underpinned by trade agreements and infrastructure connectivity (De Backer et al., 2018). Regional trade integration facilitates the development of RVCs by enabling intermediate goods flows and supporting joint upgrading strategies (De Backer et al., 2018). From the GVC/RVC perspective, identifying a country's potential role depends on its comparative advantages to supply inputs or perform tasks that match the technical and cost requirements of specific stages in the chain. A well-known example is the East Asian electronics industry, where countries like Japan focus on high-end components, South Korea on intermediate inputs, and countries such as Vietnam and Malaysia specialize in assembly—all integrated through regional trade frameworks and just-in-time logistics systems (Torsekar et al., 2019).

Although the solar PV value chain is now largely dominated by China across all production stages, its historical evolution reflects the core characteristics of a GVC. In the early stages, key technologies and equipment were primarily developed in countries like the US, Germany, and Japan (Zhang *et al.*, 2016). Overtime, however, manufacturing activities shifted to China as it offered low-cost electricity, large-scale production capacity, strong policy support, and efficient logistics (IEA, 2022b; Zhang *et al.*, 2013; Zhang & Gallagher, 2016; Zhao *et al.*, 2013). This shift shows how production tends to concentrate in locations with the right mix of cost, technology, and infrastructure advantages.

Currently, there are two definitions of solar c-Si PV industry value chain. The narrow definition begins with polysilicon production to ingot, wafer, cell, and finally to module production, while the broad definition extends the former one to include the capital equipment production and system-component manufacturing (Garlet, 2020). Zhang and Gallagher (2016) analyzed the distribution of value in the manufacturing segment of the PV value chain and found that it aligns with the "Smile Curve" hypothesis, which suggests that the initial stages, such as R&D and capital equipment, as well as the final stages, such as end-use deployment, generate higher value-added benefits. The two stages are initially dominated by firms in the United States, Europe, Japan and South Korea. In recent years, China emerged into this field through technology acquisition from Russia and its own technology R&D. In the contrast, module manufacturing, including the intermediate products such as polysilicon, ingot, wafer, and cell, which has lower technical barriers and intense competition, experiences lower profit margins and is currently dominated by China (Zhang & Gallagher, 2016).

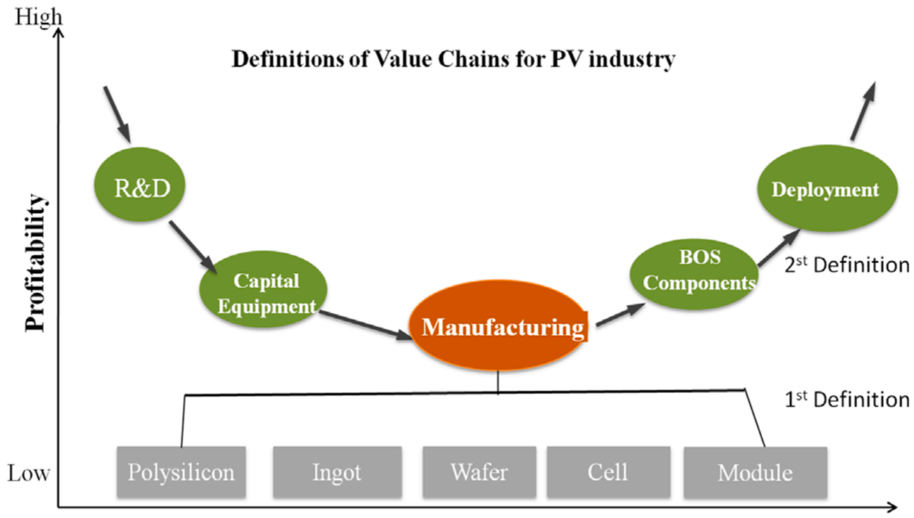


Figure 20 - Application of the "Smile Curve" to PV industry
Source: Zhang and Gallagher, 2016

2.2 Regional Cooperation and Developmental Regionalism

Although global value chains (GVCs) are typically transcontinental, empirical evidence shows that many operate within a predominantly regional structure. According to the OECD, regional value chains (RVCs) emerge when a substantial share of inputs, intermediate processing, and final demand occurs within a given geographic bloc (Kowalski *et al.*, 2015). This regional structuring allows smaller economies to enter global production networks more gradually and strategically, facilitating specialization based on comparative advantage.

A prime example is East Asia, where RVCs in electronics and automotive sectors evolved through extensive intra-regional trade, cross-border investment, and production fragmentation (Torsekar et al., 2019). Over time, production hubs emerged that leveraged the region's heterogeneity in labor costs, infrastructure, and technological capabilities, deepening regional economic interdependence (Suder, 2015). However, it is important to distinguish that these East Asian RVCs did not originate from formal regional industrial strategies. Instead, they were largely driven by market dynamics—particularly foreign direct investment (FDI), the strategies of multinational lead firms, and existing infrastructure—rather than deliberate policy coordination (Kawai & Wignaraja, 2011; Baldwin, 2013).

This form of market-driven regionalism relies primarily on liberalization mechanisms such as tariff reductions and trade facilitation. Its success depends on pre-existing capabilities, including robust infrastructure, capital availability, and private sector dynamism. However, these preconditions are often absent in less-developed regions such as East Africa.

In East Africa, the idea of developmental regionalism is especially relevant. Most countries in the region face common challenges such as limited industrial capacity, small domestic markets, and overlapping regional memberships. Developmental regionalism provides a more practical strategy by encouraging countries to work together on infrastructure, investment, and production, so they can develop industries that none could build alone (Nyadera et al., 2022). As Nyadera et al. (2022) point out, organizations such as the African Development Bank (AfDB) help put this idea into practice. The AfDB does more than lend money—it supports regional infrastructure projects, helps connect landlocked countries to markets, and promotes trade and investment across borders. These efforts support larger goals like Agenda 2063 and the African Continental Free Trade Area (AfCFTA). Instead of relying only on market forces, this approach focuses on long-term planning and shared development goals among African countries.

Legal and policy frameworks in Africa also show signs of developmental regionalism. According to Akinkugbe (2020), African regional trade agreements are not designed as strict legal systems like those in Europe. Instead, they are more flexible and focus on practical outcomes. These agreements often include both economic and non-economic goals, such as regional infrastructure, gender equality, and environmental protection. Their flexibility is not a weakness but a reflection of Africa's diverse needs and post-colonial challenges (Akinkugbe, 2020).

This flexible approach is useful in East Africa, where countries have different strengths and development goals. Trying to force a one-size-fits-all legal model may not work. Instead, as Akinkugbe (2020) explains, it is more realistic to allow room for countries to adjust the rules based on their needs. This view is supported by the Law and Development field, which emphasizes the importance of local context, informal practices, and state leadership in shaping effective regional cooperation.

In short, applying developmental regionalism to East Africa means focusing on cooperation in key areas like infrastructure, industry, and technology. It recognizes that no single country can build a full industrial base alone, and that working together—through flexible and goal-oriented regional frameworks—is the best way forward.

2.3 East Africa's Potential and Efforts in Integration in Solar PV GVC

Although most existing studies on solar PV development in Sub-Saharan Africa (SSA) focus on energy access and deployment, a smaller but growing body of literature addresses the region's potential for industrial upgrading and manufacturing integration. While these studies often cover SSA as a whole, East Africa is an integral subregion within it. This review selectively draws from the broader SSA literature and identifies insights that are directly applicable to East Africa's context.

One of the earliest systematic assessments of East Africa's solar PV industry is provided by Hansen *et al.* (2014), who reviewed the development of PV markets in Kenya, Tanzania, and Uganda. While their analysis primarily focused on market growth and deployment models, they noted the emergence of small-scale manufacturing activities in Kenya - particularly local assembly of PV components – and emphasized Kenya's relative leadership in nurturing private-sector participation. This early work highlighted the foundation role of enabling environments such as VAT exemptions, donor programs, and light-touch regulation in fostering local PV industries.

Combining the theory of Technological Innovation System (TIS), Hansen *et al.* (2015) compare solar PV diffusion in Kenya, Tanzania, and Uganda, focusing on solar home systems (SHS) and institutional PV. By examining both structural and functional components, they found Kenya to be more successful due to favorable geography, stronger market formation, and the presence of local suppliers and entrepreneurial actors. However, the study centers on off-grid applications and largely overlooks manufacturing and industrial development.

Similarly, Kebede and Mitsufuji (2017) analyzed Ethiopia as a typical technology-receiving country using a "diffusion-based TIS" approach, which emphasizes adaptation and dissemination of existing technologies rather than invention. Using event history analysis (EHA), they traced the emergence of key TIS functions between the 1980s and 2012. Although all seven functions eventually appeared, market formation was weak, and knowledge development was mostly limited to learning-by-doing. The study's national focus also limits insights into local manufacturing and regional dynamics.

More recent studies have sifted attention from deployment to manufacturing and integration into GVCs. In this regard, Ndubuisi and Avenyo (2024) offer one of the most comprehensive examinations of Africa's structural position in the solar PV GVC. They argue that while African countries individually lack the scale and capabilities to establish competitive manufacturing sectors, regional integration could unlock new opportunities. The authors emphasize the importance of leveraging Africa's critical mineral reserves, growing energy demand and rising political interest in industrialization. However, fragmented industrial ecosystems, limited technological capacity, and poor regional coordination remain key barriers. Their call for a regionally coordinated industrial strategy provides the conceptual basis for understanding how African regions- including East Africa- could specialize in different value chain segments.

Empirical evidence from East Africa is provided by Hansen *et al.* (2024), who examine Kenya's Solinc East Africa Ltd., the region's only significant solar module assembler. The study shows how Solinc maintains competitiveness through regional logistics (e.g., exports to Rwanda), integration with upstream suppliers, and the provision of value-added services. Rather than competing on price, Solinc's strategy relies on proximity, flexible production, and after-sales support. This approach could inform other East African firms seeking entry points into PV manufacturing. Their findings reveal both the fragility and the potential of localized manufacturing within an otherwise import-dominated market.

In addition, a report by Sustainable Energy for All (2023) assesses the feasibility of localizing renewable energy manufacturing in Africa by applying an investment criteria framework derived from Chinese renewable energy companies. The report evaluates African countries based on factors typically prioritized by Chinese manufacturers, such as market scale, supply chain reliability, infrastructure readiness, and industrial policy incentives. Among all the East African countries, Kenya and Tanzania are identified as relatively better positioned in terms of these factors.

Complementing these perspectives, Development Reimagined (2024) examines how Africa could become a solar PV manufacturing hub through enhanced cooperation with China. The report assesses country readiness across different segments of the PV value chain and identifies Rwanda, among other countries in East Africa, as a promising location due to its political stability, investor-friendly policies, and geographic location near key raw material sources in the Democratic Republic of Congo (DRC). Its proximity to regional markets in East Africa and access to both Central and Northern Corridors (as shown in Figure 22 & 23) strengthens its ability to serve East Africa's fast-growing solar markets.

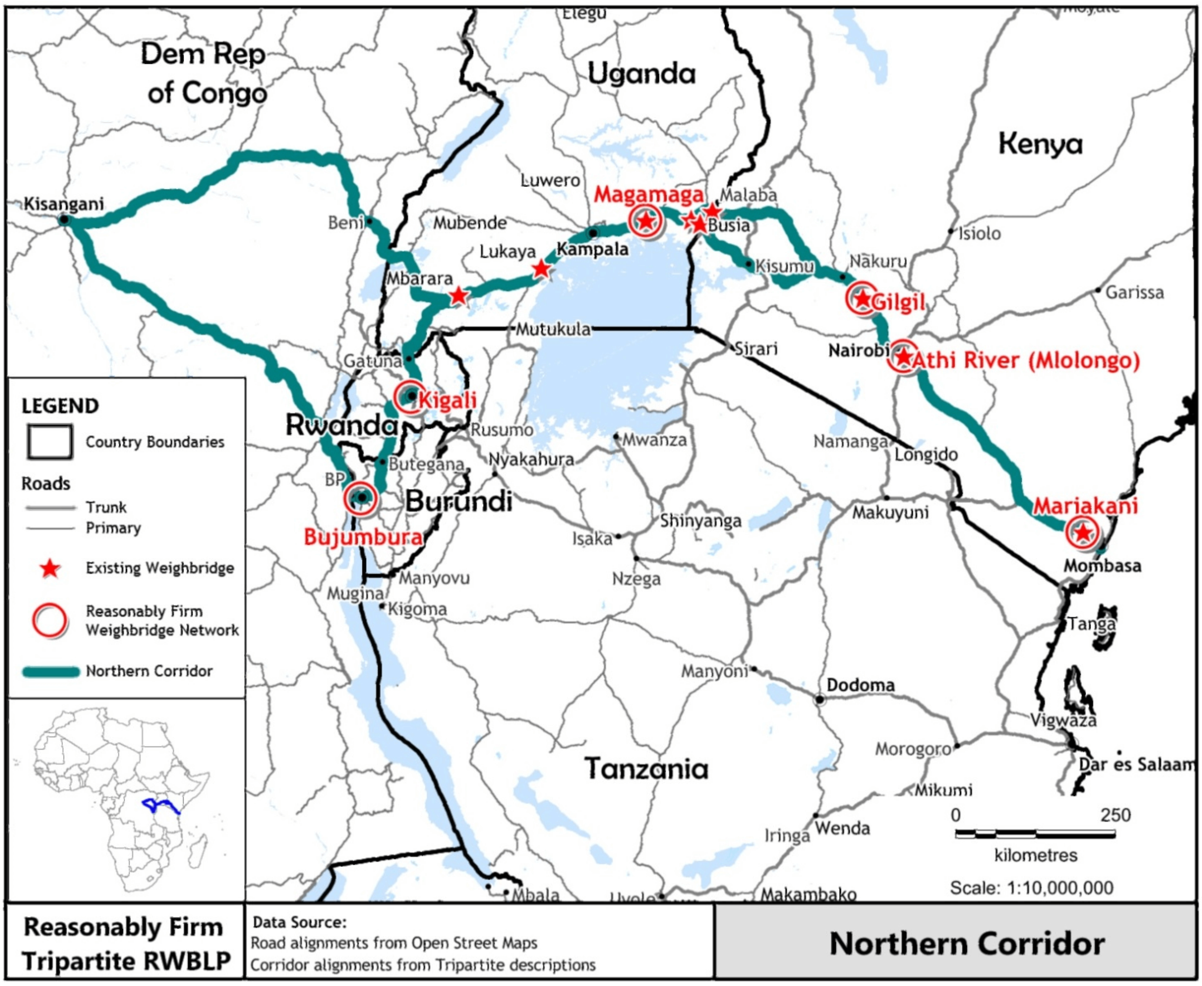


Figure 21 – Northern Corridor
Source: TTTFP

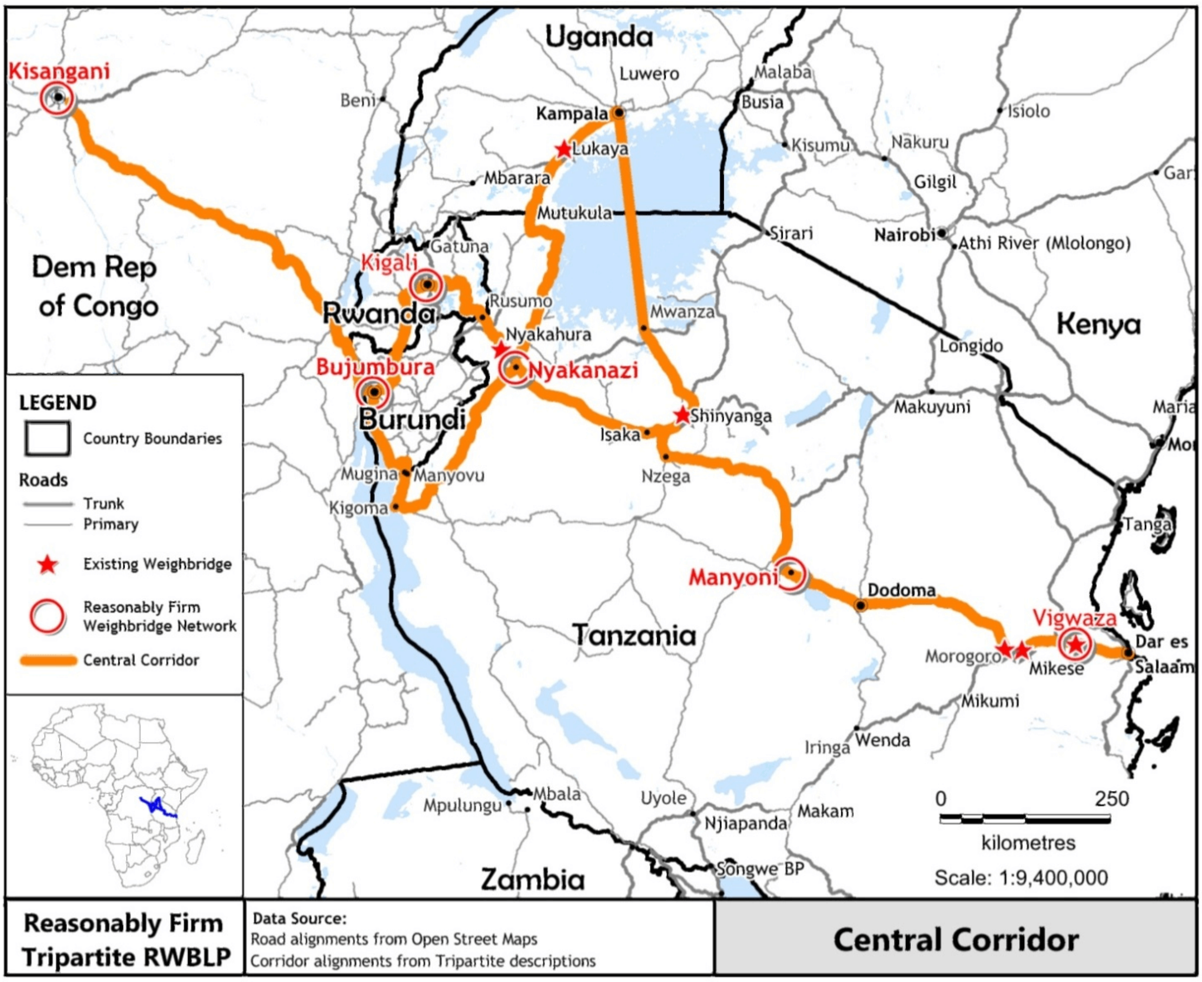


Figure 22 – Central Corridor
Source: TTTFP

In institutional context, Turksen and Abukari (2023) explores how continental frameworks like the African Continental Free Trade Area (AfCFTA) and the WTO can support clean energy transitions, including through trade facilitation and harmonized standards for solar products. While neither regime explicitly prioritizes solar PV manufacturing, their analysis shows that mechanisms such as technology transfer clauses, competition policies, and special economic treatment provisions could be leveraged to support regional value chain development. These institutional insights provide a broader governance context in which East African solar manufacturing strategies might evolve.

Despite these advances, the literature still presents several research gaps. First, most analyses focus on individual countries—particularly Kenya—and rarely examine how complementary capabilities across countries could form the basis of a regional manufacturing network. Second, upstream and midstream segments of the value chain (such as silicon purification, cell production, and module assembly) remain underexplored relative to deployment. Third, while the potential role of AfCFTA is acknowledged, few studies provide concrete proposals for coordinating investment, infrastructure, and industrial policy across East African countries.

2.4 China's integration and upgrading in solar PV GVC

One of the most significant trends in the solar PV industry in recent years has been China's deepening integration and upgrading along the global value chain. The development of China's PV industry demonstrates a clear latecomer advantage, leveraging cost competitiveness, policy support, and strategic positioning within global markets to achieve rapid growth and technological advancement.

According to Zhang and Gallagher (2016), up till 2014, China's emergence in the PV GVC can be divided into three stages. In the first stage (1998-2004), China entered the PV module manufacturing segment by acquiring technology through imported production equipment and knowledge spillovers. Firms such as Suntech and Yingli leveraged turnkey production lines, recruitment of talent from abroad and R&D cooperation with foreign partners to rapidly establish themselves. Most early Chinese PV firms were heavily export-oriented, targeting European markets that benefited from feed-in tariff (FIT) incentives (Sijm, 2002). In the second stage (2005-2008), Chinese firms pursued vertical integration within the whole manufacturing process to strengthen their cost competitiveness. While most firms initially focused on module assembly, they expanded into upstream activities such as polysilicon, wafer, and solar cell production, which allowed firms to reduce dependence on foreign suppliers. The third stage (2009-2014) marked China's expansion across the broader GVC, moving beyond manufacturing into areas such as capital equipment production and downstream deployment. This period features aggressive domestic policy support, including the Golden Sun Demonstration Program and national feed-in tariffs, which helped stimulate domestic PV adoption and reduce reliance on foreign markets (Zhang & Gallagher, 2016; Zhao *et al*., 2013).

Government intervention has been instrumental in this integration and upgrading process. Policies such as feed-in tariffs, the Renewable Energy Law, and financial subsidies have stimulated both domestic and international demand for Chinese PV products (Zhang & He, 2013). Furthermore, the government has facilitated the development of a robust PV industry by supporting R&D, fostering technology transfer, and encouraging industrial clustering (Huang et al., 2016). These efforts have enabled Chinese firms to move beyond labor-intensive manufacturing towards knowledge-intensive segments of the GVC.

2.5 Catch-up Theory and Policy Transfer

The intellectual roots of catch-up theory trace back to Alexander Gerschenkron's (1962) seminal work *Economic Backwardness in Historical Perspective*, which introduced the idea of "latecomer advantage." Gerschenkron argued that economically backward countries could skip certain developmental stages by leveraging state intervention, institutional innovations, and capital mobilization to substitute for market mechanisms—laying a critical foundation for later theories of industrial catch-up. The formal articulation of catch-up theory came with Moses Abramovitz's (1986) influential paper *Catching Up, Forging Ahead and Falling Behind*. He proposed that the ability of lagging countries to catch up with technological leaders depends on their "social capability"—that is, the institutional, educational, and infrastructural foundations necessary to absorb and exploit advanced technologies (Abramovitz's,1986).

Nelson (1993) and Lee (2005) expanded the catch-up framework by integrating insights from national innovation systems and evolutionary economics. Nelson (1993) argued that systemic features—like the organization of science, government-industry links, and education—matter as much as market forces. Lee (2005) highlighted that beyond imitation, successful catch-up increasingly depends on a country's capacity to design and develop technologies through its own innovation base.

As one of the most prominent latecomers in the clean energy sector, China's solar PV industry has become a compelling case for analyzing catch-up processes in a highly globalized and technologically competitive market. Recent research has moved beyond generic state-led industrialization models to unpack sector-specific dynamics. Binz et al. (2017) argue for a "technology-sensitive" version of catch-up theory that takes into account the specific characteristics of different technologies and their associated innovation systems. In their analysis of China's wind, solar PV, and biomass power sectors, they distinguish among different industrial logics: solar PV, as a mass-produced standardized good, was less dependent on top-down state intervention than wind energy. Instead, China's PV success relied heavily on exploiting global demand (especially from Europe), leveraging economies of scale, and adapting flexible policy mixes that supported firms' access to finance, knowledge, and legitimacy (Binz et al., 2017). Other scholars conducted a comparative study of Chinese and Indian firms in the solar power industry, concluding that Chinese firms succeeded in "output catch-up" by leveraging cost efficiency and scale, which then enabled them to progress toward "innovation catch-up." They attribute this to China's proactive industrial policies and large domestic market, while Indian firms remained locked in downstream EPC roles (Awate et al.,2018).

Complementing these production-focused accounts, Sakata and Sasaki (2013) take a science-based perspective. They found that China's contribution to global scientific research in solar cell technologies—especially in emerging areas like organic PV—has grown rapidly, suggesting a "parallel-running growth model" wherein knowledge production becomes a core pillar of catch-up alongside manufacturing capabilities.

Together, these studies demonstrate that catch-up in the solar PV sector is not a linear imitation process, but a strategic, stage-specific combination of domestic capability building and international integration. China's experience demonstrates that technological catch-up is possible for latecomer countries—given strategic coordination, policy commitment, and effective integration into global markets. The rapid growth of China's solar PV manufacturing industry suggests that late industrializers can indeed transform initial disadvantages into competitive strengths. This reinforces the theoretical proposition that latecomer advantage is not only viable but can be purposefully constructed through long-term state support, targeted capability building, and responsiveness to international opportunity structures.

However, the question remains: can the policy tools and institutional mechanisms that facilitated China's catch-up be meaningfully transferred to other regions, such as East Africa? While East African countries may not yet possess the same industrial foundations, the broader promise of catch-up suggests that the right enabling conditions can be built over time. Yet translating China's experience into effective strategies for a different context is not straightforward. This is where policy transfer theory becomes essential.

The study of policy transfer emerged in response to growing interest in how governments learn from each other in an increasingly interconnected world. The foundational idea can be traced back to the notion of "lesson-drawing," which viewed policy borrowing as a rational and voluntary process where policymakers learn from successful examples abroad to solve domestic problems (Rose, 1991). Building on this foundation, Dolowitz and Marsh significantly broadened the analytical scope. They defined policy transfer as "a process by which knowledge about policies, administrative arrangements, institutions and ideas in one political system… is used in the development of policies, arrangements, institutions and ideas in another” (Dolowitz & Marsh, 1996). Crucially, they identified a range of actors (from governments to think tanks and international organizations), types of transfer (from soft ideas to hard laws), and forms (copying, emulation, hybridization), as shown in Figure 42. They also emphasized that transfer could be coercive or voluntary, and that its success depends heavily on compatibility with the receiving context (Dolowitz & Marsh, 2000).

To address criticisms of conceptual vagueness, Evans and Davies proposed a multi-level model of policy transfer, emphasizing the role of institutional structures, actor networks, and political agendas (Evans & Davies 1999). Their work marked a shift from treating transfer as a simple diffusion of best practices to understanding it as a strategic, contested, and context-dependent process (Evans & Davies, 1999). This view has become increasingly relevant in complex sectors like energy and technology, where local institutions, infrastructure, and power relations significantly mediate how policies are received and reshaped.

Rather than assuming that successful policies can be simply copied from one setting to another, the policy transfer literature emphasizes the complexity of transferring institutional models across borders (Dolowitz & Marsh, 1996). It highlights not only what is transferred—such as regulations, incentives, or organizational designs—but also how and under what conditions transfer processes succeed or fail (Dolowitz & Marsh, 1996; Evans & Davies, 1999). In the context of solar PV manufacturing, where sectoral policies are closely tied to political economy structures, infrastructure capabilities, and global trade dynamics, these questions become especially relevant (Lema & Lema, 2016).

In summary, this section has outlined the theoretical foundation for understanding how China’s experience in solar PV manufacturing can inform regional development efforts in Africa. Catch-up theory offers strong evidence that latecomer countries, under the right strategic and institutional conditions, can build globally competitive industries. At the same time, policy transfer theory reminds us that the success of such emulation depends not only on what is transferred, but also on how, by whom, and under what circumstances.

2.6 Research Gap

Existing research on Africa’s solar PV industry has yet to provide a comprehensive framework for how African countries can develop a regional value chain that reflects today’s highly concentrated global solar PV market. While studies have explored Africa’s potential in solar

PV deployment and its challenges in local manufacturing, there remains a critical gap in understanding how regional cooperation can enable African countries to identify and seize opportunities across different stages of the solar PV value chain.

While China's rise as a global leader in solar PV manufacturing has been widely studied, existing literature does not provide a detailed, actionable analysis of how African countries can adapt relevant aspects of China's experience to build their own RVC. China's early-stage development in the PV sector shares important similarities with Africa's current situation, including limited awareness of solar PV benefits, a lack of indigenous core technology, and initial dependence on foreign expertise. However, key differences-such as China's large domestic market due to huge population, developed manufacturing base, strong central government, and ability to implement long-term, consistent industrial policies-are essential reasons why China's experience cannot be directly replicated in Africa. What remains insufficiently explored is whether regional cooperation can serve as a functional alternative to a strong centralized policy approach in fostering a solar PV RVC.

Moreover, while China's PV industry benefitted from a unique era of global industrial shifts, including growing international demand for solar energy and supply chain diversification in the early 2000s, today's solar PV market is far more mature and consolidated (Victoria et al, 2021). Chinese firms dominate more than 80% of the global production of key components such as polysilicon, wafers, and solar cells, making it increasingly difficult for new entrants, particularly from emerging markets, to compete on the same terms. Existing research does not sufficiently address how African countries can navigate these market realities by strategically positioning themselves within specific segments of the value chain where competitive advantages can be developed.

This study seeks to bridge these gaps by developing a context-specific framework for Africa's regional solar PV value chain development, analyzing how regional cooperation can enable African countries to integrate into the industry despite current global market concentration. By critically analyzing lessons from China's early PV development while accounting for today's more competitive global landscape, this thesis will explore how Africa can strategically position itself within the solar PV value chain. Through regional specialization, policy coordination, and investment attraction strategies, African countries can identify high-value opportunities across different stages of the solar PV industry, fostering long-term industrial growth despite the dominance of existing global players

3 Methodology

This study adopts a qualitative research design that integrates theory-guided diagnosis, comparative institutional analysis, and secondary data synthesis to assess the feasibility of building a regional solar PV value chain in East Africa. The research seeks to answer three core questions: whether regional cooperation can offer a viable path toward industrial upgrading in solar PV, how East African countries might functionally specialize within a coordinated value chain, and what lessons can be drawn—selectively and critically—from China's experience in solar industrial development. To address these questions, the methodology combines multiple theoretical frameworks with a structured empirical approach, allowing for both country-level evaluation and cross-regional comparison.

The research is guided by three interlinked conceptual frameworks: Technological Innovation System (TIS), Developmental Regionalism, and a combined lens of Catch-up Theory and Policy Transfer Theory. Each framework is operationalized in a specific part of the analysis, and their conceptual foundations are discussed in detail in Chapters 4, 5, and 6 respectively.

3.1 Technological Innovation System (TIS) Framework

The concept of Technological Innovation System (TIS) evolved from the earlier notion of "technological systems" introduced by Carlsson and Stankiewicz (1991), who defined it as "a network of agents interacting in a specific economic or industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology." While this original definition focused on the structural configuration surrounding a specific technology, the TIS framework has since developed into a dynamic analytical tool used to explain the emergence, development, and diffusion of new technologies, especially in the context of sustainability transitions (Markard & Truffer, 2008). It provides a structured way to assess how various actors (such as firms, universities, NGOs, and policymakers), institutions (laws, norms, policies), and their interactions contribute to or hinder technological development and diffusion (Bergek et al., 2008; Hekkert et al., 2007). This perspective is particularly relevant for analyzing emerging renewable energy technologies like solar PV in developing regions such as East Africa.

TIS analysis is typically structured around two core elements: **structural components** and **system functions**. The structural dimension includes actors (e.g., firms, research institutes, NGOs), networks (collaborative relationships), and institutions (laws, policies, norms) that shape innovation processes (Bergek et al., 2008). The functional dimension, introduced to better explain system dynamics, focuses on seven key processes: (1) knowledge development and diffusion, (2) influence on the direction of search, (3) entrepreneurial experimentation, (4) market formation, (5) legitimation, (6) resource mobilization, and (7) development of positive externalities (Bergek et al., 2008). These system functions serve both as diagnostic tools and as guides for policy interventions, helping identify system strengths and weaknesses that influence the performance of innovation processes (Edsand, 2016). For example, weak legitimacy may hinder investment in solar PV, while strong entrepreneurial experimentation may accelerate diffusion.

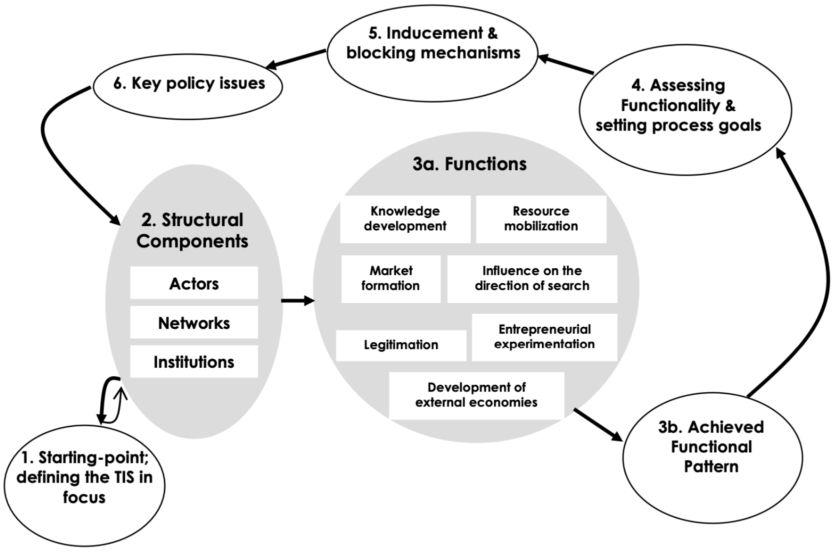


Figure 23 – The Scheme of the TIS Analysis (source: Bergek et al., 2008)

The TIS framework has already been applied to study solar PV development in East Africa. Notably, as mentioned in Chapter 2.3, Hansen *et al.* (2015) conducted a cross-country review of solar PV diffusion in Kenya, Tanzania, and Uganda using a modified TIS perspective. Their analysis primarily focused on the diffusion of solar home systems (SHS) and institutional PV systems, using both structural and functional TIS components to explain observed variation across countries. The study found that Kenya outperformed its neighbors due to favorable geographical conditions, stronger market formation, and the presence of local sub-component suppliers and entrepreneurial champions. However, their work primarily addressed the application side of solar PV—particularly off-grid deployment—while largely overlooking the manufacturing and industrial development aspects.

In addition to this regional comparison, Kebede and Mitsufuji (2017) apply the TIS framework to analyze how solar PV technology has diffused in Ethiopia, a typical technology-receiving country. The authors introduce the concept of a "diffusion-based TIS" to describe systems that focus not on the invention of new technologies but on adapting and spreading existing ones. Through event history analysis (EHA), they map the emergence of key TIS functions—such as entrepreneurial activity, knowledge development, and guidance of the search—between the 1980s and 2012. The study shows that while all seven functions eventually emerged, market formation remained weak, and knowledge development was largely limited to learning-by-doing rather than formal R&D. One limitation of the paper is its national scope and focus on diffusion rather than local manufacturing or regional linkages.

The TIS framework is particularly well suited for analyzing the diffusion and development of solar PV in East Africa due to its focus on the systemic conditions that shape technological change. Unlike linear models of innovation, TIS allows for the examination of feedback loops, actor interactions, and institutional dynamics that collectively influence the success or failure of a given technology (Hekkert et al., 2007). In the context of solar PV—a relatively mature but still evolving technology—the TIS approach provides a means to understand not only how the technology enters a new region, but also how it becomes embedded within local economic and social structures.

In East Africa, solar PV technologies are largely imported and introduced through donor support, NGOs, or private entrepreneurs rather than generated through domestic R&D efforts. This means that innovation activities are centered more on diffusion, adaptation, and system-building rather than invention. Scholars have therefore emphasized the relevance of TIS analysis in developing country contexts—particularly when reconfigured to emphasize "diffusion-based TIS" rather than "R&D-based TIS" (Kebede & Mitsufuji, 2017). This distinction is crucial because it allows us to assess how local actors in East Africa create the capabilities, networks, and institutional support necessary to absorb and scale solar PV solutions.

Furthermore, the functional perspective within the TIS framework is highly diagnostic, enabling researchers and policymakers to identify system weaknesses such as a lack of legitimacy, poor resource mobilization, or weak entrepreneurial experimentation (Bergek *et al.*, 2008; Edsand, 2016).

In addition, the TIS framework is flexible enough to incorporate spatial and institutional diversity. It accommodates both local dynamics (such as the role of specific firms or NGOs) and global influences (such as technology transfer and donor interventions). This makes it particularly appropriate for studying East Africa, where solar PV development is shaped by interactions between international finance, national policy regimes, and local implementation challenges (Desmond, 2011).

In summary, using the TIS framework to study solar PV in East Africa allows for a multi-dimensional and context-sensitive analysis of the innovation dynamics at play. It helps to uncover not just "what" is happening, but also "why" and "how" different system components interact to influence the pace and direction of solar PV adoption.

To build on this foundation, Chapter 4 adopts the TIS framework but extends it in two important directions. First, it broadens the geographic scope beyond a single-country focus by incorporating a comparative perspective across multiple East African countries, enabling a more regional understanding of solar PV innovation dynamics. Second, it shifts the analytical emphasis from end-use applications to the upstream dimension of manufacturing and industrial capability development—an area that remains relatively underexplored in existing TIS studies. This approach aims to identify structural constraints and policy gaps that may hinder the emergence of a regional solar PV manufacturing base.

3.2 Regional Integration into GVC and Developmental Regionalism

Two complementary analytical frameworks are used in Chapter 5 to assess the potential for regional task specialization and industrial cooperation in solar PV manufacturing across East African countries.

The first is the GVC competitiveness framework developed by Bamber et al. (2014), which identifies five core dimensions that shape the ability of developing countries to enter, compete, and upgrade within global and regional value chains: (1) productive capacity, (2) infrastructure and services, (3) business environment, (4) trade and investment policy, and (5) industry institutionalization. This framework goes beyond traditional comparative advantage by focusing on enabling conditions—such as reliable transport and power infrastructure, effective industrial institutions, and coherent trade policies—that determine whether initial advantages can be translated into sustainable participation in complex manufacturing chains. In the solar PV sector, these dimensions are particularly relevant due to the capital intensity, technical requirements, and standardization involved across stages such as raw material extraction, polysilicon production, ingot and wafer processing, cell manufacturing, and module assembly. The framework provides a structured basis for evaluating each country's strengths and constraints at different stages of the chain, and for identifying where targeted investments or reforms could enhance regional complementarity.

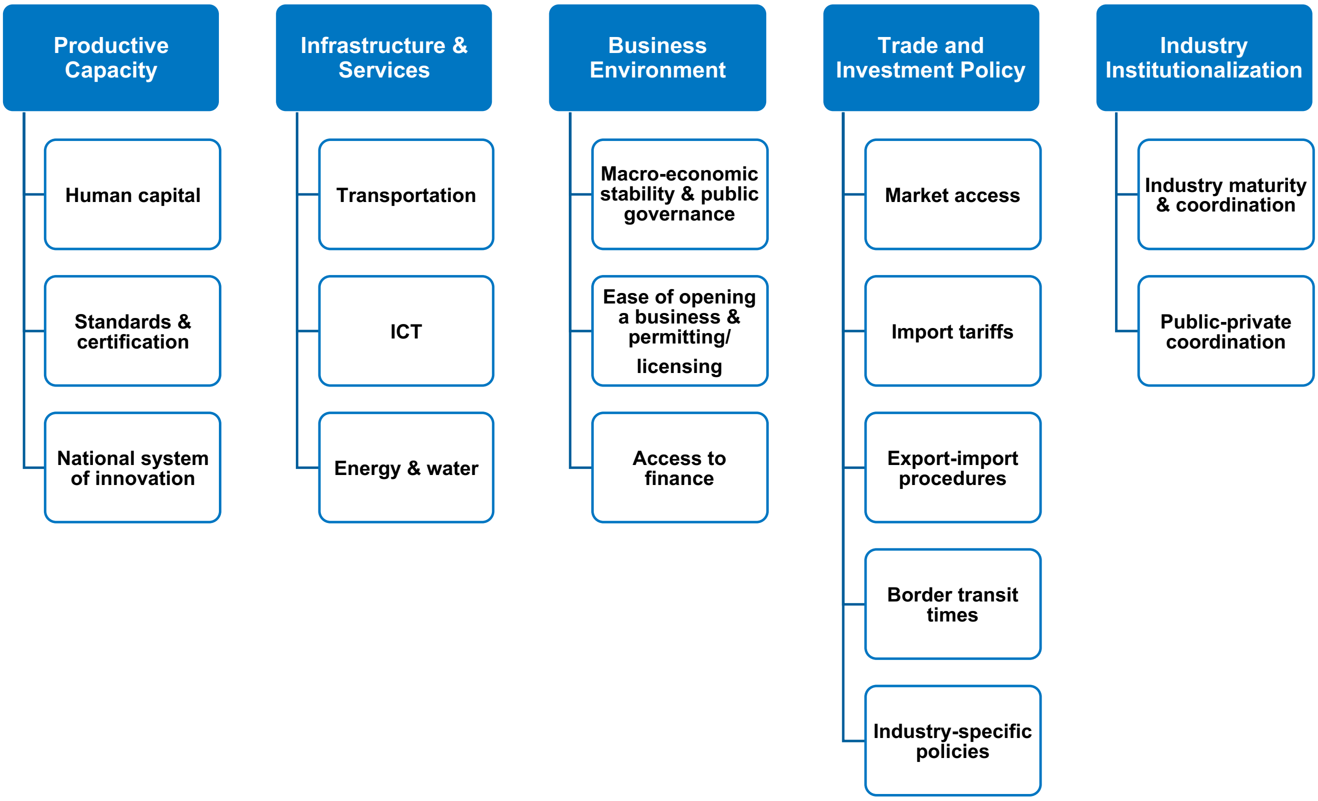


Figure 24 - Factors Affecting Developing Country Competitiveness in GVCs
Source: Bamber et al., 2014

The second analytical framework used in Chapter 5 builds on the concept of developmental regionalism, which offers a contrasting yet complementary perspective to market-driven regional integration. While regional value chains (RVCs) in certain parts of the world—most notably East and Southeast Asia—have evolved largely through private sector initiative, supported by existing infrastructure and strong lead firms, several studies have emphasized that such market-led integration is not the only, nor necessarily the most effective, pathway. In regions with fragmented markets, limited infrastructure, and weak industrial bases—as is often the case in sub-Saharan Africa—state-led coordination and strategic policy intervention can play a central role in initiating and sustaining cross-border industrial cooperation.

This perspective is rooted in a growing body of scholarship that defines developmental regionalism as a proactive approach in which regional integration serves broader goals of industrialization, structural transformation, and collective self-reliance. Akinkugbe (2020), for example, argues that African regional trade agreements increasingly embed developmental goals in their legal and institutional structures, positioning regional cooperation as a tool for overcoming individual countries' constraints in scale, capital, and capacity. Similarly, Nyadera et al. (2022) emphasize the role of supranational institutions—such as the African Development Bank and the East African Community—in promoting regionally coordinated infrastructure projects, joint investment schemes, and policy harmonization. These efforts, as they argue, are essential for building the foundations of regional production networks that would not otherwise emerge through market forces alone.

Recent policy-focused research has also supported this view. For instance, Afreximbank's (2023) regional value chain development report demonstrates how public institutions and financing mechanisms have begun to shape African RVCs through coordinated infrastructure planning, sector prioritization, and institutional alignment. These contributions challenge the assumption that regional integration must follow an organic, market-first trajectory. Instead, they suggest that deliberate, state-led regionalism can create the enabling environment in which value chains can take root and evolve.

Building on these insights, this thesis applies a developmental regionalism lens to examine how East African countries might collectively build a regionally embedded solar PV manufacturing base. This approach emphasizes the role of public policy, cross-border infrastructure coordination, and harmonized industrial strategies as critical components in shaping a regionally integrated value chain. Rather than assuming that regional complementarities will emerge naturally through comparative advantage or private initiative, the analysis in Chapter 5 explores how targeted, state-guided cooperation could accelerate and optimize the formation of a solar PV RVC. In this sense, the developmental regionalism framework not only justifies the policy recommendations put forward in Section 5.3, but also provides a theoretical foundation for viewing regional integration as an active developmental tool, rather than a passive outcome of market convergence.

3.3 Catch-up Theory and Policy Transfer

To assess the relevance and limitations of applying China's solar PV development experience to the East African context, Chapter 6 combines insights from Catch-up Theory and Policy Transfer Theory as a third analytical layer.

Catch-up Theory, rooted in development economics and innovation studies, provides a conceptual basis for understanding how latecomer countries build, adapt, and upgrade technological capabilities. As summarized by Li et al. (2020), this process typically unfolds in sequential stages: technology acquisition, assimilation, and re-innovation. The theory emphasizes the role of state-led strategies in accelerating learning, developing industrial infrastructure, and integrating into global markets. In this study, Catch-up Theory informs the interpretation of China's solar PV trajectory, particularly the interplay between strategic policy coordination and phased technological upgrading. These insights support the historical reconstruction presented in Chapter 6, which examines China's catch-up process through four key dimensions: (1) Strategic Policy Mix and Industrial Coordination, (2) Financing Mechanisms, (3) Technological Capability Building, (4) Standards and Certification Systems

To evaluate which aspects of this experience may be applicable to East Africa, the study incorporates Policy Transfer Theory as a complementary tool. Defined by Dolowitz and Marsh (1996, 2000) as the process through which knowledge about policies, institutions, or ideas in one setting is applied in another, the theory helps distinguish between successful adaptation and superficial imitation. Specifically, the analysis in Chapter 6.2 assesses the transferability of selected Chinese policy tools using five dimensions identified in Dolowitz and Marsh (2000):

1. Transferability of goals: Are the core development objectives aligned between the source and recipient context?
2. Transferability of content (policies/instruments): Can the policy mechanisms themselves be meaningfully applied?
3. Institutional similarity: Do the administrative and governance structures resemble those of the source country?
4. Administrative capacity: Is the receiving government capable of implementing comparable policies?
5. Actor willingness: Do relevant stakeholders support the transfer and adaptation process?

The concrete framework is demonstrated in Figure 25. These criteria provide a structured way to assess whether specific elements of China's experience-such as R&D subsidies, financing instruments, or quality assurance schemes-can be directly borrowed, or whether they require adaptation to local constraints in East Africa.

Together, Catch-up Theory and Policy Transfer Theory offer a complementary analytical framework. While the former helps explain how industrial capability was built in China, the latter provides a basis for evaluating the contextual compatibility of selected strategies. This combined approach supports the cross-context learning exercise in Chapter 6.

Why Transfer? Continuum Want To.. . . . . Have To			Who Is Involved in Transfer?	What Is Transferred?	From Where			Degrees of Transfer	Constraints on Transfer	How To Demonstrate Policy Transfer	How Transfer leads to Policy Failure
Voluntary	Mixtures	Coercive			Past	Within-a Nation	Cross-National				
Lesson Drawing (Perfect Rationality)	Lesson Drawing (Bounded Rationality)	Direct Imposition	Elected Officials	Policies (Goals) (content) (instruments)	Internal	State Governments	International Organizations	Copying	Policy Complexity (Newspaper) (Magazine) (TV) (Radio)	Media	Uniformed Transfer
	International Pressures		Bureaucrats Civil Servants	Programs	Global	City Governments	Regional State Local Governments	Emulation	Past Policies	Reports	Incomplete Transfer
	(Image) (Consensus) (Perceptions)									(Commissioned) (uncommissioned)	
	Externalities	Pressure Groups	Institutions			Local Authorities		Mixtures	Structural Institutional	Conferences	Inappropriate Transfer
	Conditionality	Political Parties	Ideologies					Inspiration	Feasibility	Meetings/ Visits	
	(Loans) (Conditions Attached to Business Activity)								(Ideology) (cultural proximity) (technology) (economic) (bureaucratic)		
	Obligations	Policy Entrepreneurs/ Experts	Attitudes/ Cultural Values						Language	Statements (written) (verbal)	
			Consultants Think Tanks Transnational Corporations Supranational Institutions	Negative Lessons			Past Relations				

Figure 25 - Policy Transfer Framework
Source: Dolowitz and Marsh, 2000

To operationalize these frameworks, the research follows a three-prong analytical strategy. First, the TIS framework is used to perform a functional assessment of the solar PV innovation systems across twelve East African countries. Data is derived from academic literature, public policy documents, and industry sources such as ENF Solar, PV-Tech, and PV Magazine. Each system function is assessed using qualitative indicators and triangulated evidence to evaluate the depth, maturity, and coherence of national innovation environments. The outcome is a comparative profile of innovation system performance, which is presented in Chapter 4.

Second, the research evaluates country-level competitiveness and regional complementarity in solar PV manufacturing using the framework described in Section 3.2. Drawing on international data sources—including IEA, IRENA, USGS, UNCTAD, and the World Bank—the analysis assesses structural conditions such as mineral availability, electricity costs, industrial infrastructure, and trade policy. These inputs support a cross-country comparison of value chain positioning and inform the design of a regional specialization model, which is further developed in Chapter 5.

Third, the study conducts a contextualized analysis of China's solar PV catch-up trajectory, using historical sources, policy literature, and secondary datasets. This analysis focuses on how China built manufacturing capacity through industrial coordination, financing mechanisms, technological upgrading, and certification systems. The relevance of these policy tools for East Africa is then assessed using criteria from Policy Transfer Theory (Dolowitz & Marsh, 2000), including goal alignment, content applicability, institutional similarity, administrative capacity, and stakeholder willingness. This forms the foundation of Chapter 6, which identifies selectively transferable strategies and highlights the institutional and political conditions necessary for effective adaptation.

Data collection relies exclusively on secondary sources. Academic publications are retrieved from databases such as Scopus, Web of Science, and Google Scholar. Policy and regulatory documents are accessed from the official websites of national governments, regional bodies (EAC, AfCFTA, AUDA-NEPAD), and development institutions (AfDB, UN agencies). Industry data is collected through global platforms such as ENF Solar, IEA, BloombergNEF, and PV-Tech, while trade and infrastructure statistics are drawn from UN Comtrade, World Bank Open Data, and USGS. Given the wide disparity in data availability across countries, the analysis acknowledges that data coverage is uneven: more robust for Kenya, Ethiopia, and Rwanda, and more limited for fragile or post-conflict states like South Sudan and Somalia.

Despite these constraints, the use of triangulated data, grounded theory, and comparative logic ensures methodological rigor. The combination of innovation system analysis, value chain competitiveness assessment, and policy learning offers a multi-dimensional approach to investigating how East Africa can shift from being a passive recipient of imported solar products to an active participant in a regionally embedded, industrially resilient PV manufacturing ecosystem.

The roadmap of this thesis is illustrated in Figure 26.

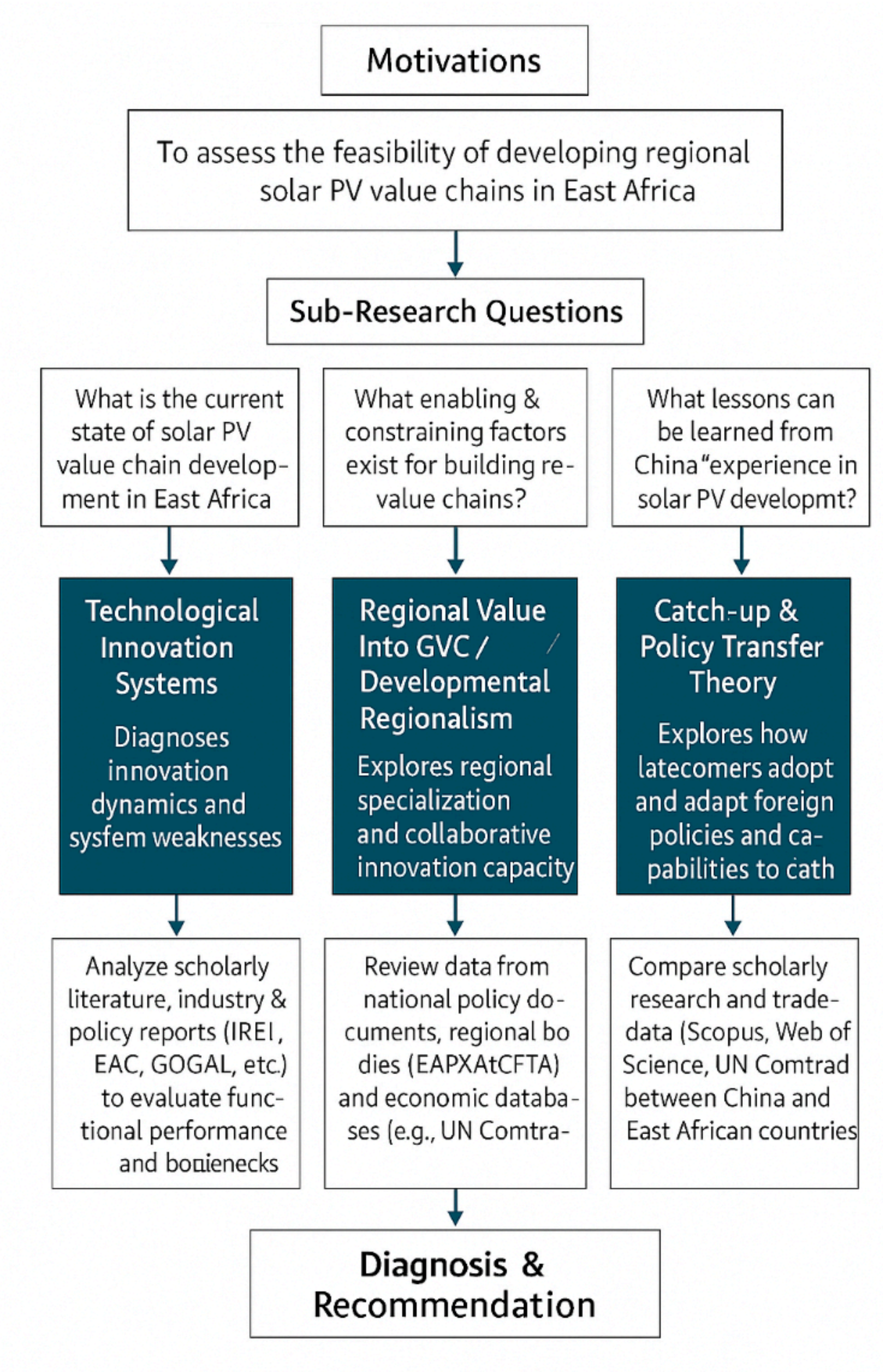


Figure 26 – Research Roadmap

4 A TIS Perspective on Solar PV Value Chain Development in East Africa

Building on the analytical framework introduced in Chapter 3.1, this chapter applies the Technological Innovation System (TIS) approach to examine the structural and functional conditions shaping solar PV manufacturing in East Africa. The goal is to diagnose system-level bottlenecks and identify enabling factors that influence the development of a regional value chain for solar technologies.

The analysis is structured in two main parts. The first investigates the structural components of the regional innovation system, including key actors, their interactions, and the institutional environment in which they operate. The second part evaluates the performance of seven core system functions—such as knowledge development, entrepreneurial experimentation, and resource mobilization—across twelve East African countries.

Empirical evidence is drawn from a wide range of sources, including national policy documents, industry databases (e.g., ENF Solar), investment agency reports, donor programs, and expert publications. By applying the TIS framework in a regional and manufacturing-oriented context, this chapter provides a detailed understanding of the systemic challenges that constrain East Africa's solar PV industrialization and lays the foundation for the value chain-oriented discussion in Chapter 5.

4.1 Structural Components of the East African Solar PV Innovation System

4.1.1 Actors

Actors are the foundational elements of any TIS. In the context of developing a local solar PV manufacturing base in East Africa, relevant actors are not limited to those engaged in the consumption or distribution of solar technologies. Instead, attention must turn to the institutions and enterprises that can or have the potential directly or indirectly influence the production of solar modules and intermediates, as well as those shaping the broader industrial environment in which manufacturing occurs. While solar PV deployment has historically dominated policy and market attention, a deeper examination of actor roles reveals potential entry points for building domestica production capacity. In East Africa, the solar PV TIS comprises a diverse array of actors operating across public, private, academic, foreign, and international domains. Each actor group plays a distinctive role in shaping the performance of the innovation system.

To systematically identify these actor groups in relation to the manufacturing segment of the solar PV value chain, a structured research process was implemented in three steps:

i. **Policy and Strategy Review**: National industrial policies, economic reform agendas, and regional development strategies were reviewed—particularly those published by key government ministries, investment authorities, and international organizations such as UNIDO and AfDB. This step helped to identify which countries have formally prioritized renewable energy manufacturing and what institutional mandates are involved.

ii. **Institutional and Investment Mapping**: The official websites, investment profiles, and sectoral opportunity guides of national investment promotion agencies (e.g., KenInvest, RDB, EIC) were analyzed to determine how solar PV manufacturing is positioned in industrial promotion efforts. This step also included the identification of domestic firms engaged in component assembly or adjacent industries.

iii. **Procurement and Program Analysis:** Public procurement documents, tender specifications, and donor-funded program records (especially from rural electrification authorities and development agencies) were assessed to understand whether government demand-side programs or donor initiatives include features—such as local content requirements or technical standards—that could influence domestic production activities.

Government and Public Institutions

Across East African countries, various public institutions exist—such as investment authorities, industrial ministries, and electrification agencies—but most do not explicitly address solar PV manufacturing. In many cases, these institutions focus on general industrial promotion or energy access without clear reference to domestic production of solar technologies.

Kenya is a notable exception. On its official investment promotion website, the Kenya Investment Authority, which is a statutory body established in 2004 under the Investment Promotion Act No. 6 of 2004 within the Ministry of Investments, Trade and Industry (MITI)), lists "Renewable Energy Equipment Manufacturing" as a priority sub-sector under manufacturing. It states that, "with Kenya's commitment to renewable energy, there is a growing demand for equipment such as solar panels, wind turbines, and energy storage systems," and that "investing in the manufacturing of renewable energy components can be a strategic move" (KenInvest, 2023). This framing suggests a degree of policy alignment between Kenya's renewable energy goals and its industrial development agenda.

By contrast, most other countries in the region—such as Uganda, Tanzania, or Rwanda—have relevant institutions in place but no publicly available strategies or investment frameworks that link solar deployment with local manufacturing. In smaller or post-conflict states like Burundi or South Sudan, institutional capacity is even more limited. Overall, clear government signaling in favor of solar PV manufacturing remains the exception rather than the norm in East Africa.

A list of relevant public actors by country, along with their main roles and official websites, is provided in Appendix A.

Private Firms and Entrepreneurs

The identification of private firms involved in solar PV sector in East Africa was supported by a targeted review of international industry databases and news platforms. Four main sources were consulted: ENF Solar, PV-Tech, PV Magazine, and "How We Made It in Africa". Each provided complementary insights into the presence, activities, and ownership structures of solar-related enterprises in the region.

i. **ENF Solar** (https://www.enfsolar.com) is the world's largest solar company directory, widely used by industry actors and researchers. It offers a structured database that categorizes firms by country, business type (e.g., panel manufacturer, installer, EPC), and technology. The platform's filtering system was used to identify firms listed as module manufacturers or component assemblers in East Africa. Profiles typically include company descriptions, product lines, contact information, and certifications, allowing for verification of manufacturing claims.
ii. **PV-Tech** (https://www.pv-tech.org) is a globally recognized news platform operated by Solar Media Ltd., covering solar manufacturing, markets, and policy. Its "Manufacturing" and "Markets & Policy" sections were searched using keywords such as "Ethiopia solar manufacturing" and "East Africa PV production." This led to the identification of key announcements, including TOYO Co. Ltd.'s 2 GW solar cell factory investment in Ethiopia.
iii. **PV Magazine** (https://www.pv-magazine.co) offers in-depth reporting on solar PV technology, project development, and industrial policy. Articles often include expert commentary, technical details, and market analysis, providing context on the scale and significance of manufacturing investments.

iv. **How We Made It in Africa** (https://www.howwemadeitinafrica.com) is a respected platform for African business reporting, frequently cited by development institutions such as the African Development Bank and World Bank. It features company case studies and investor interviews. The platform was especially useful for identifying local firms not covered in global databases.

Together, these sources allowed for the triangulation of firm-level data across local and foreign actors, enabling a distinction between companies engaged in upstream manufacturing or assembly and those focused solely on downstream distribution and services.

Search results from the consulted platforms revealed a small but emerging group of private firms engaged in solar PV manufacturing and assembly in East Africa, with notable variation across countries.

In Kenya, Solinc East Africa is the most prominent local manufacturer, operating a module production facility in Naivasha that supplies small- to medium-scale panels for off-grid markets. The company also assembles full solar kits and collaborates with rural electrification programs. While not engaged in manufacturing, companies like CEL and Go Solar Systems Ltd, listed on ENF Solar, play important roles in kit assembly and distribution, contributing to system integration.

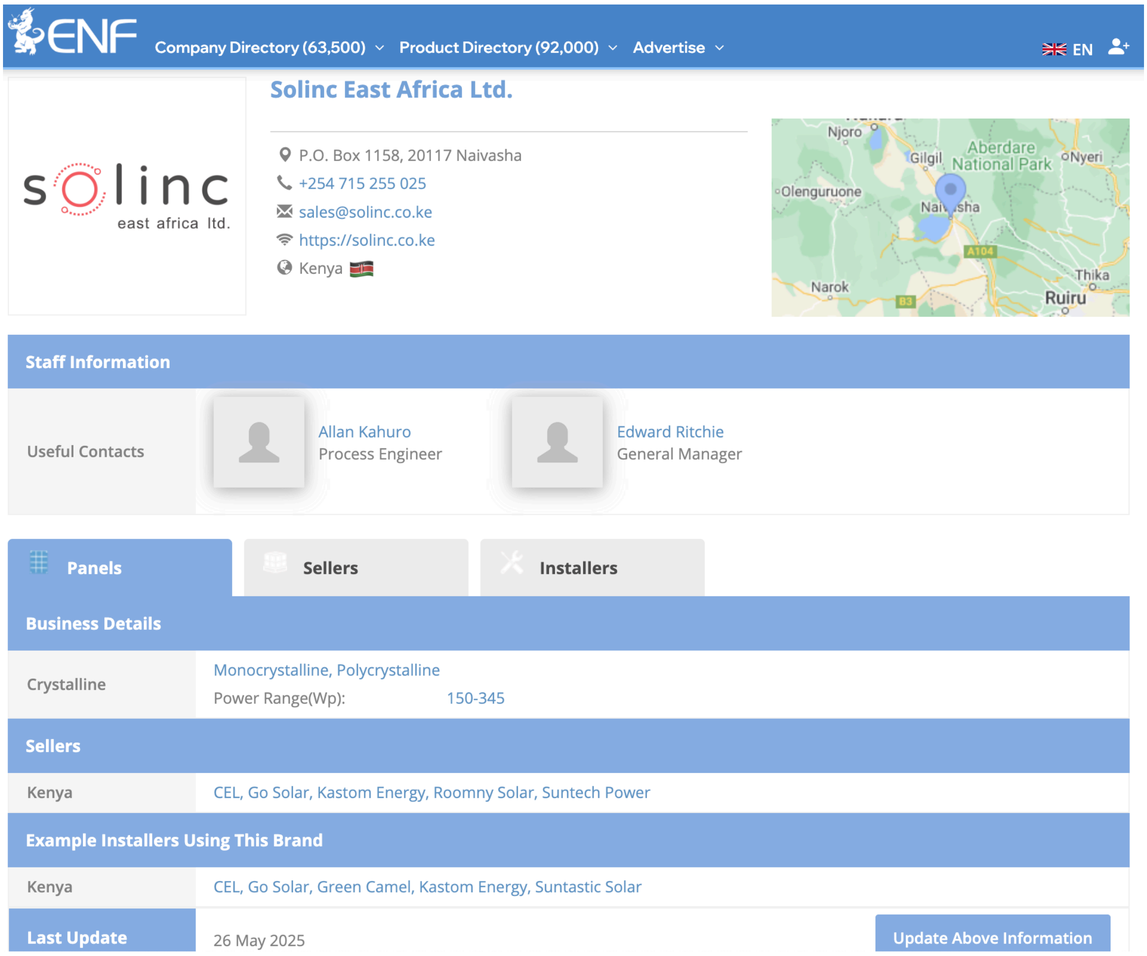


Figure 27 -Company profile of Solinc East Africa Ltd.
Source: ENFsolar)

In Ethiopia, manufacturing is driven largely by foreign investment. PV-Tech reported that Japan's TOYO Co. Ltd is constructing a US$60 million solar cell factory in Hawassa Industrial Park aimed at both local use and U.S. exports (source: PV-Tech). Local firms such as STM Solar Technologies and SahanEase Solar, noted in PV Magazine and ENF Solar, are involved in light assembly of off-grid systems, often supported by donor-funded programs.

In other East African countries, no manufacturing firms were identified in the consulted sources. While downstream activities are gradually expanding, upstream production remains minimal.

International Organizations and NGOs

A small number of International Organizations and NGOs have begun to engage with the idea of solar PV manufacturing in Africa, but their support in East Africa remains largely limited to research, feasibility studies, and policy advice. More substantial assistance—such as concessional finance and risk guarantees—is still concentrated in the application side of the solar sector.

The Africa Renewable Energy Manufacturing Initiative (Africa REMI), launched by Sustainable Energy for All (SEforALL) in 2023, includes Kenya, Tanzania, and Rwanda in its continental feasibility assessment. However, these countries are viewed as less attractive than others such as Egypt or South Africa, due to weaker infrastructure, policy uncertainty, and limited export capacity (SEforALL, 2023).

Research Institutions

To assess the role of research institutions in solar PV manufacturing in East Africa, a targeted search was conducted through the official websites and publication records of major universities and public research centers in East Africa. Institutions examined included Strathmore University, the University of Nairobi, Addis Ababa University, and the University of Rwanda, among others. The search focused on identifying projects related specifically to PV component manufacturing, materials research, or industrial process development.

The results revealed no significant or sustained research programs in this area. A few Kenyan universities such as Strathmore University and Egerton University have participated in internationally funded projects, such as the REACH-PSM initiative on perovskite solar modules, but these efforts remain externally driven and exploratory in nature (PV-magazine, 2025). No relevant initiatives were found at leading institutions in other countries. This limited engagement reflects the fact that solar PV manufacturing in the region is currently driven more by private sector and donor-led activity than by academic research. As a result, the role of research institutions in shaping the technological trajectory of solar manufacturing remains minimal at this stage.

Industry Associations

Industry associations in East Africa play a limited role in supporting solar PV manufacturing. A review of major national and regional associations—including the Kenya Renewable Energy Association (KEREA), the Kenya Association of Manufacturers (KAM), The Ethiopian Solar Energy Development Association (ESEDA), and the East African Business Council (EABC)—shows that while these organizations are active in promoting renewable energy broadly, their focus remains on deployment, off-grid access, and green policy advocacy rather than on fostering local manufacturing capabilities.

These findings suggest that intermediary actors have not yet developed the institutional focus or capacity needed to support a solar PV manufacturing system. From a TIS perspective, this reflects a weak fulfillment of system functions such as guidance of the search, resource mobilization, and legitimation.

4.1.2 Networks

In TIS, networks refer to the interactions, collaborations, and relationships between different actors that facilitate the flow of knowledge, resources, and technologies (Bergek et al., 2008). These networks enable information sharing, reduce transaction costs, and help scale innovations by linking actors across different institutional domains. In the case of solar PV manufacturing in East Africa, networks are important for coordinating fragmented initiatives, aligning incentives, and building collective momentum in a nascent sector.

To assess the presence and function of networks in this context, verifiable connections among actor categories previously identified are examined, namely private firms, public agencies, international organizations, research institutions, and industry associations. A network is considered present when there is documented evidence of collaboration, co-participation in projects, institutional affiliation, or structured interaction.

One of the few existing knowledge networks with a potential link to solar PV manufacturing in East Africa is the REACH-PSM project, led by Swansea University in the UK. The initiative aims to explore the feasibility of establishing local manufacturing capacity for perovskite solar modules—a next-generation PV technology that uses a perovskite-structured compound as the light-absorbing layer. These modules are considered promising due to their lower potential manufacturing costs, flexible processing, and high laboratory efficiency rates compared to traditional silicon-based modules.

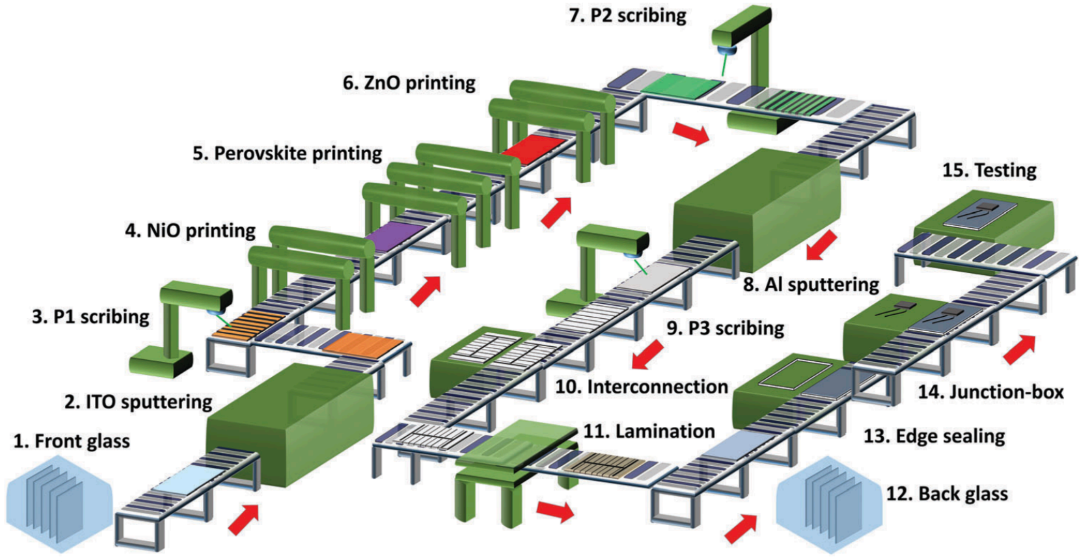


Figure 28 - Flow diagram of manufacturing process for perovskite solar modules
Source: Song *et al.*, 2017

The project involves a consortium of academic and private-sector partners across Africa, including Strathmore University and Egerton University in Kenya, the Federal University of Technology Owerri in Nigeria, and the University of Cape Town and North-West University in South Africa. It also includes private companies such as Kijani Testing (Kenya), SLS Energy (Rwanda), and Hinkley Recycling (Nigeria). While still at an early stage, this represents one of the few internationally coordinated efforts to build research-industry linkages in solar PV manufacturing within the region (PV Magazine, 2025; Sunrise, 2024).

A notable example of a functioning industry-oriented network is the relationship between Solinc East Africa Ltd, Kenya's only operational PV module manufacturer, and its downstream partners such as Chloride Exide and PAYG solar providers (e.g., Customer One and Customer Two). As shown in Figure 29, these firms formed a closely integrated distribution network that facilitated product tailoring, just-in-time delivery, and aftersales services. According to Davy et al. (2024), Solinc initially distributed modules via Chloride Exide, which was also part of its parent company structure. This vertical integration allowed for cost-efficient logistics and close feedback loops. Later, Solinc established long-term supply relationships with PAYG providers, who sourced tens of thousands of customized small-scale modules annually for off-grid households. These customers valued Solinc's ability to meet specific module sizes and deliver faster than overseas suppliers, especially for localized projects in Kenya and Rwanda (Davy et al., 2024).

These partnerships were supported by both formal agreements and informal personal networks, including shared management personnel across Solinc and its major clients. Such relational governance structures, characterized by trust, mutual dependency, and repeated interaction, enabled Solinc to compete on dimensions beyond price, such as quality assurance, responsiveness, and service (Davy et al., 2024). The presence of this industry network illustrates how firm-level integration can strengthen innovation system performance even in contexts with weak institutional and policy coordination.

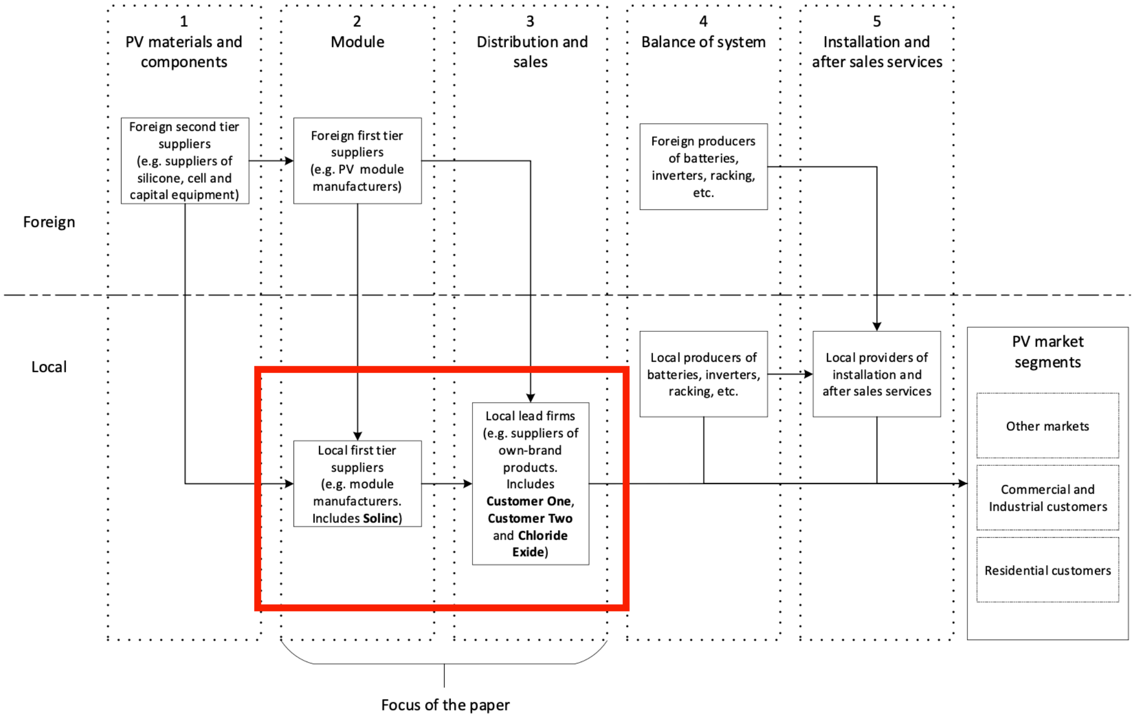


Figure 29 – Industry-oriented networks in Kenya solar PV value chain
Source: Davy *et al.*, 2024

Public-private partnerships (PPPs) have emerged as a vital mechanism for accelerating the deployment of solar PV in East Africa. Examples can be found in Ethiopia, where PPPs are playing a crucial role in expanding access to solar-powered irrigation for smallholder farmers. A collaboration between the International Water Management Institute (IWMI), the Ethiopian government, and private solar providers has enabled the deployment of solar irrigation pumps in remote farming areas. These partnerships bring together the strengths of public institutions—such as policy support, infrastructure, and funding—with the innovation and operational capacity of private enterprises to address both electrification and agricultural productivity challenges (IWMI, 2024).

Despite a few cases mentioned above, key network linkages necessary for a functioning PV manufacturing system in East Africa remain limited or underdeveloped. Research institutions are rarely connected to domestic firms. Beyond Kenya's participation in the REACH-PSM project, universities in other East African countries show no visible engagement with manufacturing actors. The lack of research–industry collaboration restricts localized learning and reduces the system's capacity for knowledge upgrading.

Horizontal linkages among private firms are also weak. There are no known manufacturing consortia, local supply chains, or shared infrastructure platforms. One partial exception is Solinc East Africa, which has built long-term relationships with downstream distributors and PAYG companies, enabling tailored production and faster delivery (Davy et al., 2024). However, even Solinc operates without clear connections to other manufacturers, input suppliers, or domestic R&D bodies.

Industry associations such as the Kenya Renewable Energy Association (KEREA), the Ethiopian Solar Energy Development Association (ESEDA), and the East African Business Council (EABC) have not taken on a coordinating role in upstream solar PV manufacturing. A review of their official websites, policy documents, and public communications revealed no initiatives related to component standardization, joint procurement mechanisms, or technical training tailored to manufacturing. Their activities remain largely focused on solar deployment, advocacy for electrification, and promotion of investment in downstream energy services. This absence of targeted support structures suggests that these associations have yet to assume intermediary functions essential to manufacturing system development.

Compared to countries like China, where dense industry clusters, active associations, and university–industry partnerships support coordinated capability building (Ge et al., 2022), East Africa lacks the institutionalized networks needed to anchor manufacturing. From a TIS perspective, these gaps constrain functions such as knowledge diffusion, legitimation, and the development of shared visions—core elements for early-stage industrial emergence.

4.1.3 Institutions

Institutions play a foundational role in shaping innovation systems, particularly in early-stage manufacturing sectors that require coordinated policy support, investment facilitation, and risk mitigation. In East Africa, however, institutional frameworks related to solar PV remain heavily focused on deployment and energy access, with little attention given to the production side of the value chain.

As part of this research, the official websites and strategic documents of key public actors—such as ministries of energy and industry, investment authorities, and electrification agencies—were reviewed for references to solar PV manufacturing. The findings reveal that while renewable energy frequently appears as a policy priority, it is almost always framed around access, electrification, or grid expansion. Manufacturing is rarely mentioned. Even in countries with more visible industrial promotion efforts, such as Kenya or Ethiopia, no cross-sectoral policy instruments were found that target upstream PV production or link energy planning with industrial development goals.

Similarly, investment promotion agencies tend to highlight renewable energy as a growth sector, but specific incentives for PV component manufacturing are absent. No tailored measures—such as tax breaks, infrastructure access, or concessional financing—could be identified for this segment. Existing incentives are generic and designed for broader light industry, with no alignment to the technical and financial needs of PV manufacturing.

This lack of institutional focus has limited key system functions such as guidance of the search and resource mobilization. Without clear mandates, strategic incentives, or coordinated planning, local and foreign actors face high uncertainty and weak signals about the region's long-term commitment to solar manufacturing.

4.2 Functional Analysis of the East African Solar PV Innovation System

4.2.1 Knowledge Development and Diffusion

A key barrier to developing a regional solar PV value chain in East Africa lies in both the lack of access to specialized knowledge and the weak diffusion of available practical know-how. While basic skills for installation and maintenance are starting to spread in some countries through local practices, more advanced knowledge—such as system design, component manufacturing, and business model adaptation—remains scarce and poorly shared across the region (IRENA, 2017; Watson *et al.*, 2012). Local firms often remain constrained to distribution roles and lack the engineering or financial expertise needed to move upstream (Lema *et al.*, 2022).

This is not only due to internal gaps in training and coordination. Much of the high-level PV technology, especially in cell manufacturing and power electronics, is protected by patents or kept proprietary by global firms (Lema et al., 2020). Technology holders (as shown in Table 4) in countries like Japan, South Korea, and the U.S. have limited incentives to transfer this know-how without strong commercial, geopolitical, or contractual guarantees (Awate et al., 2018; Byrne *et al.*, 2012). As a result, even if East African firms or governments are willing to invest, they often face systemic exclusion from critical segments of the innovation chain.

Table 4 - Top assignees by number of granted patents and their top technology classifications

Assignees	Number of solar power patents	Top five classes	Class description (in addition to Table 1)
Canon Inc. (Japan)	73	136, 52, 60, 323, 363	52: Static structures (Buildings)
General Electric (US)	70	307, 363, 290, 700, 323	
Semiconductor Energy Laboratory (Japan)	30	257, 313, 365, 438, 235	313: Electric lamp and electric space discharge devices (e.g. photosensitive discharge devices) 365: Static information storage and retrieval 235: Registers (machines ascertaining the number of movements of various devices)
Sanyo Electric Company Ltd. (Japanese)	30	136, 257, 307, 320, D13	320: Electricity: battery or capacitor charging or discharging D13: Equipment for production, distribution, or transformation of energy
The Boeing Company (US)	25	136, 244, 438, 701, 257	244: Aeronautics and astronautics 701: Data processing: vehicles, navigation, and relative location
Samsung (South Korea)	25	307, 320, 429, 323, 363	320: Electricity: battery or capacitor charging or discharging 429: Chemistry: electrical current producing apparatus, product, and process
Hitachi Ltd. (Japan)	24	73, 257, 345, 360, 210	73: Measuring and testing 345: Computer graphic processing and selective visual display systems 360: Dynamic magnetic information storage and retrieval 210: Liquid purification or separation
Sharp Corporation (Japan)	23	345, 136, 118, 320, 323	345: Computer graphic processing and selective visual display systems 118: Coating apparatus 320: Electricity: battery or capacitor charging or discharging
Mitsubishi (Japan)	22	118, 136, 438, 244, 204	118: Coating apparatus 244: Aeronautics and astronautics 204: Chemistry: electrical and wave energy
IBM (US)	18	700, 174, 257, 136, 438	174: Electricity: conductors and insulators

Source: Awate et al., 2018

To better understand the specific knowledge gaps that constrain value chain development in East Africa, different types of knowledge required across the PV sector are distinguished ranging from basic installation skills to advanced manufacturing know-how. These knowledge types vary in both content and difficulty of diffusion. As shown in Table 5, while some areas such as installation and customer engagement are relatively easy to scale through local training and peer learning, others—particularly system design, financial modeling, and PV component manufacturing—remain far more complex (IRENA, 2017). The latter often require formal engineering education, cross-sectoral collaboration, or access to proprietary knowledge protected by patents (Byrne *et al.*, 2012).

Table 5 – Type of Knowledge for Solar PV Value Chain Development in East Africa

Knowledge Type	Use in Value Chain	Diffusion Difficulty	Main Learners	Suggested Learning Mode
Basic Installation & O&M	SHS, mini-grid deployment	★☆☆☆☆ (Low)	Technicians, installers	Vocational training, on-the-job practice
Customer Engagement & Service Models	PAYG, after-sales, consumer education	★★☆☆☆ (Low–Medium)	Sales agents, local entrepreneurs	Field-based learning, peer training
Regulatory & Procurement Know-how	Licenses, tenders, FiTs, RBF, quality enforcement	★ ★ ☆ ☆ ☆ (Medium)	Government, regulators	Toolkits, regional harmonization forums
Business Model & Financing Design	PAYG structure, bundling, mini-grid financing	★ ★ ★ ☆ ☆ (Medium–High)	Entrepreneurs, project developers	Case studies, incubators, blended finance
System Design & Engineering	Mini-grid layout, sizing, hybrid integration	★★★★☆ (High)	Engineers, integrators	University courses, joint project design
Component Manufacturing & IP Know-how	PV module, inverter production, cell efficiency control	★★★★★ (Very High)	Industrial firms, R&D teams	Licensing, tech transfer, joint ventures

Source: Adapted based on IRENA (2017)

These differences suggest that a one-size-fits-all capacity-building approach will not work. For East Africa to strengthen its innovation system and move up the value chain, it must match knowledge diffusion strategies to the specific type and difficulty of each knowledge domain. The table below outlines this typology and proposes potential learning pathways

While basic diffusion failures can be addressed through vocational training and knowledge-sharing platforms, the structural exclusion from advanced technical knowledge presents a deeper systemic constraint. Overcoming this will require not only better local absorptive capacity, but also strategic partnerships with technology owners and policy tools to negotiate access to protected knowledge domains.

4.2.2 Influence on the Direction of Search

Kenya provides one of the strongest examples of directional clarity. Through the Kenya Off-Grid Solar Access Project (KOSAP), the government—supported by the World Bank—has created results-based financing, tax incentives, and public-private platforms that clearly signal opportunities in PAYG and mini-grid markets. This has guided firms and donors alike toward inclusive off-grid business models, supported by state agencies such as the Ministry of Energy and Rural Electrification and Renewable Energy Corporation (REREC).

Rwanda has adopted a similarly access-first approach, with solar subsidies delivered via the national development bank (BRD) through ASCENT project. However, the policy signal remains focused on household-level deployment, with limited guidance toward manufacturing or technology upgrading. Directional influence here is more donor-driven and less oriented toward long-term industrial goals.

In contrast, Tanzania and Ethiopia illustrate weaker directionality. Tanzania's energy strategies reference solar but lack specific instruments or institutional coordination to guide private sector investments in either business model innovation or local production. Ethiopia has made broader investments in industrial parks but without targeted strategies for solar PV.

For the remaining countries in the region, there is limited evidence of strong or coordinated policy signals guiding the solar PV sector. While some have donor-led programs promoting rural access, none appear to offer clear guidance for firms regarding innovation or value chain upgrading.

While this access-first approach addresses urgent development needs, it also means that broader, long-term opportunities in the solar sector—such as local manufacturing, technology upgrading, and job creation—have received less attention. These objectives may not yield immediate returns, but they are crucial for building a resilient solar industry and creating economic spillovers beyond household electrification.

4.2.3 Entrepreneurial Experimentation

Entrepreneurial activity in the East African solar PV sector has grown steadily in recent years, especially in distribution, installation, and project deployment. Data from ENF Solar as illustrated in Figure 30 shows that Kenya dominates the region, hosting over 130 companies—

mainly installers and project developers—followed by more modest clusters in Rwanda, Tanzania, and Ethiopia. The table includes only companies registered on the ENF Solar platform; locally operating firms that are not listed may be omitted.

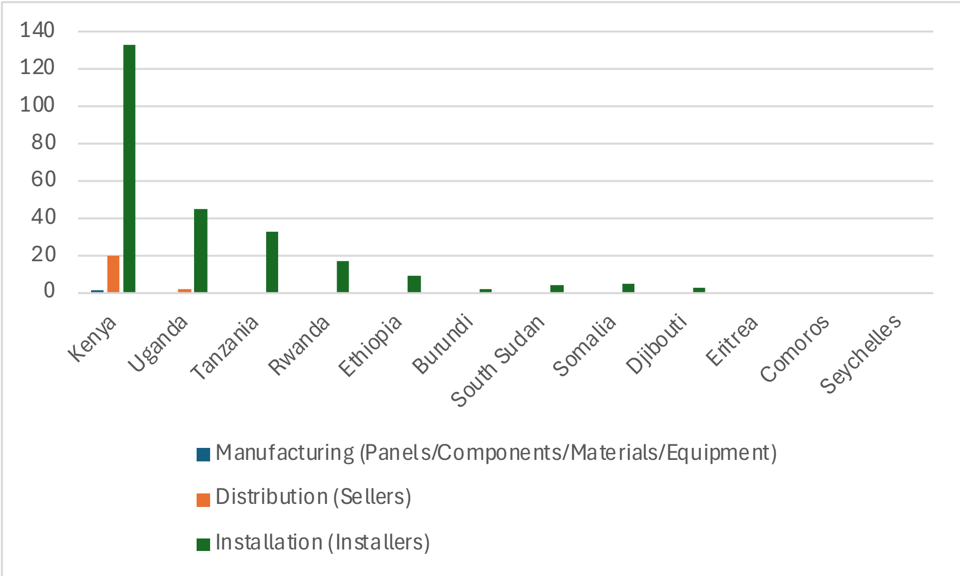


Figure 30 – Distribution of Solar PV Companies by Sector in East African Countries
Source: enfsolar, 2025

Upstream experimentation—such as PV module manufacturing, inverter assembly, or materials processing—is much more limited. However, this does not necessarily mean there have been no efforts. In countries like Kenya and Ethiopia, there have been attempts to establish local assembly lines or initiate domestic component production. Yet many of these initiatives appear to have struggled or failed to scale except Solinc in Kenya (Davy, 2024).

Several factors may explain this. First, upstream manufacturing is capital-intensive and requires advanced technical know-how, which is often protected by patents or not readily available in the region. Second, local markets may be too small or fragmented to support economies of scale, especially given the dominance of cheap imported components. Third, national industrial policies and trade regimes may not provide sufficient incentives—such as tax breaks, subsidies, or tariff protection—to make local production competitive. Finally, access to affordable long-term finance remains a major constraint, especially for high-risk ventures with longer payback periods.

As a result, most entrepreneurial efforts have remained concentrated in segments with lower entry barriers. While this has helped expand access and build local delivery capacity, it also risks reinforcing a structural imbalance: too many actors competing in limited downstream markets, while upstream opportunities remain underdeveloped or abandoned. Supporting experimentation across the full value chain will require not only stronger technical and financial support, but also more strategic alignment between energy policy and industrial development.

4.2.4 Market Formation

In most East African countries, solar PV markets are still in the early "nursing" phase. A market report by Lighting Global (2020) discovers that initial demand has been driven largely by donor programs and development agencies, targeting rural households with low-tier solar products (e.g., solar lanterns and small SHS). Purchasing decisions are shaped by affordability, availability of mobile payments, and access to PAYG models, rather than by institutional demand or long-term planning. However, country-level differences reveal how structural actors influence the depth and durability of market formation.

In Kenya, market formation is relatively advanced, thanks to a strong policy-regulatory framework and active public-private collaboration. The Ministry of Energy, together with the Rural Electrification and Renewable Energy Corporation (REREC) and donor-backed initiatives like KOSAP, provides coordinated support for market development. Results-based financing, consumer subsidies, and VAT exemptions have enabled firms such as M-KOPA and d.light to scale PAYG operations. Standards and licensing are enforced through Kenya Bureau of Standards (KEBS), further reinforcing formalization (World Bank, 2020; UNCTAD, 2023).

Rwanda offers a more centralized model. The Development Bank of Rwanda (BRD) plays a critical role in channeling subsidies to SHS providers, supported by the World Bank and Energizing Development (EnDev). While this has led to rapid deployment in rural areas, the role of the private sector remains narrower, and the market is highly dependent on external financing. The Rwanda Utilities Regulatory Authority (RURA) oversees licensing and tariffs but offers limited market-building instruments beyond access targets (IRENA, 2021).

In Ethiopia, the solar market is strongly shaped by public planning under the National Electrification Program (NEP), but private sector participation is minimal. The Ministry of Water and Energy and the Ethiopian Electric Utility (EEU) dominate implementation through public tenders, while PAYG and SHS markets in private sector are nascent. Standards and after-sales systems remain underdeveloped, reflecting weak institutional support for market evolution (UNCTAD, 2023).

Uganda and Tanzania present hybrid cases. Uganda has a large SHS user base and growing private sector participation, but the absence of robust standards and inconsistent enforcement by the Uganda National Bureau of Standards (UNBS) limits product quality and consumer trust. In Tanzania, policy ambiguity and weak coordination between the Rural Energy Agency (REA) and energy regulators have constrained market growth. Import duties and unclear licensing rules discourage private investment in both hardware and service models (Lighting Global, 2020).

In contrast, countries such as Burundi, South Sudan, Somalia, Djibouti, and Eritrea exhibit minimal structural engagement. Solar adoption remains donor-driven, and government agencies have yet to establish dedicated solar policies, regulatory institutions, or public financing mechanisms.

In sum, while Kenya has built the strongest enabling structure for market formation, supported by active coordination between ministries, regulators, and firms, Rwanda and Uganda follow with partial institutional support. Other countries lag due to fragmented or absent structural components, resulting in highly dependent and narrow markets.

Market formation for upstream solar PV manufacturing remains weak across the region. Most policies prioritize deployment and rural access, with little support for local production. Kenya's Energy Act (2019), for example, lacks clear incentives for PV manufacturing. Ethiopia's industrial parks offer infrastructure but no targeted demand signals such as local content rules or public procurement. Without supportive market conditions such as offtake guarantees or concessional finance, firms face limited incentives to invest in module assembly or component production. As a result, the region's solar industry remains import-dependent, missing opportunities for industrial upgrading and value chain integration.

4.2.5 Legitimation

Over the past decade, solar PV has gained growing legitimacy in East Africa as a practical and socially desirable solution to energy poverty. However, solar PV is still perceived primarily as a rural or transitional solution, rather than a central pillar of long-term energy planning. This perception is reinforced by the lack of visible integration of solar in industrial or urban energy policies. In urban settings, solar is often treated as a backup to the grid rather than a mainstream energy source.

In Kenya, solar manufacturing has been mentioned in strategic documents such as the Kenya Energy Transition Plan and the Kenya Investment Authority's sector briefs, which list solar equipment production as an investment opportunity (SEforALL, 2023).The Energy and Petroleum Regulatory Authority (EPRA) and Kenya Bureau of Standards (KEBS) focus primarily on regulating imports, and manufacturers such as Solinc East Africa operate without evident preferential market access or coordinated industrial policy support (UNCTAD, 2023).

Ethiopia has made the most tangible move toward legitimizing PV manufacturing through industrial park policy. In 2025, Toyo Solar, a Japanese firm, began production at a 2 GW solar cell and module plant in Hawassa Industrial Park (PV Magazine, 2025). The Ethiopian government has included solar components in its list of priority sectors for industrial parks, offering incentives such as tax holidays and access to infrastructure (GGGI, 2021). However, this legitimation remains externally driven: the project was initiated by foreign capital, and there is still no national strategy linking PV manufacturing with local R&D or domestic market integration.

At the regulatory level, most East African countries lack institutional frameworks to support the legitimacy of domestic PV products. Testing facilities, certification schemes, and public quality assurance mechanisms for locally made components are virtually absent. Without these structural supports, local manufacturers struggle to compete with imported products—many of which are low-cost and supported by foreign export incentives.

In sum, the legitimation of solar PV manufacturing in East Africa remains weak, with few countries offering institutional, regulatory, or policy-level signals that it is a credible industrial pathway. While Ethiopia's industrial parks signal partial progress, regional legitimation remains fragmented and externally led, leaving domestic industry actors without a strong foundation for growth or long-term policy engagement.

4.2.6 Resource Mobilization

While donor and DFI funding has supported solar deployment across East Africa, resource mobilization for PV manufacturing remains weak and fragmented. Most countries lack national financing mechanisms, industrial credit lines, or targeted incentives to support local production. In Kenya, investment in solar has largely focused on deployment. Local firms like Solinc East Africa have struggled to access long-term capital, partly due to unstable tax policies and the absence of green industrial finance (How We Made It in Africa, 2015). Although the Kenya Green Manufacturing Investment Guide lists solar as a priority, concrete financial tools remain underdeveloped (SEforALL, 2023). Ethiopia is a notable exception, having attracted foreign investment through its industrial park system. The government offers tax holidays and infrastructure access, which enabled Toyo Solar to launch a 2 GW cell and module plant in 2025. However, the project is almost entirely foreign-funded, with little local capital mobilization (PV Magazine, 2025) Elsewhere, including Rwanda and Uganda, public financing focuses on off-grid access rather than upstream production. There are no dedicated funds, credit schemes, or procurement guarantees for domestic manufacturers (UNCTAD, 2023).

To understand what kinds of support are needed for the solar PV sector to grow across all stages of the value chain, it is important to distinguish between different types of resources. Each type plays a unique role in enabling firms and institutions to innovate, scale, and sustain operations. The table below summarizes the key categories of resources—financial, human, and institutional—and outlines where they are applied in the solar value chain and how they can typically be accessed.

Table 6 - Key Resources for Developing the Solar PV Value Chain

Resource Type	Application in PV Value Chain	Typical Access Channels
Financial Capital	Project finance, equipment procurement, business scaling	DFIs, concessional loans, RBF schemes, local banks, green bonds
Working Capital	Inventory, operations, logistics	Microfinance, trade credit, supplier financing
Human Resources	Installation, system design, engineering, sales	Technical training centers, university programs, on-the-job training
Entrepreneurial Talent	Business model development, market entry, local adaptation	Incubators, accelerators, diaspora networks, entrepreneurial grants
Managerial Capacity	Supply chain management, financial control, compliance	MBA-level training, peer learning, donor-funded TA programs
Technical Knowledge	PV system engineering, quality control, software integration	Technology partnerships, licensing, open-source toolkits

Policy & Regulatory Know-how	Licensing, PPA negotiation, tariff setting, quality enforcement	Regional training programs, peer exchanges, donor policy advisory
Physical Infrastructure	Testing labs, component manufacturing, logistics hubs	Industrial zones, PPPs, donor-funded capex support
Standards & Certification Systems	Product quality, installer certification, market trust	National standards bodies, IEC adoption, donor support (e.g. Lighting Africa)
Institutional Coordination Capacity	Cross-agency planning, multi-stakeholder alignment	Inter-ministerial working groups, regional energy platforms

Source: Adapted based on IRENA (2017)

This table helps clarify where current gaps exist—for instance, in long-term finance, managerial capacity, or industrial infrastructure—and highlights the need for a coordinated approach that mobilizes diverse resources through both public and private channels. Strengthening resource mobilization across all these dimensions is essential for creating a more self-reliant solar PV innovation system in East Africa.

4.2.7 Development of Positive Externalities

As solar PV activity expands in East Africa, some positive externalities have emerged, especially in the off-grid sector. In Kenya and Uganda, PAYG models have supported mobile money uptake, enhanced digital literacy, and enabled the development of informal credit histories, particularly in rural areas (Lighting Global, 2020; GSMA, 2019).

However, in the context of PV manufacturing, positive externalities remain weak. In Ethiopia, the Toyo Solar plant established in 2025 in Hawassa Industrial Park was financed by foreign capital and operates with limited linkages to local SMEs or training institutions (PV Magazine, 2025). Similarly, Kenya's manufacturers such as Solinc have faced barriers to integration with public R&D bodies or technical education systems, operating largely in isolation (How We Made It in Africa, 2015).

At the regional level, platforms for cross-border knowledge exchange, joint training, and industrial collaboration are largely absent. UNCTAD (2023) notes that many developing countries lack institutional mechanisms linking industrial parks, research institutes, and vocational systems—limiting technology diffusion and innovation spillovers.

In summary, while deployment-focused models have generated socio-economic benefits, PV manufacturing in East Africa has yet to catalyze systemic learning effects or industrial clustering due to weak institutional coordination.

4.3 Cross-Country Comparison of System Performance

A comparative review of the system functions across East African countries reveals significant disparities in the performance of the solar PV TIS. Only a few countries—most notably Kenya and Ethiopia—show tangible progress in system functions related to upstream manufacturing, while others remain largely focused on downstream deployment or show minimal activity.

Kenya demonstrates the most balanced system performance across functions. Entrepreneurial experimentation is visible through Solinc East Africa's active module production and its integration with downstream distributors and PAYG providers. This is supported by a functioning industry network that enables product customization and fast delivery. Kenya also stands out in terms of guidance of the search: official documents from KenInvest and other public agencies explicitly list renewable energy equipment manufacturing as an investment priority. While formal research engagement remains limited, Kenya is the only country in the region participating in an internationally coordinated manufacturing research initiative (REACH-PSM). These structural elements contribute to relatively stronger performance in knowledge development, legitimation, and market formation.

Ethiopia, by contrast, is primarily driven by foreign investment, with TOYO Co. Ltd.'s solar cell factory under construction. Although this signals progress in resource mobilization and industrial capacity, most TIS functions—especially domestic knowledge development, entrepreneurial experimentation, and network formation—remain weak. The initiative is not embedded in broader research–industry collaboration or supported by strong institutional networks. Moreover, while PPPs are emerging in the context of solar irrigation, these are not clearly linked to manufacturing development.

Rwanda and Tanzania demonstrate some progress in market formation and entrepreneurial activity, particularly through PAYG business models and local solar kit distribution. However, there is little evidence of upstream experimentation or industrial-scale resource mobilization. Although they are included in international feasibility assessments (e.g., Africa REMI), no concrete manufacturing initiatives or institutional frameworks have emerged. Networks, research involvement, and policy alignment for manufacturing remain minimal.

Uganda shares a similar profile. The country has a number of solar distribution firms registered on ENF Solar, but no identified local manufacturing actors or relevant industry networks. There is limited evidence of cross-sector collaboration, and market formation remains dependent on donor support. As such, key system functions like knowledge upgrading, guidance of the search, and legitimation for manufacturing remain underdeveloped.

The remaining countries—Burundi, South Sudan, Somalia, Eritrea, Djibouti, Comoros, and Seychelles—exhibit little to no functional activity related to upstream solar PV innovation. Structural components such as domestic firms, research institutions, and intermediary organizations are either absent or inactive. Solar PV activity, where present, is confined to downstream deployment and donor-led electrification efforts, with no evidence of TIS functions oriented toward local manufacturing.

Overall, this comparison highlights that solar PV TIS performance in East Africa is highly uneven. Kenya shows the most integrated development across structural and functional components, followed by Ethiopia's foreign-led industrial investment. Other countries remain focused on deployment, with limited prospects for manufacturing unless deliberate efforts are made to strengthen institutions, networks, and entrepreneurial ecosystems.

4.4 Summary of TIS Diagnoses: Key Systemic Bottlenecks

The cross-country TIS analysis reveals several persistent and interrelated bottlenecks that hinder the emergence of a coherent solar PV manufacturing innovation system in East Africa.

First, knowledge development and diffusion remain severely constrained. While basic installation and distribution know-how is gradually spreading, advanced technical knowledge related to component manufacturing, system design, and quality assurance is almost entirely absent at the local level. Few countries exhibit any institutional or industrial capacity to absorb or adapt upstream PV technologies. Research–industry linkages are nearly nonexistent, with Kenya as the only country participating in an international research initiative (REACH-PSM), and even there, engagement remains externally driven and exploratory.

Second, the direction of search across the region is narrowly framed. Policy attention continues to prioritize rural electrification and off-grid deployment, largely shaped by donor agendas and short-term development targets. Although important for addressing energy poverty, these signals do not incentivize investment in higher-value segments such as module production, inverter assembly, or solar-powered industrial use. Consequently, the innovation system is skewed toward downstream solutions with limited pathways for industrial upgrading.

Third, entrepreneurial experimentation is concentrated in retail, installation, and PAYG services. Very few ventures attempt upstream activities, and those that do—such as Solinc in Kenya—operate in isolation and face high entry barriers. Resource mobilization is also uneven. Financial capital, technical expertise, and enabling infrastructure are clustered in Kenya and Ethiopia, while most other countries rely almost entirely on donor support for deployment, with no domestically mobilized resources to support industrial activities.

Fourth, functional networks are weak or absent. Collaborative ties between firms, research institutions, and public agencies are rare, and industry associations remain focused on downstream market development rather than manufacturing coordination. This weakens the system's ability to generate shared visions, align investments, or build collective learning platforms.

Finally, legitimation is growing but partial. Solar PV enjoys increasing political and social acceptance as a tool for rural energy access, yet its role in industrial development and regional integration is underrecognized. Most countries lack formal standards, certification mechanisms, or policy mandates that would embed solar manufacturing within broader industrial strategies. As a result, the sector lacks the institutional credibility required to attract sustained investment or policy support.

In sum, East Africa's solar PV innovation system remains fragmented and deployment-oriented. Without deliberate interventions to broaden the direction of search, deepen knowledge capabilities, and mobilize resources for upstream innovation, the current system trajectory is unlikely to deliver regionally integrated manufacturing or significant value capture. Addressing these bottlenecks requires coordinated regional action—spanning policy alignment, capacity building, and industrial co-development.

4.5 Implications for Regional Value Chain Development and Policy

The TIS analysis reveals that although solar PV deployment is gradually expanding in East Africa, most policy and institutional attention remains focused on downstream segments—particularly rural electrification through small-scale systems. This focus has yielded social benefits but has done little to stimulate upstream manufacturing or midstream engineering services. As a result, opportunities for local value addition, industrial employment, and technological upgrading remain largely untapped.

To support the emergence of a regional solar PV value chain, policymakers must broaden their approach beyond access-based interventions. This includes encouraging solar deployment in commercial, industrial, and public infrastructure settings—such as schools, health clinics, and small enterprises—which can generate more stable and diversified demand for local production and service provision. Building legitimacy and market confidence in grid-tied and mid-sized systems will also be essential for anchoring future manufacturing activities.

Regional coordination is particularly critical. Cross-border initiatives—such as harmonized standards, joint training programs, and pooled procurement—can help overcome national market fragmentation and reduce entry barriers for local firms. Governments and regional economic communities should also promote stronger alignment between energy policy, trade policy, and industrial strategy, which currently operate in silos. Without such alignment, industrial ambitions are unlikely to gain traction within the energy sector, and vice versa.

In addition, efforts to support firm-level upgrading must address the knowledge and financing bottlenecks identified in this study. Targeted support for capability development—such as regional centers of excellence, technical partnerships, and concessional financing for capital equipment—could help firms transition from retail and installation to higher-value activities.
Further research is needed to better understand the systemic obstacles to upstream experimentation, including why early manufacturing efforts often fail to scale. It is also important to examine how knowledge circulates—or fails to circulate—across borders, and what institutional arrangements facilitate effective learning and technology adaptation. Finally, donor-supported programs should be more explicitly designed to build enduring local capacity, rather than short-term delivery outcomes. These insights will be essential for shaping policies that move East Africa beyond basic energy access toward an integrated, innovation-driven solar PV economy.

5 Regional Cooperation and the Development of a Regional Solar PV Value Chain in East Africa

While the previous chapter applied the Technological Innovation System (TIS) framework to diagnose structural and functional barriers to solar PV manufacturing in East Africa, this chapter shifts focus from innovation dynamics to strategic value chain positioning. The key question is no longer whether innovation system functions are present, but rather: how can East African countries participate meaningfully in the production side of the solar PV value chain, given their current constraints and asymmetries?

To address this question, the analysis draws on two complementary frameworks. First, it applies the "Factors Affecting Developing Country Competitiveness in GVCs" framework proposed by Bamber et al. (2014), which identifies five key dimensions—productive capacity, infrastructure and services, business environment, trade and investment policy, and industry institutionalization—as critical enablers or constraints for industrial upgrading in global and regional value chains. This approach is particularly relevant for East Africa, where most countries have limited manufacturing bases, fragmented demand, and high entry barriers to upstream PV production.

Second, the analysis is situated within the theoretical lens of developmental regionalism, which views regional integration not merely as a tool for market enlargement, but as an active strategy for structural transformation. Unlike traditional regionalism driven by trade liberalization alone, developmental regionalism emphasizes coordinated industrial policy, cross-border infrastructure, and joint capability development to foster functional specialization and intra-regional upgrading (UNCTAD, 2023a). This perspective is especially pertinent in the East African context, where no single country currently possesses all the capabilities required to develop a full solar PV manufacturing chain independently.

By combining these two frameworks, this chapter evaluates the relative strengths and constraints of East African countries across the solar PV manufacturing process. The aim is to identify where individual countries might specialize based on their comparative advantages and improve competitiveness, and how regional complementarities could be leveraged to create an integrated, distributed, and feasible solar PV production network in the region.

5.1 Competitiveness in and within East African Countries

The viability of building a regional solar PV value chain in East Africa depends not only on the global competitiveness of the region as a whole but also on the complementary strengths of individual countries. Therefore, this section distinguishes between two levels of competitiveness:

(1) competitiveness that position East Africa favorably relative to other regions in the world, and
(2) Country-level competitiveness that can support functional specialization within the region.

5.1.1 Regional-level latent competitiveness: East Africa in the Global Context

At the regional level, East Africa presents several features that may offer potential advantages for constructing solar PV competitiveness. These include the presence of underutilized mineral resources and steadily growing population.

Mineral Endowments and Potential for Upstream Integration

To evaluate East Africa's readiness to participate in the upstream stages of the solar PV value chain, it is important to examine the current production levels of key raw materials used in PV manufacturing. Figure 31 maps the annual output of selected critical minerals—such as copper, silver, tin, and zinc—across 12 East African countries. The data reveal that while production remains limited in most countries, several possess notable extraction capacity. Eritrea, for example, reports an annual copper output of 17,595 metric tons and zinc production exceeding 116,000 metric tons, positioning it as a potential upstream contributor. Rwanda and Tanzania also show meaningful tin production, at 3,210 and 316 metric tons per year, respectively, while silver is produced in small quantities in Eritrea (49 metric tons) and Ethiopia (1 metric ton). Although production is concentrated in a few countries, these figures suggest that the region holds a fragmented but tangible base of mineral activity upon which a more integrated and specialized supply chain could be developed.

	Aluminum	Antimony	Copper	Indium	Lead	Silicon	Silver	Tin	Zinc
Burundi								70	
Comoros									
Djibouti									
Eritrea			17595				49		116829
Ethiopia							1		
Kenya									
Rwanda								3210	
Seychelles									
Somalia									
South Sudan									
Tanzania			3785				14	316	
Uganda									

Figure 31 - Annual Production of Key Solar PV-Related Minerals in East African Countries
Source: World Mining Data, 2023

As shown in Figure 32 (IEA, 2021), countries such as Burundi, Rwanda, Eritrea, and Uganda derive over 30% of their total product exports from minerals and metals. This pattern suggests that while these nations may not lead in global output, their economies depend heavily on mineral extraction, which in turn implies substantial resource endowments. For example, Burundi and Rwanda are known for tantalum and tin, while Uganda has growing interest in its graphite and nickel reserves. Tanzania, also included in the chart, has expanding copper and rare earth exploration projects.

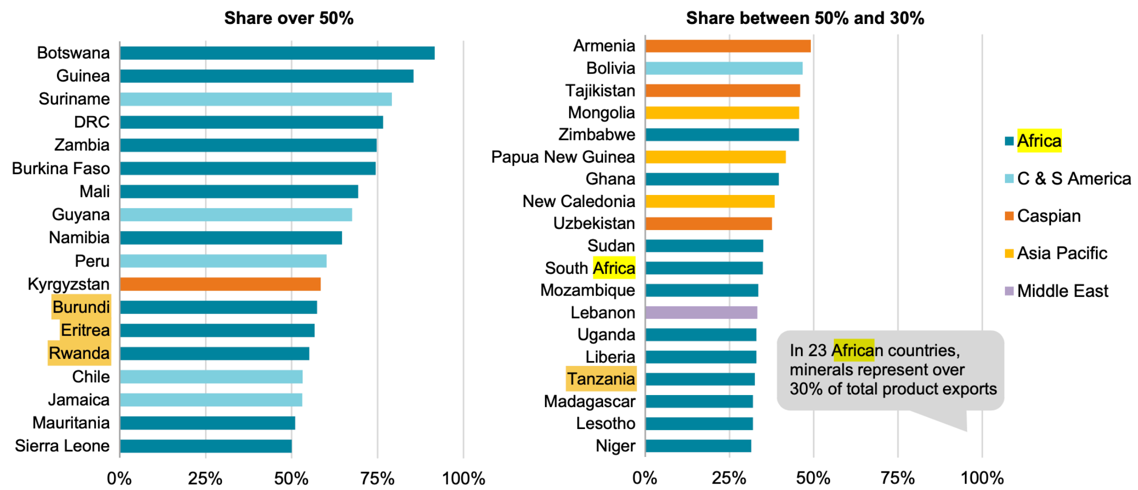


Figure 32 - Share of minerals and metals in total product exports for mineral producing countries
Source: IEA, 2021

However, a clear distinction must be made between reserves (geological availability) and production capacity (actual output). East Africa’s mining sector remains underdeveloped, with limited downstream processing infrastructure and low levels of industrial integration.

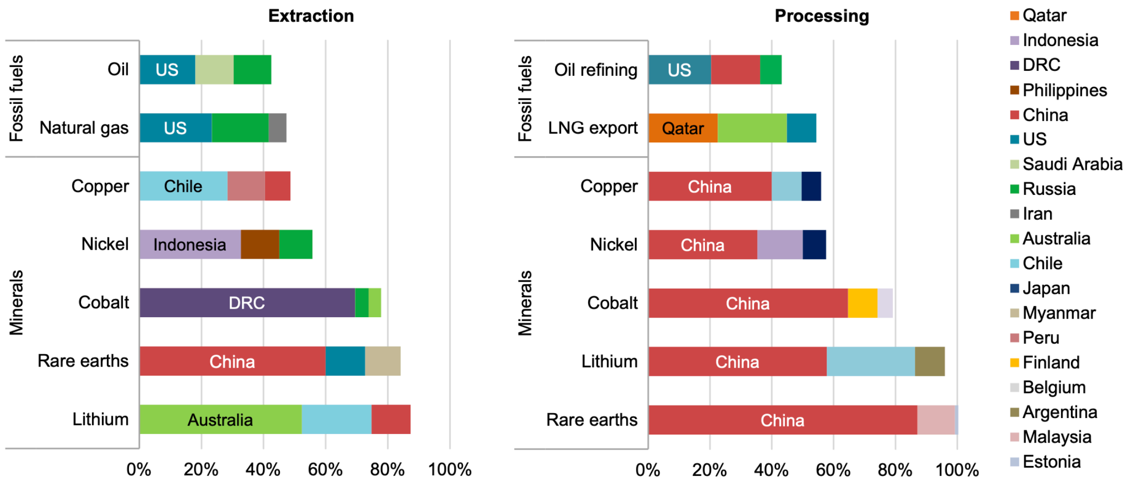


Figure 33 - Share of top three producing countries in Extraction and Processing of selected minerals and fossil fuels （source: IEA, 2021; USGS, 2021）

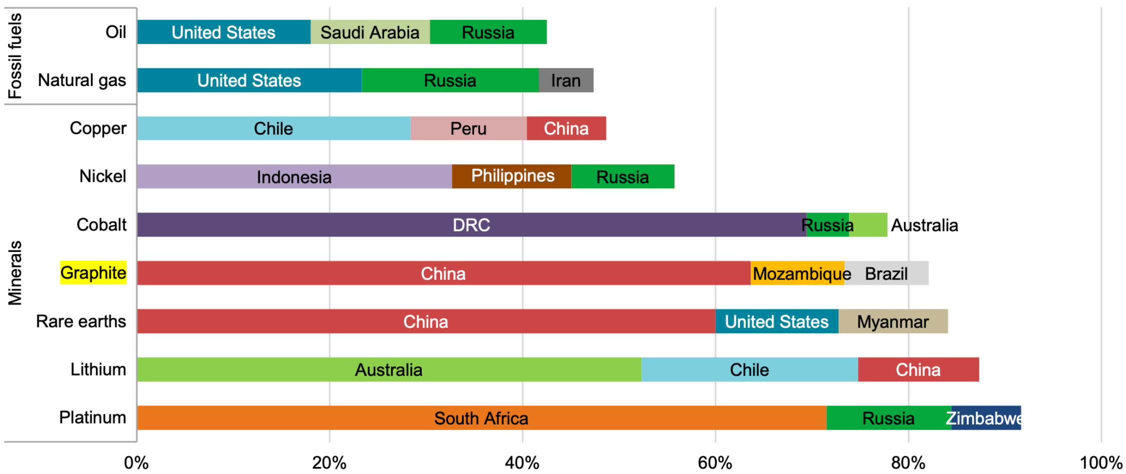


Figure 34 - Share of top three producing countries in total production for selected minerals and fossil fuels (source: IEA, 2021; USGS, 2021）

This gap limits the region's ability to leverage its mineral wealth into functional manufacturing advantages. For instance, even if high-purity quartz or metallurgical-grade silicon-grade sand is available, the absence of domestic smelting or refining capacity means such materials are either exported in raw form or underutilized (IEA, 2021). Without upstream integration, these resources remain part of global commodity circuits rather than regional industrial ecosystems.

Nevertheless, emerging ore processing capacities do exist in certain countries, offering foundational assets that can be built upon. These facilities, although limited in scale, demonstrate the potential for incremental industrial upgrading. Figure 35 shows the geographic distribution of mineral processing facilities across Africa, based on the AfricaMaVal GIS database. While processing capacity is heavily concentrated in Southern Africa, East African countries like Rwanda (tin), Uganda (cobalt), and Eritrea (copper) host modest but operational facilities relevant to solar PV or battery manufacturing. This highlights that East Africa, though limited in scale, already possesses foundational assets that could support regional specialization if strategically coordinated. Such progress can be achieved either individually—by expanding national capacities through targeted investment—or through regional collaboration, whereby neighboring countries pool resources and share access to existing facilities. Leveraging these early-stage assets could support the development of a more integrated and competitive regional mineral processing base, which is essential for upstream participation in the solar PV value chain.

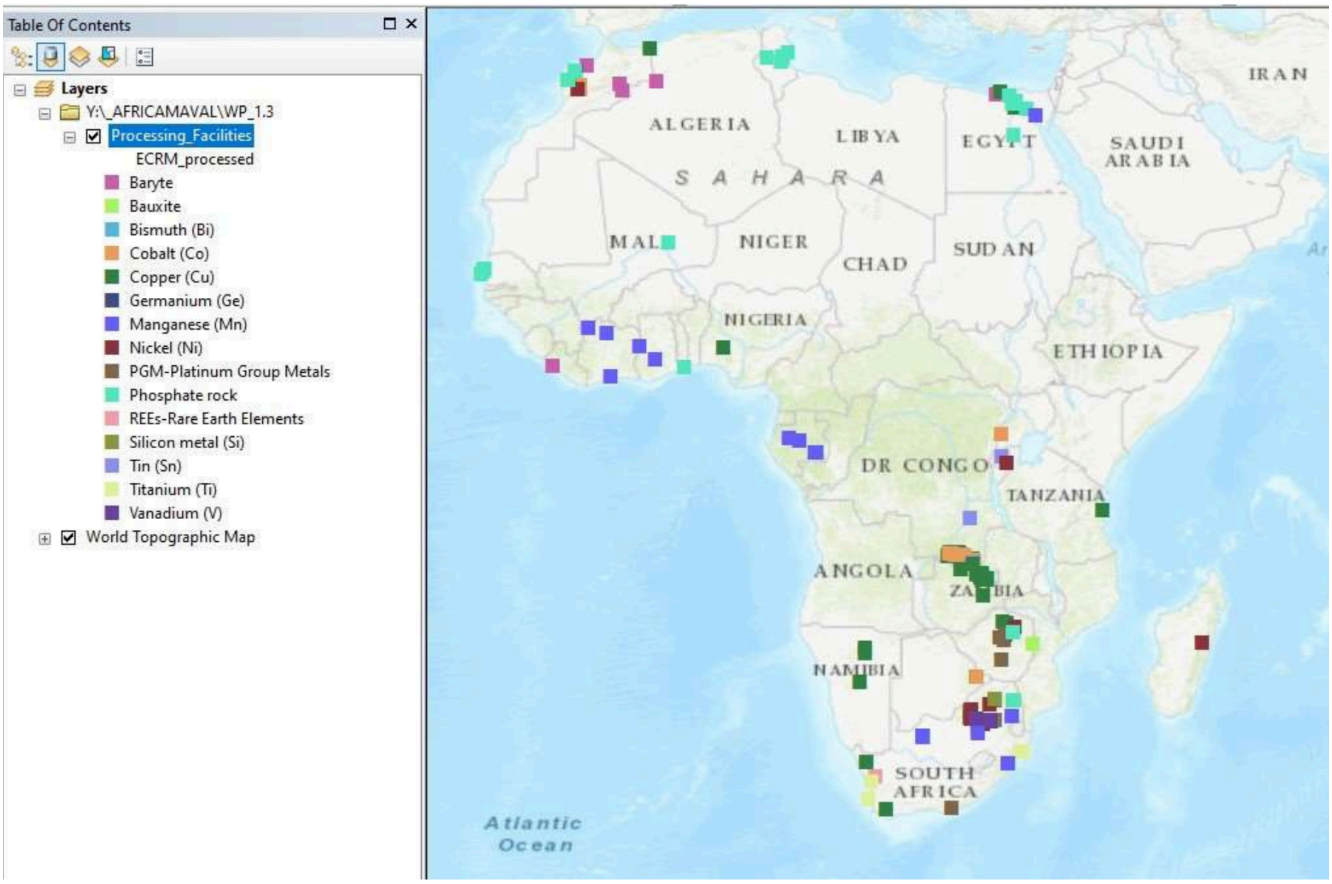


Figure 35 – Overview of AfricaMaVal GIS geodatabase showing the processing facilities distribution
Source: de Oliveira *et al.*, 2023

In sum, the regional distribution of mineral wealth, as suggested by the high mineral export shares, offers a latent comparative advantage—particularly if infrastructure, environmental management, and investment frameworks can be gradually strengthened. Over time, targeted efforts to localize parts of the raw materials and metallurgical stages could contribute to a more complete and competitive solar PV value chain in East Africa.

Demographics and Labor Availability

East Africa possesses one of the youngest demographic profiles globally. According to UN DESA (2022), the median age in countries such as Uganda (16.7), Tanzania (17.7), and Ethiopia (19.5) is among the lowest worldwide, far below the global average of 30.2 and significantly younger than countries like China (38.4). The region's working-age population (15–64 years) is projected to grow by more than 60% between 2020 and 2050, offering a long-term labor force base for industrial development.

While this youth bulge does not constitute an immediate advantage—given persistent deficits in vocational training, labor productivity, and formal employment structures—it represents a latent comparative advantage for labor-intensive manufacturing segments such as module assembly. These stages are relatively low in capital intensity and have high employment multipliers. The IEA (2022) estimates that every gigawatt of PV module assembly capacity can generate between 500 and 700 direct jobs, making it a promising foothold for developing economies with surplus labor.

As shown in Figure 31, East African countries such as Uganda, Tanzania, and Ethiopia are projected to experience some of the highest population growth rates globally in 2025—ranging from 1.9 to 3.7 per 1,000 population. In stark contrast, China falls into the lowest category, with an annual population decline of more than 0.2 per 1,000. This divergence underscores a critical long-term asymmetry: East Africa's labor force is expanding, while China's is shrinking.

For solar PV manufacturing—especially labor-intensive stages like module assembly—this difference is consequential. While China may face growing labor shortages and rising wage pressures, East Africa's young and growing population could serve as a long-term comparative advantage, provided that adequate investment is made in skills development and industrial infrastructure.

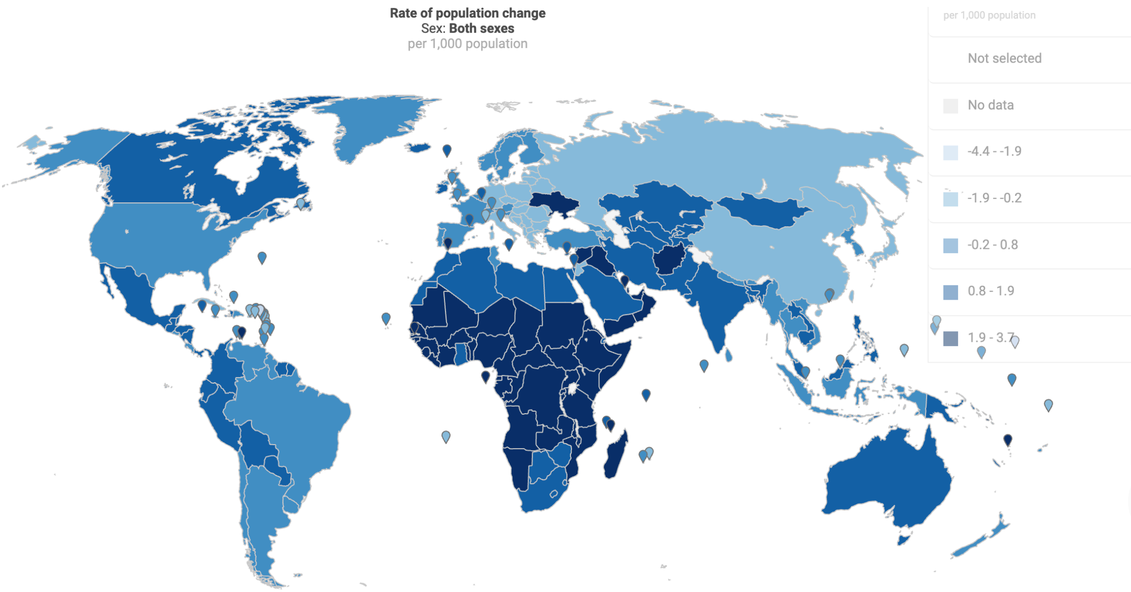


Figure 36 – Global rate of population change (source: UN DESA, 2022)

By contrast, China—the current dominant player in the global solar PV manufacturing value chain—is entering a phase of accelerated demographic aging. As of 2023, China's median age had risen to 38.4, and projections suggest it will surpass 48 by 2050 (UN DESA, 2022). Compounding this trend is a sustained decline in fertility rates, which fell below 1.1 births per woman in 2022, far below the replacement rate of 2.1. This has raised serious concerns about future labor shortages, rising wage costs, and the long-term sustainability of China's labor-intensive manufacturing dominance (Liu et al., 2023).

Over the coming decades, these divergent demographic trajectories may reconfigure global manufacturing geographies. While East Africa is not yet ready to absorb large-scale industrial relocation, its youthful and growing labor force—if matched with investment in skills, infrastructure, and regional coordination—could gradually position the region as a destination for offshored low- and mid-skill manufacturing functions.

5.1.2 Country-Level Complementarities: Functional Specialization within East Africa

At the national level, countries within the region exhibit varied conditions that may hold potential for building a complementary and regionally integrated solar PV value chain. Differences in mineral resource endowments, electricity prices, existing industrial capabilities, and solar market development suggest that functional specialization across the manufacturing stages may be feasible. In order to assess how these differentiated advantages can be leveraged, the following sections analyze each stage of the solar PV manufacturing process—identifying which countries may hold specific strengths or opportunities for targeted industrial development.

Comparative Advantage at the Raw Materials Stage: Mineral Endowments and Energy Infrastructure

The initial stage of solar PV manufacturing—centered on the extraction and processing of high-purity quartz, coal/charcoal, and critical minerals such as copper and tin—relies predominantly on two dimensions of competitiveness: natural mineral endowments and infrastructure & services, particularly energy supply. These are foundational inputs for the production of metallurgical-grade silicon (MG-Si), the entry point into the crystalline silicon value chain.

Across East Africa, countries such as Rwanda, Tanzania, and Uganda demonstrate comparatively stronger positions in terms of mineral availability. According to UNCTAD (2023), Rwanda consistently ranks among the top ten African exporters of tin concentrates, which are essential for soldering and interconnects in solar modules. Tanzania, meanwhile, holds commercially significant reserves of copper, graphite, and rare earths (USGS, 2022), while Uganda is undertaking exploration for silica sand and other industrial minerals, though large-scale exploitation has yet to materialize.

While mineral reserves are geologically widespread in East Africa, actual production remains concentrated in a few countries. As illustrated in Figure 31, Eritrea stands out with an annual copper output of 17,595 metric tons and zinc production of 116,829 tons, alongside moderate silver extraction (49 tons). Rwanda and Tanzania also contribute meaningfully to tin supply, producing 3,210 and 316 tons respectively. Though Ethiopia only reports 1 ton of silver output, exploration for silica and quartz is ongoing. This fragmented landscape suggests that no single country possesses a full spectrum of raw material strengths, but several hold niche capabilities that could anchor parts of a regionalized value chain.

Moreover, processing capacity is highly uneven. According to AfricaMaVal GIS data (Figure 35), East Africa hosts only a handful of relevant facilities—Rwanda for tin, Uganda for cobalt, and Eritrea for copper—while most mineral beneficiation occurs in Southern Africa. This underlines the urgency of either upgrading national capabilities or fostering cross-border collaboration to overcome industrial fragmentation.

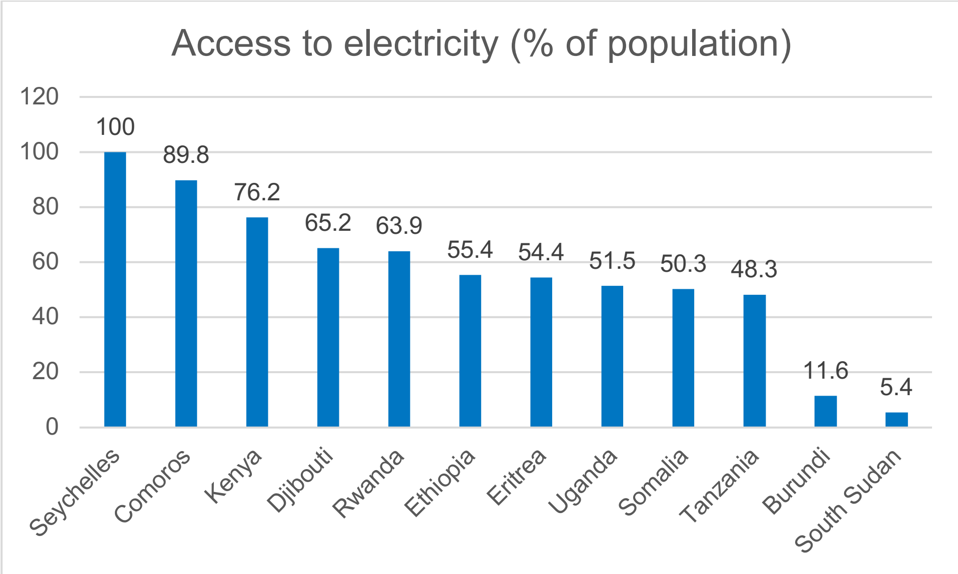


Figure 37 – Access to electricity in East African countries
Source: World Bank, 2023

Mineral endowment alone is insufficient to confer advantage. Electricity availability is another decisive factor in enabling mineral processing and upstream integration. Figures 37 and 38 reveal wide disparities: Seychelles and Comoros boast electricity access rates above 80%, while Burundi and South Sudan remain below 12%.

In terms of generation, Kenya and Ethiopia dominate, with 12.8 and 18.3 TWh per year respectively. In this regard, Tanzania lags behind, with only basic mineral beneficiation infrastructure and limited grid coverage beyond urban centers. According to the World Bank database (2023), national electricity access rate in Tanzania remains below 50%, and reliability—as measured by SAIDI (System Average Interruption Duration Index)/SAIFI (System Average Interruption Frequency Index)—is poor by international standards.

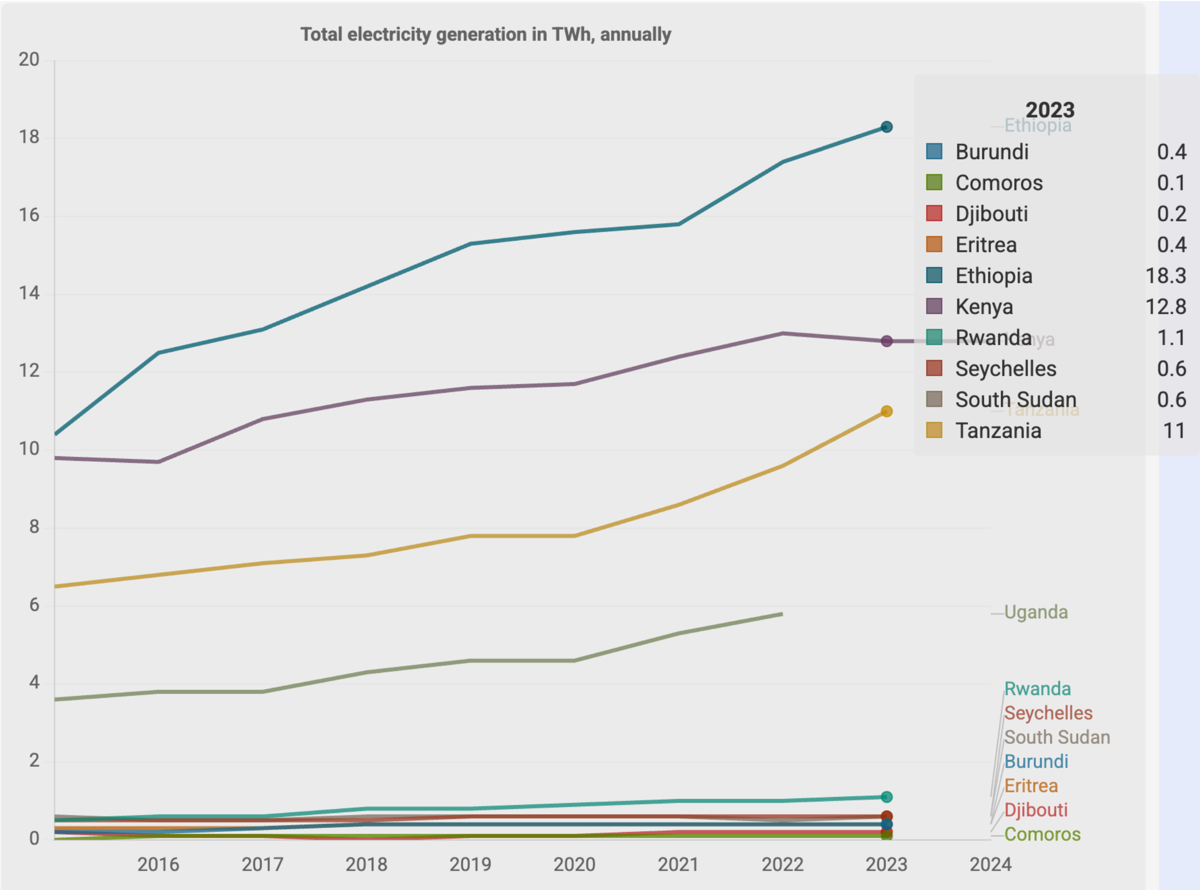


Figure 38 – Electricity Generation in East African countries
Source: ChartingTheGlobe, 2023

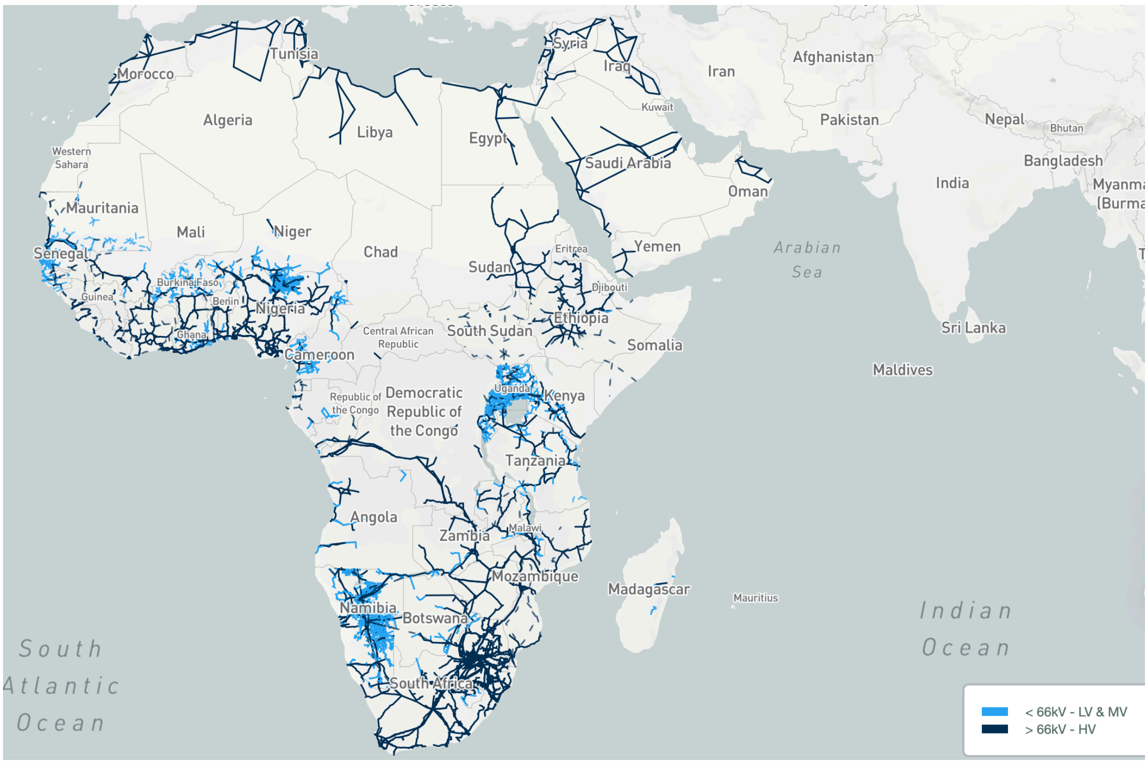


Figure 39 -Transmission Grid Infrastructure in Africa by Voltage Level, 2023
Source: World Bank EnergyData.info – Africa Electricity Transmission Network

In addition to current levels of electricity access and generation, several East African countries possess substantial latent potential in renewable energy resources.

Table 7 – Electricity Price of Selected East African Countries in comparison with China (source: World Bank, 2019)

Country	Electricity Price (US Cents per kWh)
Burundi	17.3
Comoros	28.1
Djibouti	26.2
Ethiopia	**3.6**
Kenya	21.7
Rwanda	**13.7**
Seychelles	32.1
Tanzania	**12.6**
Uganda	16.9
China	14.6

Note: data for Eritrea, Somalia, and South Sudan is missing in the original dataset.
Source: https://databank.worldbank.org/embed/Electric-Prices-by-Country/id/7b12e700

Ethiopia stands out in the region with an estimated 45,000 MW of untapped hydropower potential, one of the largest in Africa. This endowment has already enabled the country to invest heavily in large-scale dams such as the Grand Ethiopian Renaissance Dam (GERD). As a result, Ethiopia enjoys one of the lowest industrial electricity tariffs globally, around $0.036 per kWh, significantly undercutting China's average ($0.146/kWh). Although its mineral production relevant to PV is currently limited, this cost advantage in clean, renewable energy makes Ethiopia an ideal candidate for hosting energy-intensive stages such as metallurgical-grade silicon (MG-Si) production, provided that suitable quartz resources are confirmed. Its surplus energy could also be exported to neighboring countries through enhanced interconnection.

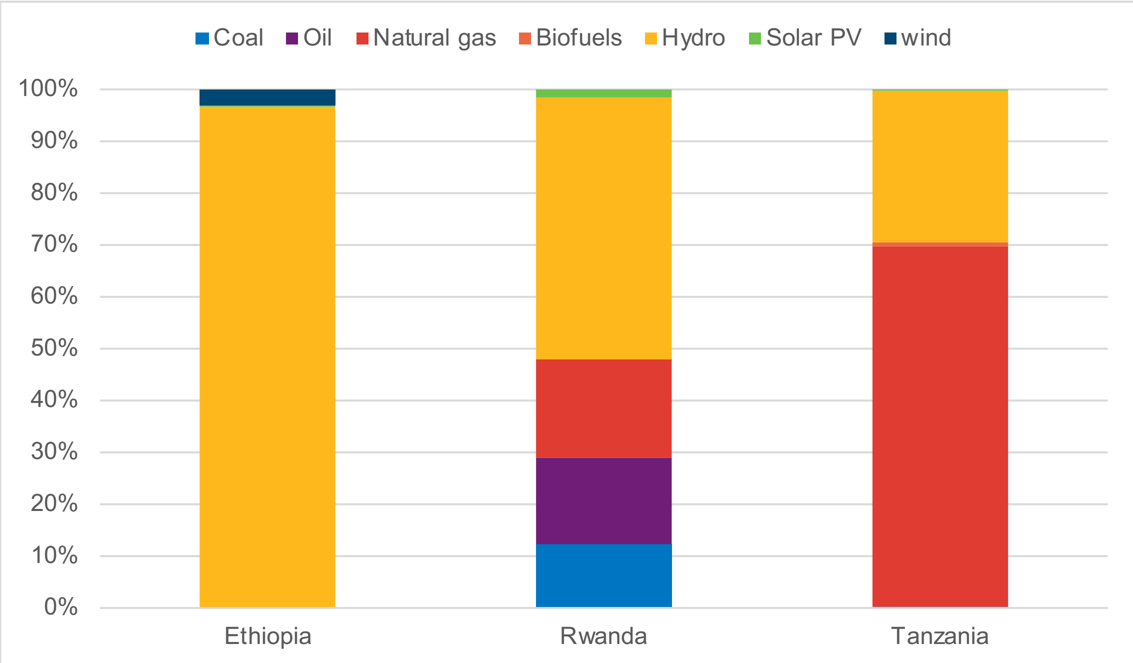


Figure 40 – Electricity Generation Sources Composition in Ethiopia, Rwanda, and Tanzania
Source: IEA website, 2022

Tanzania has moderate hydropower capacity (as shown in Figure 40) and emerging solar potential, but it suffers from limited electricity access (48.3%) and a relatively weak transmission network outside urban centers. Nevertheless, its growing generation capacity (11 TWh annually) and proximity to mineral-rich zones position it as a candidate for localized mineral processing, especially if connected to cross-border power trade arrangements. Targeted investment in renewable capacity and grid reliability could unlock greater value from its tin and copper resources.

Rwanda has limited domestic electricity generation (around 1.1 TWh) and access rates just above 60%. While industrial tariffs remain relatively moderate ($0.137/kWh), Rwanda's geographic constraints and modest renewable capacity limit its role as an energy exporter. However, its strong institutional performance and presence of tin smelting infrastructure provide a foundation for processing specialization, particularly if supported by regional energy flows from neighbors like Ethiopia or Kenya.

Uganda shares similar hydropower characteristics with Ethiopia, though at smaller scale, and maintains a competitive electricity tariff ($0.169/kWh). Its generation has steadily grown, reaching 4.4 TWh in 2023. With known reserves of cobalt and ongoing exploration of quartz and other industrial minerals, Uganda could feasibly host small-scale upstream activities powered by domestic renewables. Improved grid integration with Kenya and Ethiopia would further enhance its viability as a regional processing partner.

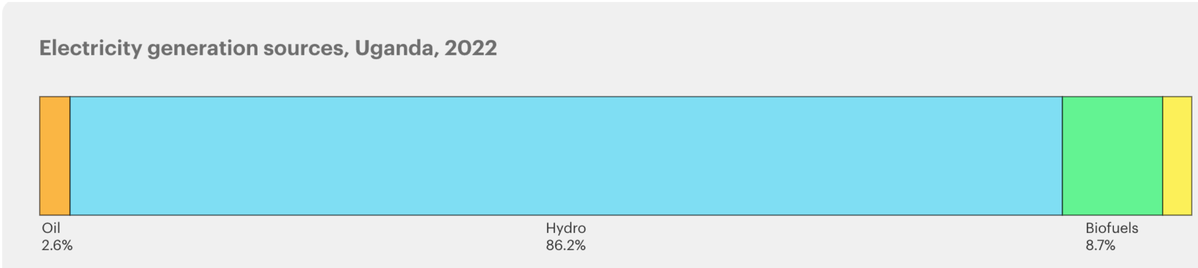


Figure 41 - Electricity Generation Sources Composition in Uganda
Source: IEA website, 2022

Kenya possesses over 7,000 MW of geothermal energy reserves, the largest in Africa, offering significant potential for low-carbon, base-load power generation. While Kenya's industrial electricity prices remain high (around $0.217/kWh), the country benefits from superior grid density and regional transmission coverage (see Figure 39), which could support co-location of mineral processing hubs and logistics centers. Kenya's transmission leadership also makes it a key player in regional power trade initiatives under the East African Power Pool (EAPP). Strategically, Kenya could act as an energy corridor and infrastructure anchor, complementing the strengths of mineral-rich but grid-poor neighbors.

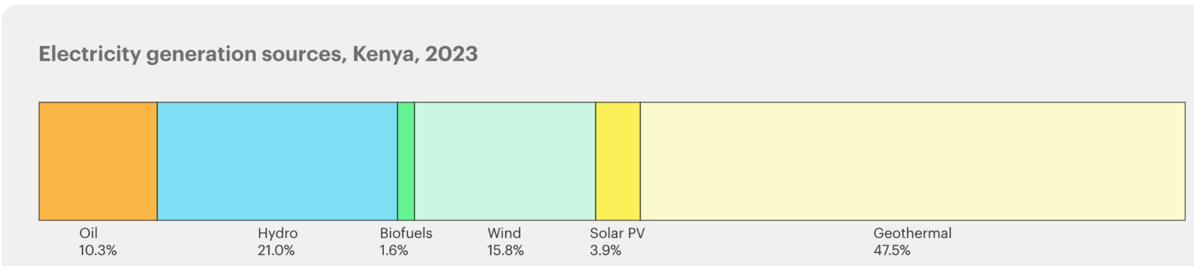


Figure 42 - Electricity Generation Sources Composition in Kenya
Source: IEA website, 2022

Eritrea, while hosting significant mineral production (especially copper and zinc), faces severe electricity constraints, both in terms of generation (0.4 TWh) and access rates (~54%). However, its proximity to Ethiopia and existing copper beneficiation infrastructure make it a logical candidate for cross-border power cooperation. If hydropower from Ethiopia could be extended through EAPP or bilateral arrangements, Eritrea's upstream processing role could be significantly strengthened.

Other countries such as Burundi, South Sudan, and Somalia suffer from extremely low electricity access (<12%) and negligible generation capacity (<0.5 TWh), which severely constrains their industrial potential in the short term. Nonetheless, many of these countries possess high solar irradiation (>5 kWh/m^2/day) and are situated within the EAPP footprint, offering long-term potential if investments in solar generation and grid integration materialize.

Thus, while no single country currently combines both high mineral resource endowment and low-cost energy, the regional landscape reveals complementary assets: mineral inputs in Rwanda and Tanzania, and energy infrastructure in Ethiopia and Kenya. These conditions suggest that cross-border integration and specialization—rather than full verticalization within a single country—will be essential to establish a viable raw material base for solar PV manufacturing in East Africa.

Polysilicon: Energy Efficiency, Electricity Costs, and Exposure to Price Volatility

As introduced in Chapter 1.1.2, the purification of polysilicon is the most energy-intensive stage of the entire solar PV manufacturing chain. This makes infrastructure & services, particularly stable and low-cost electricity, the single most important enabling factor at this stage.

As discussed in the raw materials section, Ethiopia's hydropower-driven grid continues to offer the lowest industrial electricity tariff in East Africa—around $0.036/kWh, significantly cheaper than China's national average of $0.146/kWh. This positions Ethiopia as the only regional economy with a structural electricity cost advantage sufficient to support large-scale polysilicon production. However, actual competitiveness will hinge on the reliability and industrial prioritization of electricity distribution, which remains a work in progress.

Another key enabler of competitiveness in polysilicon manufacturing is trade and investment policy coordination—particularly through regional institutions like the East African Community (EAC). Given the high energy intensity and global price volatility of polysilicon production, individual East African countries are unlikely to build competitive capacity on their own. However, by harmonizing industrial investment policies and reducing cross-border input frictions within the EAC, member states could collectively lower the cost and risk of upstream supply chain development. For example, facilitating duty-free quartz transport from Tanzania to a potential processing hub in Kenya, or streamlining customs procedures for shared electricity infrastructure, could allow the region to gradually internalize segments of the value chain that are currently fully import-dependent. In this way, regional collaboration becomes not just about reducing vulnerability, but about creating domestic capability that does not yet exist.

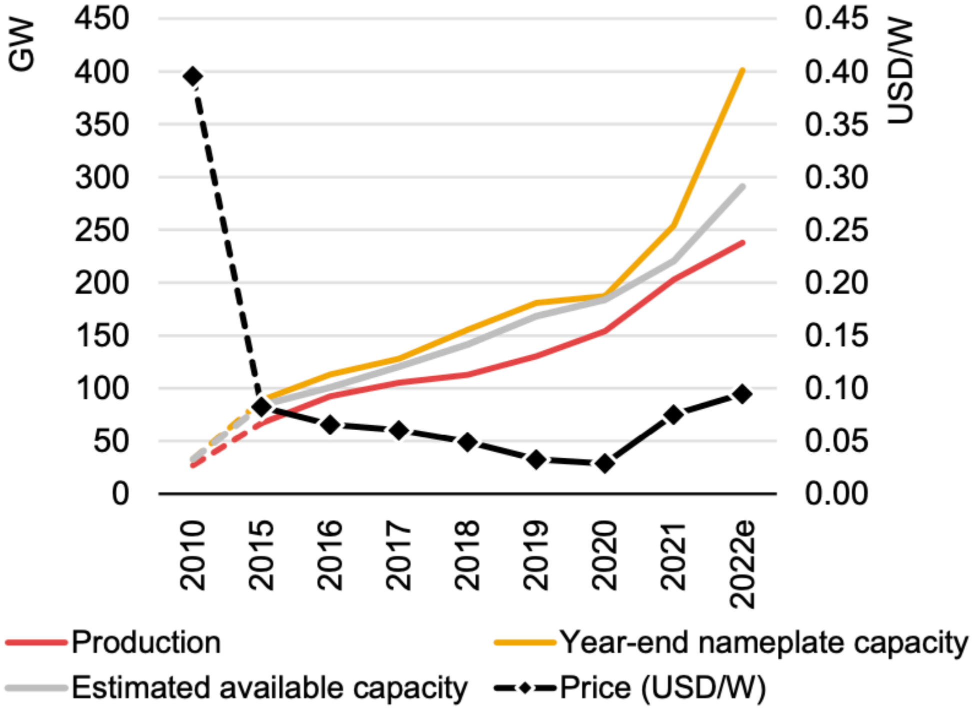


Figure 43 - Polysilicon manufacturing capacity, production and price
Source: IEA, 2022b

Ethiopia's track record of macroeconomic volatility—particularly high inflation and exchange rate instability—poses significant challenges for long-term industrial investment, despite its clear advantage in electricity costs. From 2015 to 2021, the Ethiopian birr experienced persistent and sharp depreciation, with annual growth rates of the official exchange rate frequently exceeding 10% and peaking above 25% in 2020. In contrast, the Kenyan shilling remained relatively stable, with changes mostly within a ±5% band. Inflation trends further highlight this gap: in 2023, Ethiopia recorded a consumer price inflation of 14.4%, while Kenya maintained a much lower rate of 3.8% (Trading Economics, 2024). These indicators suggest that while Ethiopia offers lower operating costs, Kenya's greater macroeconomic stability may be more conducive to attracting capital-intensive investments such as polysilicon refining.

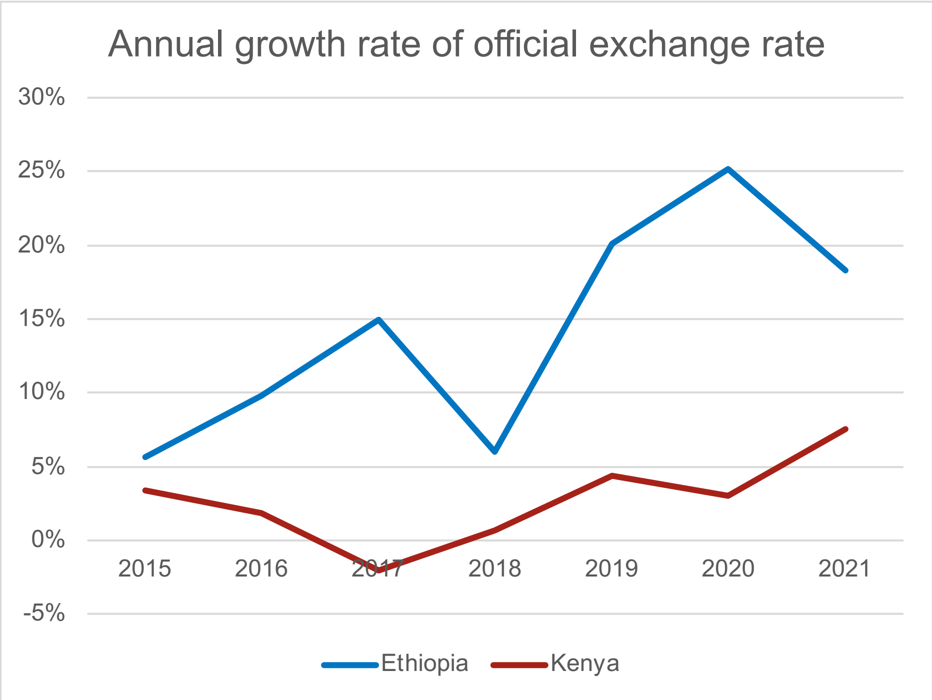


Figure 44 – Annual change rate of official exchange rate of Ethiopia and Kenya
Source: World Bank, 2022

Comparative Advantage at the Ingot & Wafer Stage: Industrial Clustering and Infrastructure

While electricity remains a non-negligible cost—roughly 20% of total expenses at this stage (IEA, 2022)—as previously discussed, the decisive factors for ingot casting and wafer slicing lie in infrastructure connectivity, industrial scale, and clustering. This stage benefits significantly from co-location of upstream and downstream facilities, access to specialized machinery, and coordinated delivery of consumables such as crucibles and diamond wire.

In this regard, Kenya and Rwanda exhibit relative advantages through their ongoing development of Special Economic Zones (SEZs)—designated areas that offer infrastructure, regulatory incentives, and streamlined administrative services to attract investment. Kenya's Konza Technopolis, located south East of Nairobi, is a flagship SEZ aimed at technology-intensive industries, offering benefits such as VAT exemptions and corporate tax holidays (Konza Technopolis, 2025). Rwanda's Kigali Innovation City, developed within the Kigali SEZ, aspires to become a regional hub for digital economy and light manufacturing, with support from Africa50 and the Rwandan government (Africa50, 2025).

However, serious gaps remain in industry institutionalization. No country in the region has yet developed a solar manufacturing cluster with shared cleanroom facilities, R&D infrastructure, or coordination platforms for suppliers and downstream clients. In addition, productive capacity is constrained by a shortage of technical personnel with expertise in high-precision materials processing and equipment operation. While Kenya and Uganda have made progress in technical and vocational education, specialized training for PV manufacturing remains underdeveloped across the region.

Comparative Advantage at the Cell Manufacturing Stage: Technical Capability and Standards Gaps

The manufacturing of solar cells is a highly technical process involving doping, diffusion, anti-reflective coatings, and screen printing. It demands cleanroom environments, precision machinery, and stringent quality control (IEA, 2022), placing a strong emphasis on productive capacity, particularly human capital, standards infrastructure, and a functioning innovation system. At this stage, the ability to comply with international efficiency and reliability standards (such as IEC 61215 and IEC 61730) is essential for market competitiveness.

Notably, Ethiopia has recently emerged as a potential outlier in this segment with the launch of a 2 GW solar cell manufacturing facility by Toyo Engineering in 2024, located in the Eastern Industry Zone near Addis Ababa. This represents the first large-scale cell manufacturing operation in East Africa and signals a possible shift in the region's industrial trajectory. However, the project is foreign-led, with limited evidence of local workforce integration, supply chain localization, or domestic standardization support. Without deliberate policy measures to embed such investments within national innovation systems—through technology transfer, technical training, and supplier development—Ethiopia's role may remain that of a low-cost assembly base rather than an integrated industrial hub.

Looking forward, advancing in this segment will require coordinated investment in clean manufacturing infrastructure, accredited testing labs, and vocational programs focused on photovoltaic process engineering. The establishment of regional standards bodies under the African Organization for Standardization (ARSO) or AfCFTA could also help harmonize quality frameworks and reduce dependence on external certification.

Comparative Advantage at the Module Assembly Stage: Ease of Entry, Logistics, and Policy Incentives

Module assembly is the least technologically and financially demanding part of the PV manufacturing chain. It involves tabbing and stringing of solar cells, lamination, framing, and testing. As such, it features low barriers to entry and can be localized relatively easily, provided basic manufacturing infrastructure, trained technicians, and consistent supply of components are in place. The key enabling factors at this stage are business environment, especially the ease of doing business, logistics, and trade policy.

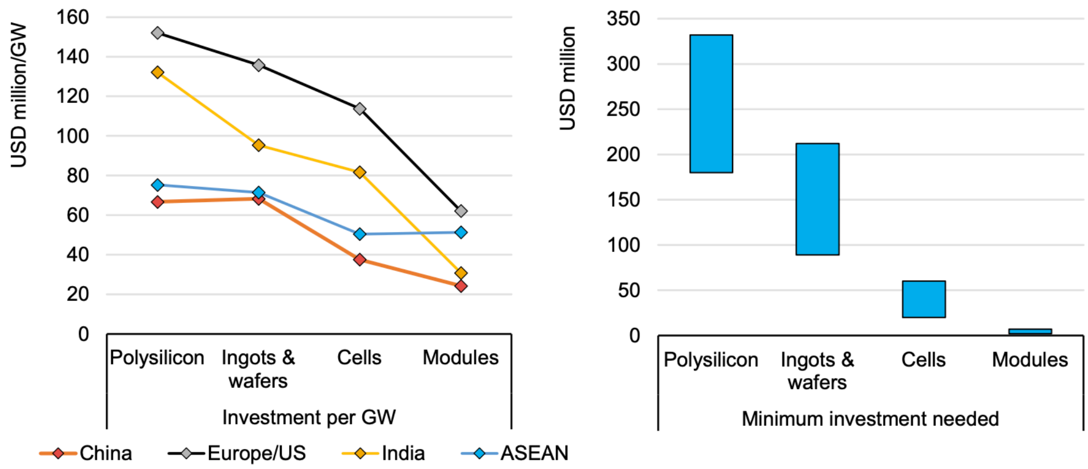


Figure 45 – Investment costs (left) and minimum investment requirements (right) by PV manufacturing segment
Source: IEA, 2022b

Several East African countries have begun to enter this segment. Kenya hosts Solinc East Africa, a module assembler operating in Naivasha with a capacity of around 30 MW/year, sourcing cells from China (Davy et al., 2024). However, firms in this segment face high import dependency, with EVA sheets, glass, junction boxes, and cells all sourced externally. Tariffs on these inputs and customs delays can erode cost advantages.

To scale this segment, governments could offer import duty exemptions on intermediate components, expedite customs clearance, and integrate local firms into public procurement schemes. Given the relatively low capital intensity, module assembly could serve as an entry point into manufacturing for countries such as Tanzania or Ethiopia, especially if linked with utility-scale deployment programs or regional demand aggregation through the Eastern Africa Power Pool (EAPP).

5.2 Regional Specialization: Strategic Positioning of East African Countries in the PV Value Chain

While no single East African country currently possesses the full set of capabilities required for a vertically integrated solar PV manufacturing industry, the preceding analysis has shown that several countries exhibit clear comparative advantages at specific stages of the value chain. This uneven yet complementary distribution of strengths suggests a viable path forward through regional specialization, wherein each country focuses on segments most aligned with its industrial conditions, energy resources, and institutional capacity.

At the upstream stage, Rwanda, Tanzania, and Uganda possess important mineral inputs such as quartz, tin, and copper. Although current extraction is largely export-oriented and unrefined, these countries could serve as raw material suppliers to regional processing hubs. In contrast, Ethiopia, with its abundant low-cost hydropower and growing industrial infrastructure, is uniquely positioned to undertake energy-intensive processes like polysilicon production and ingot crystallization. The use of renewable electricity not only enhances cost competitiveness but also aligns with global decarbonization goals for PV supply chains (IEA, 2022). Ethiopia's recent attraction of foreign direct investment into cell manufacturing demonstrates the potential to evolve into a regional center for upstream and midstream PV activities—provided grid reliability, infrastructure siting, and input logistics (e.g., via Djibouti Port) continue to improve. Further downstream, Kenya is currently the most industrially advanced PV manufacturer in the region, with operational module assembly facilities such as Solinc. It benefits from port access, industrial base, and active solar deployment markets. While cell manufacturing remains absent, Kenya's existing base could be scaled through targeted incentives, cross-border sourcing of intermediate inputs, and joint ventures with Asian or European partners. Its relative lead makes it a strong candidate to coordinate downstream integration and value addition for the region. Other countries like Rwanda and Uganda may not yet have industrial production capacity but could specialize in supporting functions. Rwanda's regulatory efficiency and logistical orientation make it suitable for regional testing, certification, and trade facilitation.

Building on these domestic strengths, foreign direct investment (FDI)—particularly from countries with mature PV industries—can play a catalytic role in operationalizing regional specialization. For example, Ethiopia's recent success in attracting FDI into cell and module manufacturing demonstrates how targeted industrial policy, low-cost electricity, and land availability can align to attract technologically intensive investment. Given China's global leadership in solar PV manufacturing and its expanding engagement in African infrastructure and industrial development, East African countries may consider selectively opening up to Chinese firms—not just for capital, but also for access to turnkey production lines, know-how transfer, and integration into global supply chains. Rather than pursuing indiscriminate liberalization, however, such openness should be strategic and conditional: investments should be aligned with domestic upgrading goals, promote local employment and skills development, and support the emergence of regionally integrated production systems. By leveraging FDI in this way, East Africa can accelerate its entry into higher-value segments of the solar PV value chain, while reducing dependency on imported technologies and creating a foundation for long-term industrial resilience.

In summary, this proposed regional layout envisions (as shown in the figure below): raw material supply from Rwanda, Tanzania, and Uganda; upstream and midstream processing in Ethiopia; module assembly and downstream integration in Kenya; and institutional and technical services from Rwanda and Uganda. Realizing such a model will require more than comparative advantage—it will depend on cross-border coordination, harmonized standards, infrastructure connectivity, and the strategic use of regional mechanisms like the AfCFTA and EAC to overcome fragmentation. Without deliberate integration, isolated efforts risk remaining subscale and disconnected from global PV value chains.

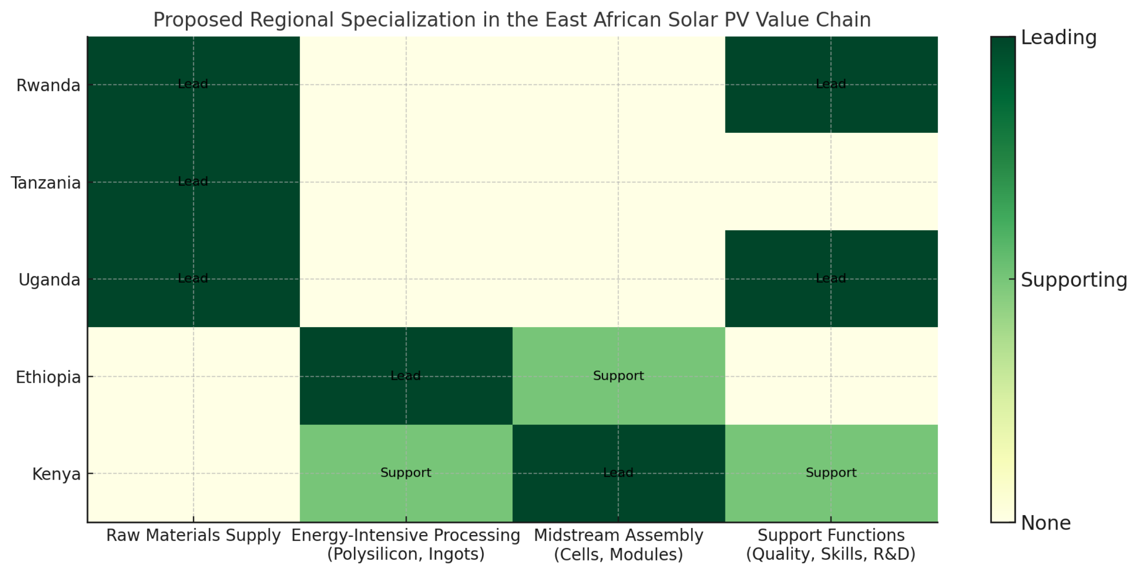


Figure 46 – Proposed regional specialization in the East African solar PV value chain

5.3 Regional Cooperation Mechanisms and Policy Recommendations

Realizing the regional specialization model outlined above will require more than just aligning comparative advantages—it demands deliberate, institutionalized forms of regional cooperation. Currently, East Africa lacks a dedicated industrial coordination platform tailored to the solar PV sector. Without such coordination, national initiatives risk duplication, underutilization, or fragmentation. Based on the theoretical foundation of Developmental Regionalism in Chapter 2.2 and Chapter 3.2, this section outlines key mechanisms and policy levers to support the emergence of a regionally integrated solar PV manufacturing ecosystem.

1. **Trade Facilitation and Regional Procurement Coordination**

   To unlock economies of scale and reduce transaction costs across borders, governments should prioritize the harmonization of tariffs, rules of origin, and customs procedures within the framework of the African Continental Free Trade Area (AfCFTA) and the East African Community (EAC). Specifically, solar components and manufacturing inputs—such as quartz, metallurgical-grade silicon, machinery, and consumables—should be designated as "green industrial goods" with preferential treatment. Regional institutions can also coordinate joint procurement platforms for equipment and raw materials to reduce import dependency and increase bargaining power vis-à-vis global suppliers.

2. **Skills Mobility and Technical Capacity-Sharing**

   Given the uneven distribution of technical training infrastructure across East African countries, cross-border skills mobility and certification recognition will be critical. Governments should establish regional mutual recognition agreements (MRAs) for solar manufacturing-related TVET qualifications, enabling engineers, technicians, and vocational graduates to work freely across borders. Regional centers of excellence—such as those emerging in Kenya and Ethiopia—can be financially supported to serve the broader region through open-access training modules, internship exchanges, and remote laboratory services.

3. **Infrastructure and Energy Connectivity**

   The physical movement of goods, energy, and labor remain a bottleneck to regional integration. National grid interconnections, such as those under the Eastern Africa Power Pool (EAPP), must be strategically aligned to support industrial corridors relevant to solar manufacturing—particularly between energy-rich countries like Ethiopia and industrial zones in Kenya and Uganda. Similarly, investment in transport corridors (e.g., the Northern Corridor linking Mombasa to Kampala and Addis Ababa) and dry ports (e.g., Modjo in Ethiopia) will be essential to lower logistics costs and enhance regional competitiveness.

4. **Investment and Financing Mechanisms**
   To overcome the capital-intensity of upstream and midstream PV manufacturing stages, the region should consider establishing a Regional Green Industrial Development Fund backed by a coalition of development finance institutions (DFIs), sovereign wealth funds, and climate finance mechanisms such as the Green Climate Fund (GCF). This fund could prioritize blended finance schemes that de-risk investment into manufacturing, while supporting public-private partnerships in common infrastructure such as testing labs, industrial parks, and logistics hubs.

5. **Institutional Platforms for Coordination and Policy Alignment**
   There is a pressing need for a dedicated regional coordination body focused on renewable energy industrialization, perhaps as a sub-platform under the EAC or AUDA-NEPAD. This platform could convene policymakers, industry associations, standards bodies, and research institutions to coordinate policy harmonization, data sharing, and technology foresight. Beyond periodic dialogue, such a platform should be empowered to develop regional industrial strategies, standardize quality frameworks, and coordinate international partnerships (e.g., with Chinese or Indian equipment suppliers).

6. **South–South Cooperation and Technology Transfer**
   To accelerate upgrading within the regional value chain, East African countries should leverage South–South cooperation platforms to secure affordable technology transfer arrangements, particularly with partners from China, India, and ASEAN. These can include manufacturing joint ventures, equipment leasing models, and open-source process technology sharing—preferably with incentives linked to local content or skill-building requirements.

5.4 Challenges

Despite promising signs of comparative advantage and early industrial activity across East African countries, substantial structural challenges remain. These constraints may limit the region's ability to scale up a competitive and coherent solar PV manufacturing industry without targeted interventions and regional coordination.

1. **Resource Endowment ≠ Industrial Capability**

   As discussed earlier, East Africa is relatively well-endowed with key mineral inputs—such as quartz, copper, and tin—but these natural assets have yet to translate into domestic industrial capacity. The distinction between geological reserves and commercial production is essential: most deposits remain underexplored, and the region lacks facilities for beneficiation, refining, or high-purity processing. Without upstream processing capabilities, these resources will continue to be extracted for export with minimal local value addition.

2. **Long Lead Times and Investment Uncertainty in Mining**

   The development cycle for new mining operations is exceptionally long. According to IEA (2021), the average lead time from discovery to production between 2010 and 2019 was 17 years, with 13 years spent on exploration and feasibility studies, and another 4 years on construction. These delays create temporal mismatches between rising mineral demand and actual supply capacity, particularly as global deployment of clean energy accelerates.

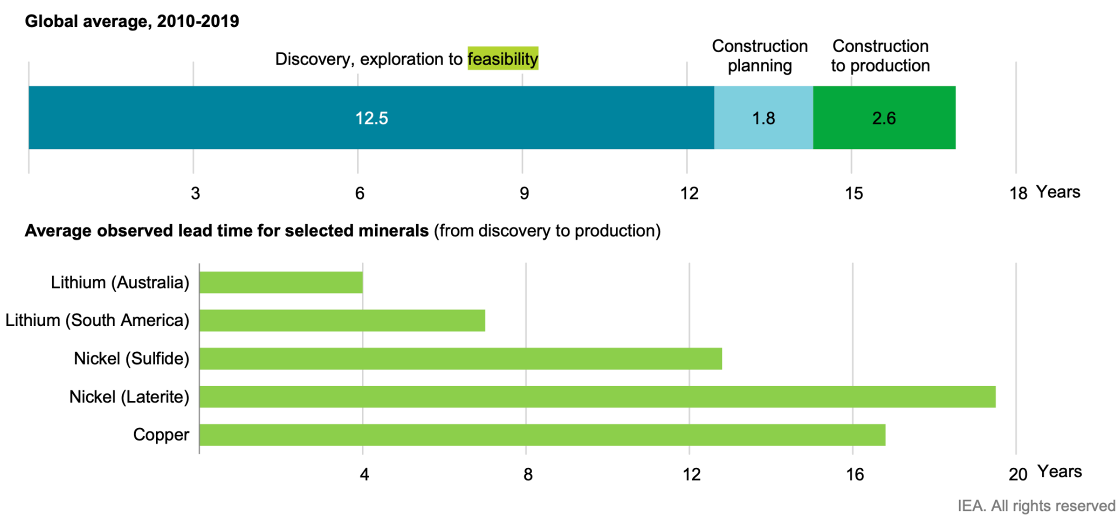


Figure 47 – Global average lead times from discovery to production, 2010-2019
Source: IEA, 2021

Furthermore, investment in mineral supply is highly sensitive to policy certainty. As the IEA (2021) emphasizes, without clear, credible, and consistent policy signals on climate and energy transitions, companies tend to adopt conservative investment strategies, leading to underinvestment and future bottlenecks. Rapid, orderly energy transitions will therefore depend on stronger institutional frameworks to de-risk mining projects, shorten permitting timelines, and mobilize long-term capital. Resource-owning governments can also accelerate project pipelines by reinforcing national geological surveys, improving public awareness, and offering fiscal incentives linked to sustainability targets.

3. **Technical Barriers and Industrial Learning Gaps**

   PV manufacturing—especially upstream segments like polysilicon, ingots, and cell fabrication—demands precision engineering, cleanroom management, and quality control systems that are not yet established in East African industrial ecosystems. Countries also lack equipment suppliers, certification bodies, and R&D institutions needed to support process upgrading. Without long-term industrial policy commitments and South–South technology partnerships, the region risks being locked into low-margin assembly and import-dependence.

4. **Infrastructure and Logistics Bottlenecks**

   Landlocked countries like Ethiopia and Uganda remain dependent on regional ports such as Mombasa and Djibouti, which face congestion, bureaucratic inefficiencies, and high transaction costs. Moreover, domestic infrastructure is uneven: electricity reliability, road quality, water access, and digital infrastructure are insufficient in many inland industrial zones. These constraints raise the cost and uncertainty of industrial investment, especially for high-precision and energy-intensive processes.

5. **Global Market Pressures and Structural Vulnerability**

   Even with domestic capabilities in place, East African manufacturers will face stiff competition from entrenched global incumbents—especially Chinese firms, which dominate every stage of the crystalline silicon value chain. In addition, the region is exposed to commodity price volatility, exchange rate risks, and policy shifts in global markets. Without a strong internal market and strategic regional procurement mechanisms, local producers may struggle to reach minimum efficient scale or secure reliable demand.

This chapter has demonstrated that although no single East African country currently possesses the full set of capabilities to establish a vertically integrated solar PV manufacturing industry, strategic regional specialization offers a promising alternative. By aligning national comparative advantages—such as Rwanda and Tanzania's mineral endowments, Ethiopia's low-cost renewable energy, and Kenya's industrial and logistical strengths—a coordinated regional value chain (RVC) can be developed to overcome existing structural limitations.

In doing so, this chapter directly addresses several of the barriers identified in Chapter 4, including fragmented industrial capacity, limited local value addition, underdeveloped infrastructure, and weak innovation system functions. The analysis has shown that through functional differentiation and cross-border collaboration, it is possible to compensate for these gaps collectively. However, realizing this vision will require more than market forces—it demands institutional coordination, regional planning, and strategic industrial policy, especially in attracting targeted foreign investment and fostering intra-regional trade.

The next chapter turns to the experience of China, whose rise in the global PV value chain offers both inspiration and cautionary lessons. By examining how China combined state-led coordination, technological upgrading, and international linkages to overcome similar latecomer constraints, we assess which elements of the Chinese model may be transferable—or adaptable—to the East African context.

6 Leveraging China's Experiences to Build a Regional Solar PV Manufacturing Value Chain in East Africa

Building on the theoretical foundations laid out in Chapter 2.5 and Chapter 3.3, this chapter examines how China's experience in solar PV industrial development can inform the construction of a competitive and context-sensitive regional value chain in East Africa. The analytical lens is rooted in two complementary frameworks: catch-up theory and policy transfer theory.

As previously discussed, catch-up theory provides insights into how latecomer countries can transform their initial disadvantages into developmental advantages through targeted capability building and strategic integration into global markets (Gerschenkron, 1962; Abramovitz, 1986; Nelson, 1993; Lee, 2005). China's solar PV industry has emerged as a paradigmatic case, demonstrating that technological catch-up is not a linear process of imitation but rather a dynamic combination of state coordination, firm-level innovation, and responsiveness to international demand (Binz et al., 2017; Awate et al., 2018; Sakata & Sasaki, 2013).

However, the relevance of China's path for East African countries cannot be assumed. While China leveraged a large domestic market, robust industrial policy, and evolving innovation capabilities, most East African economies operate under very different structural and institutional conditions. Therefore, this chapter also draws on policy transfer theory to evaluate how and under what conditions the mechanisms that supported China's rise could be adapted to the East African context (Dolowitz & Marsh, 1996, 2000; Evans & Davies, 1999). This framework emphasizes the complexities of transferring institutional models across borders, highlighting the importance of actor networks, contextual fit, and local adaptation in shaping policy outcomes.

Section 6.2 retraces the key phases of China's solar PV development, identifying the industrial policies and strategic interventions that enabled its rapid ascent. Section 6.3 explores the components of this experience that may hold relevance for East Africa, distinguishing between short-term actionable lessons and longer-term strategic directions. Section 6.4 critically assesses the contextual conditions in East Africa that may facilitate or constrain such policy learning. Through this structure, the chapter seeks to provide a grounded and theoretically informed answer to the research sub-question: How can China's solar PV industry development experience inform the establishment of a competitive and context-adapted regional value chain (RVC) for East Africa under current global market dynamics?

Building on these theoretical insights, the rest of this chapter explores how Chinese policy experiences might be selectively and strategically adapted to East Africa. Section 6.1 reviews the development trajectory of China's solar PV industry, with particular emphasis on the strategic policies that enabled its rise. Section 6.2 critically assesses the limitations of direct policy borrowing, highlighting the key differences in political, economic, and industrial structures between the two regions. Section 6.3 identifies policy elements and institutional practices that may be transferable to the East African context. Finally, Section 6.4 draws cautionary lessons from China's PV journey, focusing on the risks of overcapacity, uncoordinated competition, and policy overshooting that East Africa should avoid. Together, these sections aim to answer the final research sub-question: How can China's solar PV industry development experience inform the establishment of a competitive and context-adapted regional value chain (RVC) for East Africa under current global market dynamics?

6.1 China's Industrial Strategy for solar PV Manufacturing

6.1.1 Historical Overview: From Latecomer to Significant Global Player

The development trajectory of China's solar PV manufacturing industry exemplifies a typical pattern of technological catch-up by a latecomer. Based on the evolution of technological capabilities, market expansion, and policy guidance, China's PV industry progression can be broadly categorized into five distinct stages: Germination Period (1958–1999), Export-Led Takeoff (2000–2008), Domestic Market Emergence (2009–2012), Global Leadership and Structural Adjustment (2013–Present).

1. Germination Period (1958–1999): Science-Led and Niche Applications

China's initial engagement with PV technology began in the late 1950s with the production of crystalline silicon for satellite applications. In 1968, a research institute in Tianjin developed the first solar cells for space use, followed by limited deployments in military and telecommunication systems throughout the 1970s and 1980s (Huang et al., 2016; Zhao et al., 2013).

However, large-scale commercialization was absent during this period. Domestic R&D capabilities were fragmented, and most solar panels used in rural electrification projects were imported from Japan and Germany. This stage was characterized by state-led research rather than industrial policy support, with a focus on knowledge accumulation in national laboratories and academies (Huang et al., 2016).

2. Export-Led Takeoff (2000–2008): Foreign Demand and Entrepreneurial Entry

Driven by booming global demand—particularly from Germany after its Renewable Energy Act in 2000—China's PV manufacturing began to scale rapidly. Entrepreneurs such as Shi Zhengrong of Suntech acquired turnkey production lines from Europe and launched private firms that quickly entered global markets (Huang et al., 2016).

Between 2002 and 2007, China's share of global solar cell production increased dramatically (as shown in Figure 48). By 2007, five of the world's top ten solar manufacturers were Chinese (Huang et al., 2016). Notably, this phase unfolded largely without strong domestic policy support; the central government focused its industrial planning on wind power, while PV growth was enabled by low labor costs, abundant land, and entrepreneurial experimentation (Awate et al., 2018).

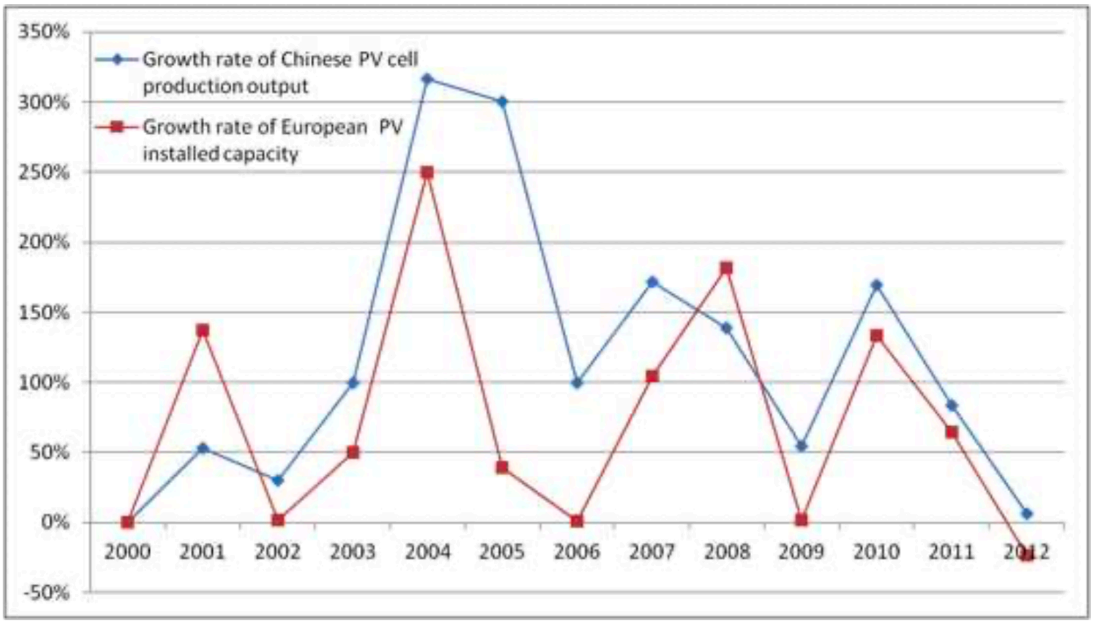


Figure 48 - Comparison of the growth rate of Chinese PV cell production output and European PV installation capacity from 2000 to 2012 (MWp)
Source: Huang et al., 2016

This export-oriented model of catch-up emphasized "cost-based imitation," as Chinese firms competed on scale and price rather than innovation. Nevertheless, it laid the industrial foundation for future upgrading (Awate et al., 2018).

3. Domestic Market Emergence (2009–2012): Strategic Policy Interventions

Following the global financial crisis, declining foreign demand exposed China's overreliance on exports. In response, the government launched a suite of domestic market-stimulating policies. These included three major initiatives. First, the Golden Sun Demonstration Program, launched in 2009, provided capital subsidies of up to 50–70% for solar PV projects in areas with good solar resources and grid access. It aimed to stimulate domestic deployment and create demand for local manufacturers. Second, the government introduced rooftop PV subsidies, offering financial support to distributed solar installations, particularly on public and commercial buildings, to diversify application scenarios beyond utility-scale farms. Third, in 2011, the national feed-in tariff (FiT) scheme was established, guaranteeing fixed electricity prices for grid-connected solar power over a 20-year period. This reduced investment risks and significantly boosted investor confidence (Zhang & He, 2013; Zhang & Zhao, 2013).

Table 8 - Golden sun demonstration program

Phase	Year	Approved projects	Approved capacity (MW)	Subsidy (RMB/W)	
				Solar PV building	Off-grid
I	2009	98	201	14.5	20
II	2010	50	272	11.5	16
III	2011	140	690	C-Si: 9.0, a-Si: 8.5	
IV	2012	167	1709	5.5	> 7.0
Total		455	2872	—	—

Source: Zhang & He, 2013

As shown in Table 8, these interventions triggered a surge in domestic installations: from just 140 MW in 2008 to over 3.3 GW in 2011 (Zhang & He, 2013). PV targets were incorporated into the 12th Five-Year Plan, and local governments like Jiangsu and Zhejiang provided land access, tax incentives, and pilot projects (Zhao et al., 2013). This phase marked the shift from passive manufacturing to coordinated market formation and active government steering.

Table 9 - Share of off-grid and on-grid solar PV in China, 2004–2011

	Off-grid (MW)	Share	On-grid (MW)	Share	Annual (MW)	Cumulative (MW)
2004	8.8	88%	1.2	12%	10	62.1
2005	7.4	93.7%	1.5	6.3%	7.9	70
2006	9	90%	1	10%	10	80
2007	17.8	89%	2.2	11%	20	100
2008	19	90.5%	21	9.5%	40	140
2009	18	12.7%	142	87.3%	160	300
2010	25	5.3%	475	94.7%	500	800
2011	20	0.8%	2480	99.2%	2500	3300

Source: Zhang & He, 2013

4. **Global Leadership and Structural Adjustment (2013–Present): Innovation and Consolidation**

By 2013, China had become both the world's largest PV producer and installer. However, years of subsidy-driven expansion led to overcapacity, falling margins, and bankruptcies. Firms such as LDK and Suntech collapsed under financial stress, exposing weaknesses in the growth model (Haley & Haley, 2013; Zhao et al., 2013).

To stabilize the industry, the government promoted consolidation, phased-out outdated capacity, and launched R&D-focused programs under the "Made in China 2025" strategy (Li et al., 2020). Policies began emphasizing distributed PV, grid parity, smart systems, and overseas expansion through the Belt and Road Initiative. By 2021, China's installed PV capacity surpassed 300 GW, with leading firms dominating every segment from polysilicon to modules (Zhao et al., 2013).

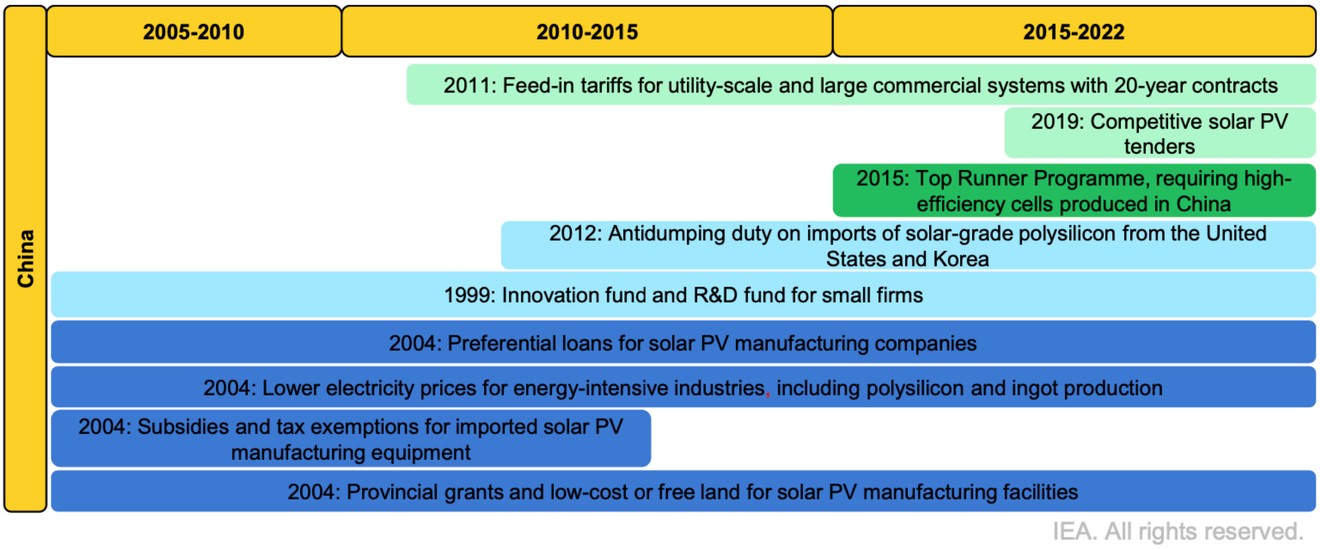
6.1.2 Strategic Policy Mix and Industrial Coordination

The development of China's solar PV industry was not the result of a single policy or linear planning logic, but rather a strategically sequenced and coordinated policy mix that evolved with industrial needs and market shifts. This mix was accompanied by multi-level industrial coordination mechanisms, enabling rapid scale-up, spatial concentration, and systemic upgrading of the sector.

Layered Policy Composition and Lifecycle Alignment

China's policy framework combined supply-push instruments (e.g., R&D funding, equipment import tax exemptions, preferential loans) with demand-pull mechanisms (e.g., feed-in tariffs, competitive bidding, high-efficiency product mandates). Crucially, these instruments were not applied simultaneously, but rather in a sequenced and layered manner, responsive to the stage of industry development—from production capacity formation to market creation and quality enhancement.

As shown in Figure 49, early policies (2004–2010) focused on indirect and direct supply support, such as tax exemptions for imported manufacturing equipment, low electricity prices for energy-intensive industries (including polysilicon and ingot production), and provincial-level land subsidies. From 2011 onward, demand-side incentives gained prominence: the national feed-in tariff (FiT) in 2011 guaranteed 20-year contracts for utility-scale PV, and in 2015 the Top Runner Programme mandated high-efficiency solar cells to drive technology upgrading. In 2019, competitive bidding was introduced to replace administratively-set tariffs, increasing market efficiency and cost pressure (IEA, 2022).



Notes: Light green = indirect demand. Dark green = direct demand. Light blue = indirect supply. Dark blue = direct supply.

Figure 49 – Supply and demand policies targeting solar PV manufacturing in China, 2005-2022
Source: IEA, 2022b

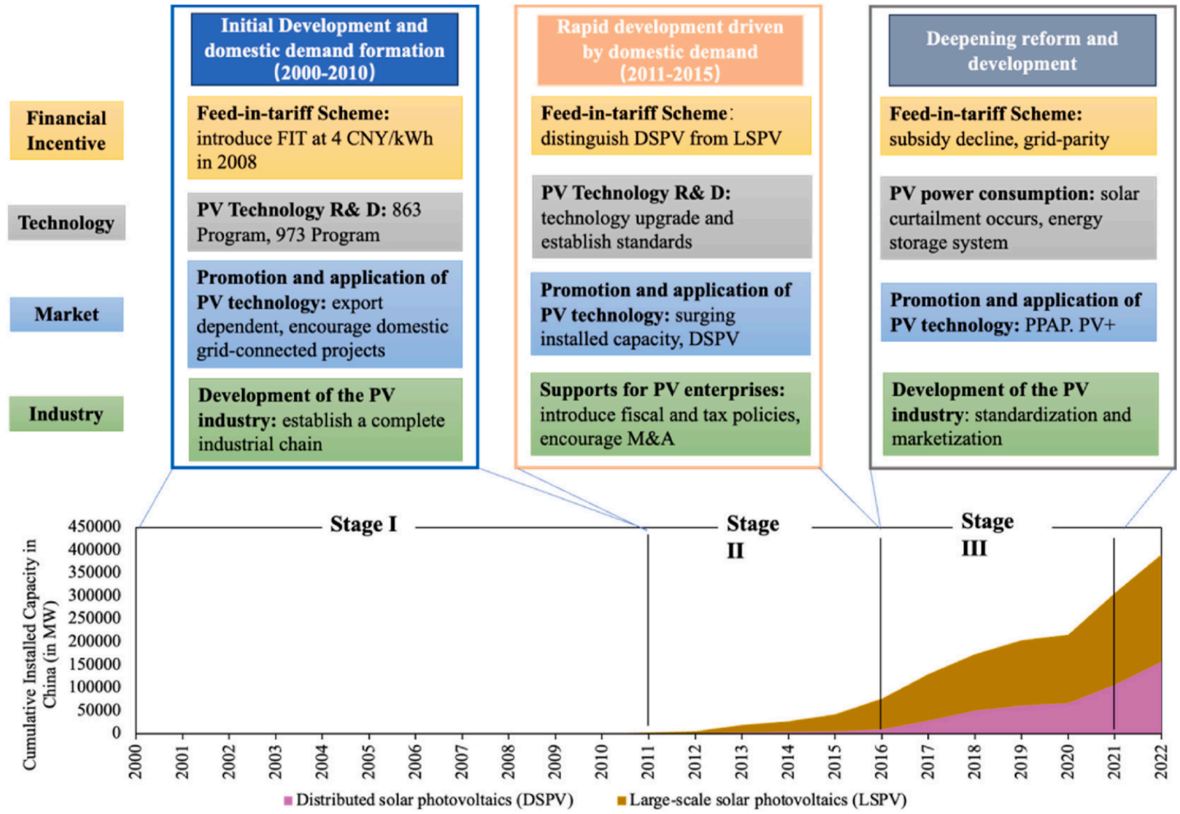


Figure 50 - The policy evolution framework of solar PV industry
Source: Bai et al., 2024

This structured rollout—moving from foundational supply support to strategic demand stimulation and then toward competitive market discipline—illustrates how policy layering aligned with the industrial life cycle. It also exemplifies how China's solar PV development was governed not by a single master plan, but by an evolving policy architecture combining instruments of varied types, intensities, and institutional origins (Binz et al., 2017; Zhao et al., 2013).

Central-Local Division of Responsibility and Vertical Coordination

China's solar PV industry developed under a strategic division of responsibilities between central and local governments. At the central level, national agencies such as the National Development and Reform Commission (NDRC), the Ministry of Finance, and the State Council were responsible for formulating long-term goals, designing regulatory frameworks, and introducing nationwide incentive schemes. Instruments such as the Feed-in Tariff (FiT) and the Top Runner Programme promoted the adoption of high-efficiency technologies (IEA, 2022). These policies created broad investment certainty and market demand, while local governments implemented more granular, region-specific policies based on their industrial priorities (Zhang & He, 2013; Zhao et al., 2013; Corwin & Johnson, 2019).

Table 10 – China's feed-in tariff subsidies for common PV power stations

China's feed-in tariff subsidies for common PV power stations

Time	Large-scale solar PV station (CNY/kWh)			Distributed solar PV station (CNY/kWh)	
	Resource Area I	Resource Area II	Resource Area III	Industrial & Commercial	Household
2021.08	–	–	–		0.03
2020.06	0.35	0.40	0.49	0.05	0.08
2019.07	0.40	0.45	0.55	0.1	0.18
2018.06	0.50	0.60	0.70	0.32	
2018	0.55	0.65	0.75	0.37	
2017	0.65	0.75	0.85	0.42	
2016	0.80	0.88	0.98	0.42	
2015	0.90	0.95	1.00	0.42	
2014	0.90	0.95	1.00	0.42	
2013	0.90	0.95	1.00	0.42	

Source: NDRC

Source: NDRC, 2024

A key feature of this governance model was the vertical division of labor and incentive alignment across administrative levels. While central authorities focused on sectoral coordination and macroeconomic stability, local governments pursued industrial upgrading, employment generation, and fiscal growth. This division gave rise to regional clusters that specialized in different segments of the PV value chain. For example, Jiangsu and Zhejiang provinces emerged as manufacturing centers due to their strong industrial base and logistics connectivity, while western regions such as Xinjiang and Gansu hosted large-scale utility installations to take advantage of solar irradiance and land availability (Corwin & Johnson, 2019).

Local governments provided a wide array of industrial incentives, including land discounts, preferential electricity tariffs, tax holidays, and R&D subsidies. These measures were not only crucial for firm attraction but also for sustaining operations and cushioning firms during market downturns. The case of JinkoSolar is particularly illustrative: between 2012 and 2016, the company received steadily increasing local subsidies, reaching USD 25.9 million in 2016 alone from Shangrao (Jiangxi) and Haining (Zhejiang) governments. The figure below shows the annual subsidy levels received by Jinko, highlighting the active role of subnational actors in firm survival and expansion.

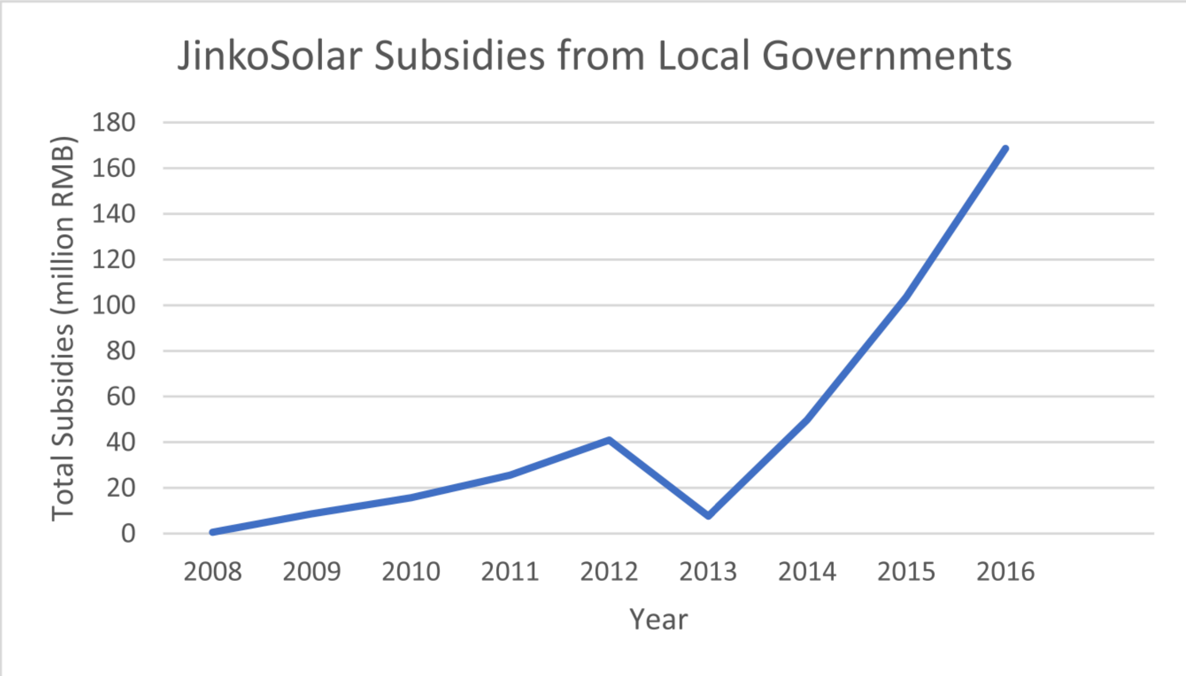


Figure 51- Local government subsidies provided to JinkoSolar
Source: Corwin & Johnson, 2019

Beyond direct subsidies to firms, provincial and municipal governments actively shaped the geographical distribution of manufacturing capacity through targeted industrial policy.

Provinces such as Jiangxi and Zhejiang, both leading producers of solar cells, supported upstream manufacturing through a mix of land-use benefits, electricity discounts, and equipment purchase subsidies, aiming to build localized value chains and attract auxiliary industries (Corwin & Johnson, 2019).

Figure 52 illustrates the provincial distribution of solar cell output in 2015, revealing the high concentration of production in a few Eastern provinces—most notably Jiangsu, Zhejiang, and Jiangxi. This spatial clustering reflects both historical industrial bases and the differentiated policy packages offered by local governments, which competed to attract investment and build PV manufacturing hubs (Corwin & Johnson, 2019).

However, the absence of centralized capacity coordination also led to excessive regional duplication, as multiple provinces pursued similar strategies without integration. This contributed to structural overcapacity in the mid-2010s, particularly in solar cells and modules, amplifying price competition and reducing firm-level margins. Such outcomes highlight both the strengths and limitations of China's multi-level governance model: while it enabled rapid industrial expansion, it also revealed coordination failures in managing aggregate production targets (Corwin & Johnson, 2019).

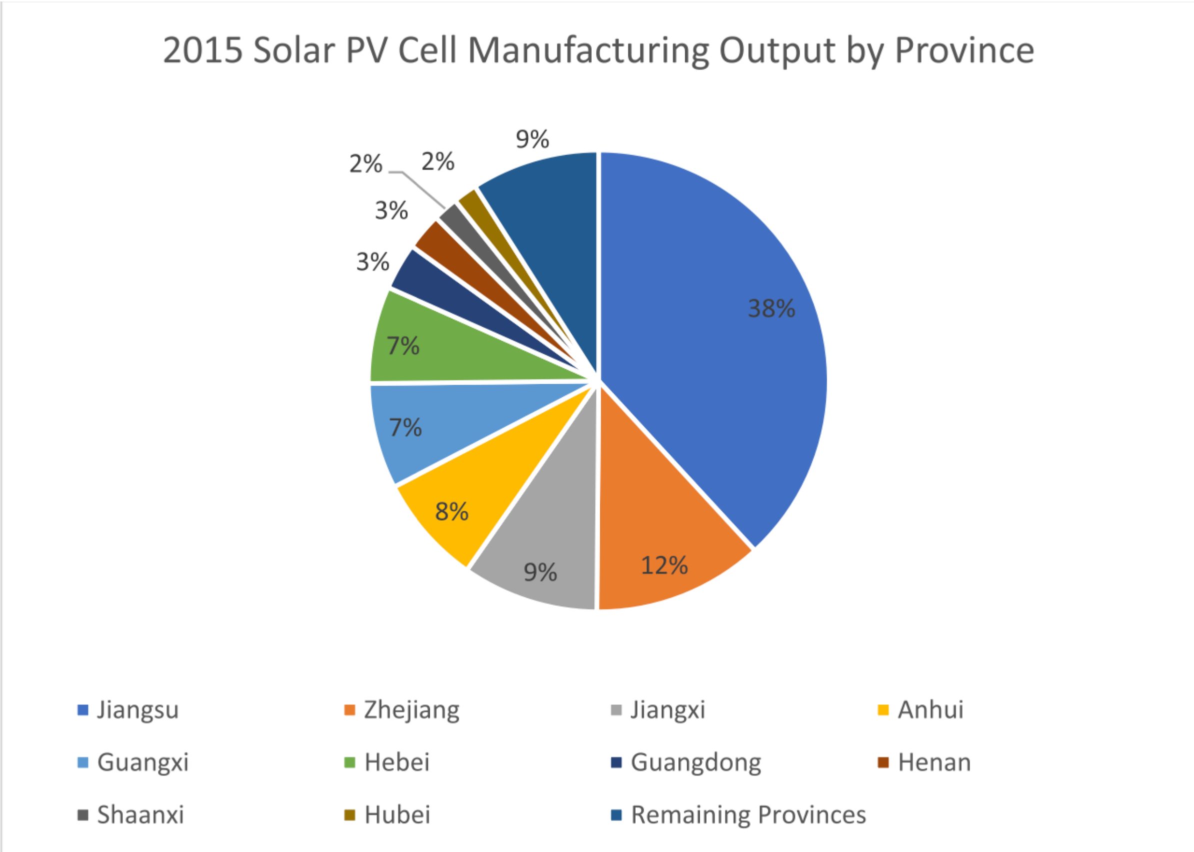


Figure 52 - 2015 solar PV cell manufacturing output by province
Source: Corwin & Johnson, 2019

6.1.3 Financial Mechanisms and Market Development

The development of China's solar PV industry was supported by a sophisticated set of financial mechanisms designed to reduce investment risk, ensure liquidity, and stimulate market formation. These mechanisms operated at multiple levels and were structured to support both supply-side manufacturing growth and demand-side deployment expansion.

At the national level, the central government introduced key demand-side mechanisms such as the Feed-in Tariff (FiT) scheme (2011), which offered long-term power purchase contracts at fixed prices. This instrument improved revenue certainty for investors and enabled project-level bankability. Earlier, the Golden Sun Demonstration Program (2009) had provided upfront capital grants covering up to 50–70% of installation costs for selected projects, stimulating early domestic deployment (Zhao et al., 2013).

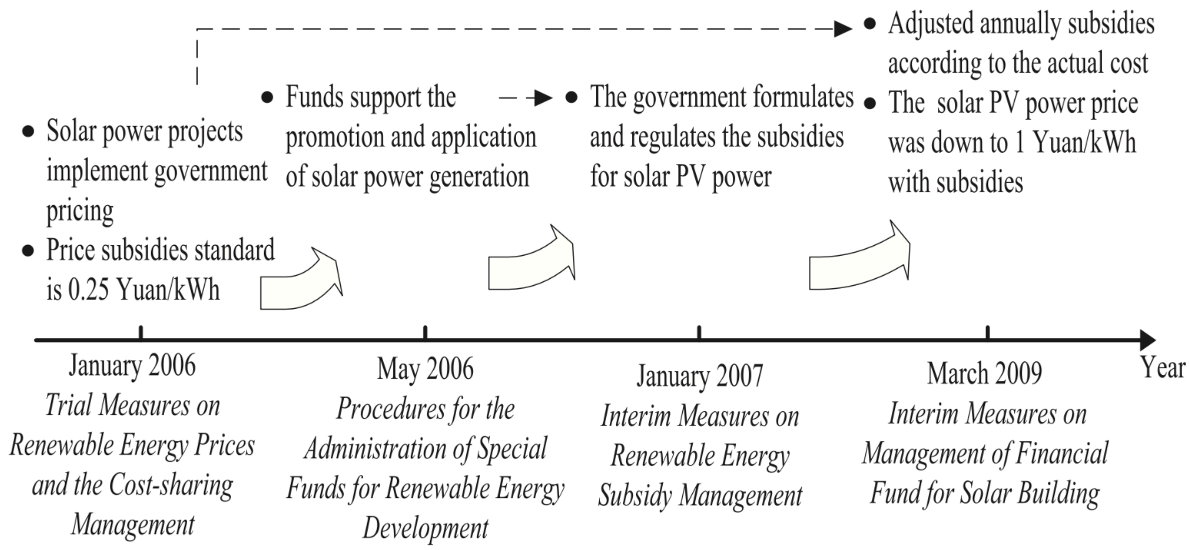


Figure 53 - Growth of financial subsidy policies supporting solar PV power pricing in China
Source: Zhao et al., 2013

In parallel, local governments engineered a variety of direct financial instruments to support local firms and retain industrial activity. These included:

1. Budgeted subsidies, allocated directly from municipal and county finance departments to firms in the form of cash transfers, often without strict performance conditions. For example, JinkoSolar received steadily increasing local subsidies from its host cities between 2012 and 2016 (Corwin & Johnson, 2019).
2. Preferential loans and interest rebates, typically arranged in coordination with regional banks or state-owned financial institutions, sometimes involving implicit guarantees or debt restructuring backed by local authorities. Notable cases include Wuxi's rescue of Suntech and Jiangxi's credit facilitation for LDK Solar (Corwin & Johnson, 2019).
3. Production- or employment-linked fiscal rewards, wherein local authorities calibrated financial support based on firms' output, export volume, or job creation, creating a quasi-performance-based support system to incentivize operational expansion.
4. Installation-linked subsidies, where local governments offered downstream deployment incentives specifically to encourage uptake of locally manufactured products. CREIA data indicates that several provinces tied deployment incentives to their own production bases, revealing an integrated approach to stimulate localized demand (Corwin & Johnson, 2019).

These financial mechanisms collectively enabled the formation of stable, jurisdiction-specific PV markets, supported long-term capacity planning, and enhanced investor confidence. By structuring financial flows to support both upstream production and downstream consumption, local and national authorities together constructed a self-reinforcing industrial ecosystem.

6.1.4 Technological Capability Building and Innovation

The development of China's solar PV industry is not only characterized by rapid expansion in production capacity and market share but also by a gradual and strategic enhancement in technological capabilities. This trajectory can be understood as a transition from reliance on imported equipment and know-how towards indigenous innovation and R&D-driven competitiveness.

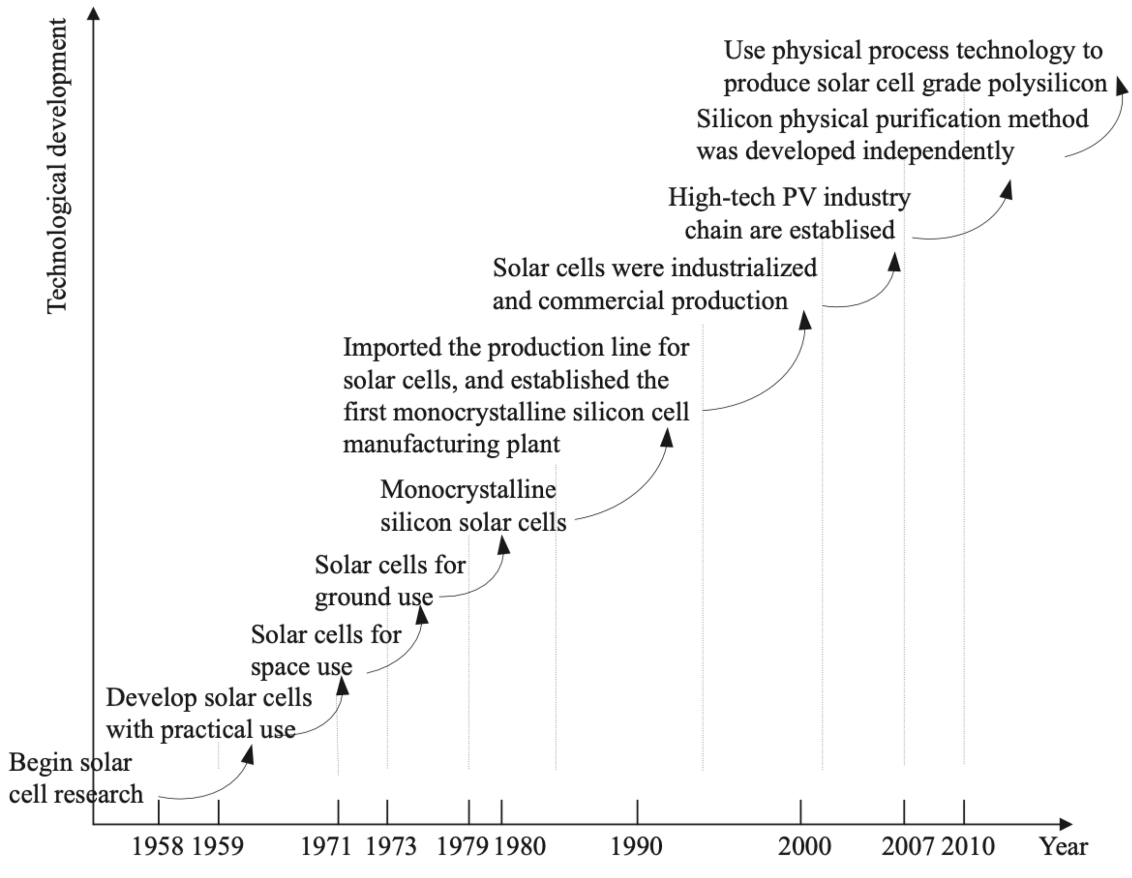


Figure 54 - Milestones in the development of the solar PV power technology development in China
Source: Zhao et al., 2013

In the early stages, domestic firms entered the global market by assembling modules using imported turnkey equipment, with competitive advantage rooted in low production costs, scale, and policy support rather than proprietary knowledge (Awate et al., 2018). Government intervention during this period focused on expanding manufacturing capacity and promoting exports, reflecting a policy mix suited to standardized mass production rather than innovation-intensive sectors (Binz et al., 2017).

This began to change in the mid-2000s, when renewable energy, including solar PV, was identified as a strategic sector under China's "Medium- and Long-Term Plan for Science and Technology Development (2006–2020)." Public investments in applied research increased, and firms began building in-house R&D capacity. Companies such as Suntech and Trina Solar gradually shifted from pure manufacturing to process refinement and incremental innovation, supported by learning-by-doing and close engagement with equipment suppliers (Awate et al., 2018).

Scientific capability development occurred in parallel. China's share of global publications in solar cell research—particularly in applied areas like crystalline silicon and organic PV—grew rapidly throughout the 2000s, demonstrating what Sasaki and Sakata (2013) describe as a "parallel-running" model of catch-up, where industrial and scientific progress evolve together. *Acta Energiae Solaris Sinica*, China's leading journal in solar energy research, provides valuable insight into the evolution of domestic PV R&D. As shown in Figure below, the proportion of funded papers and the number of participating institutions increased markedly after 2000. In addition to internal learning, Chinese firms also benefited from acquiring foreign companies and technologies, especially during periods of global industry consolidation. These acquisitions helped accelerate local adaptation and deepened engineering knowledge (Awate et al., 2018).

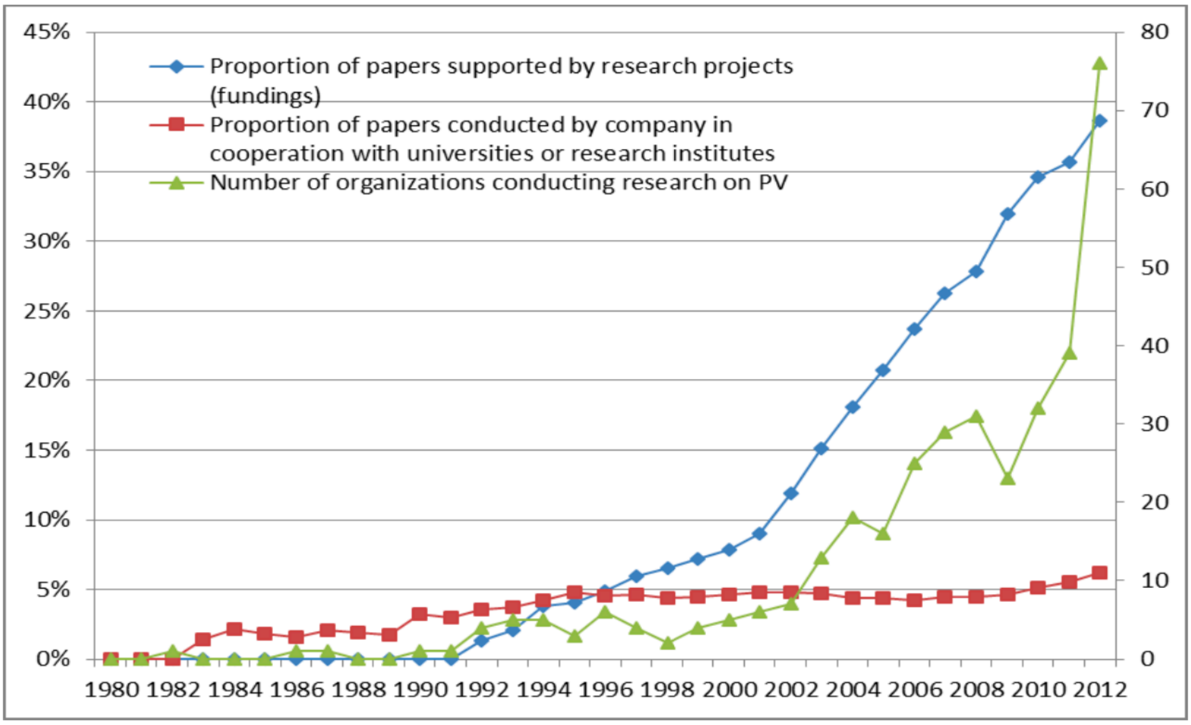


Figure 55 - Knowledge development regarding PV from the journal *Acta Energiae Solaris Sinica*
Source: Huang et al., 2016

Enterprise-led R&D in China's solar PV sector gained momentum during the late 2000s, marking a transition from manufacturing-led learning to firm-level innovation. Leading companies such as Trina Solar, JA Solar, and Yingli Green Energy began establishing internal R&D centers focusing on areas such as solar cell design, wafer processing, and materials testing, aiming to enhance efficiency and product reliability (Awate et al., 2018).

Patent data confirm the scale and direction of these innovation efforts. Trina Solar had filed 372 patent applications globally by 2015, with 342 registered in China and 25 through WIPO, covering technologies from crystal growth to semiconductor device processing. Yingli, similarly, had accumulated over 160 applications, including inventions in module interconnection and photovoltaic components (Awate et al., 2018). These patterns suggest that innovation in Chinese firms was not limited to downstream assembly but extended across the full value chain.

Table 11 - R & D expense and patent applications of the solar cell market leaders

Market leaders	R & D expense in 2015 ($ million)	WIPO patent applications
Yingli Green	63.8	Total: 162 Chinese Patent office (CN): 149 European Patent office (EP): 1 USPTO: 1 WIPO: 11
Hanwha Q-cells[a]	48.3	Total: 21 EP: 9 USPTO: 6 WIPO: 3 Spanish Patent office: 2 Japanese Patent office: 1
GCL	40.75[b]	Total: 41 CN: 41
Trina Solar	34.1	Total: 372 Chinese Patent office (CN): 342 European Patent office (EP): 2 USPTO: 3 WIPO: 25
JA Solar	23	Total: 76 CN: 74 WIPO: 2
Jinko Solar	22.2	Total: 130 CN: 130
Canadian Solar	17.05	Total: 32 CN: 32

Source: Awate et al., 2018

At the same time, domestic firms progressed in localizing production equipment. By 2009, Chinese manufacturers were able to produce a large share—around 70%—of the equipment used in new crystalline silicon solar cell production lines. While some high-end components still lagged in stability compared to international counterparts, this shift marked a major step toward domestic capability in PV machinery (Huang et al., 2016).

In sum, the technological upgrading of China's solar PV industry reflects a cumulative process of capability building, enabled by strategic industrial policy, targeted public R&D investment, and firm-level learning. From early dependence on foreign technology and equipment, Chinese firms progressively advanced toward localized engineering, applied innovation, and growing scientific engagement. The simultaneous rise in patenting activity, domestic equipment manufacturing, and research output illustrates a shift toward a more autonomous and innovation-oriented industrial structure.

6.1.5 Standardization, Certification, and International Influence

The institutionalization of technical standards and certification systems has been a critical enabler in China's solar PV industrial development, particularly in facilitating product quality assurance and access to export markets. In the early stages of industry formation, China lacked a coherent technical standardization system for solar PV products, leading to inconsistencies in quality and limiting the international competitiveness of domestically produced modules.

A major turning point came with the “Renewable Energy Development Eleventh Five-Year Plan,” released by the National Development and Reform Commission in 2008. The plan explicitly called for the formulation of technical standards for solar public lighting, rooftop PV installations, and utility-scale systems, emphasizing the need for standardized system design and grid integration (Zhao et al., 2013). These efforts were closely linked with state-led deployment programs such as “Golden Sun” and “Solar Roofs,” which conditioned financial support on compliance with newly established national norms. Although policies such as the “Golden Sun” and “Solar Roofs” programs were primarily designed to stimulate downstream deployment, their implementation had important upstream implications. As participation in these programs required certified products and compliance with national technical specifications, manufacturers were compelled to upgrade production processes, align designs with standardized performance parameters, and engage with accredited testing institutions. This policy-induced demand for compliance accelerated the development of internal quality management systems within module and inverter firms, thereby embedding standardization practices directly into the manufacturing phase.

To support implementation, institutions such as the China Quality Certification Center (CQC) and the National Energy Administration began coordinating certification and product testing. This helped align domestic practices with international quality frameworks and facilitated access to global markets, particularly in Europe and North America. By the early 2010s, major Chinese manufacturers had obtained certifications such as TÜV (Germany) and UL (USA), signaling compliance with International Electrotechnical Commission (IEC) standards and strengthening global trust in Chinese PV products (Awate et al., 2018).

Beyond compliance, China has gradually shifted toward a more proactive role in international standard-setting. Leading firms and research institutes began participating in technical committees of organizations such as the International Electrotechnical Commission (IEC). While still in a consolidating phase, this participation reflects a broader transition from rule-taker to rule-shaper. The ability to influence global norms not only reinforces China's industrial legitimacy but also helps align international requirements with domestic technological strengths (Binz et al., 2017)

China’s evolving standardization and certification regime has served as both a foundation for industrial upgrading and a vehicle for international integration. Initially driven by policy mandates and deployment-linked compliance mechanisms, these frameworks prompted manufacturers to internalize quality standards and adapt to increasingly formalized technical requirements. Over time, this contributed not only to improved product reliability and export readiness, but also to China's growing engagement in global standard-setting arenas—marking a shift from passive adoption to active institutional participation.

6.2 Limits of Applicability and Required Adaptation

Drawing on the theoretical discussions in Section 2.5 (Policy Transfer Theory) and Section 3.3 (Catch-up Conditions in Context), this section critically examines which elements of China’s solar PV industrial strategy are not directly applicable to East Africa and where significant adaptation would be required. Policy transfer, as outlined by Dolowitz and Marsh (2000), depends not only on the characteristics of the policy being transferred, but also on institutional similarity, administrative capacity, and the willingness of actors to adopt and adapt foreign models. In the context of East Africa—a region composed of diverse, resource-constrained states—certain structural features of China’s developmental model are either incompatible or only partially transferable.

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6.2.1 Structural Divergence in Governance Systems

China’s solar PV expansion was coordinated through a vertically integrated system, where central and local governments jointly aligned on targets, resource allocation, and implementation. In contrast, East Africa is a multi-country region with distinct national policies, priorities, and institutional capacities. While coordination platforms like the EAC exist, they lack binding authority or centralized budgeting power. As a result, mechanisms that rely on unified planning, such as nationwide feed-in tariffs or centralized industrial siting strategies, face significant governance barriers in the East African context. Regional industrial development in East Africa will thus require a more decentralized, consensus-based approach.

6.2.2 Fiscal and Financial Limitations

China's solar manufacturing growth was heavily supported by large-scale public investments, soft credit from state-owned banks, and expansive fiscal space. In East Africa, limited national budgets, high external debt, and underdeveloped financial markets constrain the availability of low-cost capital for manufacturing development. Instruments such as performance-based industrial subsidies or bailouts of struggling firms (e.g., Suntech, LDK) are not fiscally viable in most East African countries. Instead, reliance on blended finance from development partners and donor-backed de-risking mechanisms will be essential, but these require different institutional arrangements than China's state-led financing model.

6.2.3 Weak Implementation and Monitoring Capacity

The design and enforcement of China's industrial policies relied on a highly capable bureaucracy with the ability to monitor firm performance, enforce standards, and adjust incentives accordingly. In contrast, many East African governments face capacity limitations in technical regulation, data monitoring, and inter-agency coordination. Tools like production-linked incentives or high-efficiency technology mandates—as implemented under China's Top Runner Program—require reliable verification systems and enforcement bodies, which are not yet present in many East African states. Simplified and transparent policy tools may be more appropriate in the near term.

6.2.4 Timing and Global Market Conditions

China entered the global PV market during a period of rapidly expanding international demand and limited competition, especially from Europe. Its firms benefited from early-mover advantages in cost competitiveness and scale. East African countries, by contrast, are entering the sector at a time of global overcapacity, intense price competition, and dominance by entrenched players. Replicating China's export-led model is therefore unlikely to yield similar results. East Africa may instead need to focus on import substitution, regional procurement aggregation, and public-led demand creation rather than seeking immediate integration into global export markets.

6.2.5 Developmental State Logic vs. Political Fragmentation

Much of China's solar PV industrial success stemmed from a strong developmental state tradition, in which local governments proactively invested in infrastructure, subsidized firms, and competed to host strategic industries. This logic is not easily replicable in East Africa, where electoral cycles, fiscal decentralization, and uneven institutional strength may undermine long-term industrial commitment. Policy tools that rely on sustained local-state coordination—such as the creation of specialized solar industrial clusters—may require external facilitation or regional development agencies to fill coordination gaps.

In summary, while China's policy mix contributed to rapid industrialization, its effectiveness was contingent on a specific configuration of centralized authority, bureaucratic capacity, fiscal autonomy, and favorable market timing. These conditions are not fully present in East Africa, and therefore, policy borrowing must proceed cautiously. Rather than adopting China's strategy wholesale, East African countries should focus on selectively adapting relevant components in ways that match their institutional realities, resource constraints, and regional coordination frameworks. The following section identifies which elements of China's PV strategy exhibit high potential for contextual transfer and how they can be tailored to support East Africa's regional value chain goals.

6.3 Transferable Lessons for East Africa

Having identified the key structural and contextual barriers that limit the direct transfer of China's solar PV industrial strategy, this section turns to explore which components of that experience offer practical relevance for East Africa. Drawing again on the policy transfer criteria outlined in Section 2.5—particularly the compatibility of goals, policy instrument design, institutional functionality, and actor willingness—a subset of policy tools and implementation strategies are identified from China that are relatively less dependent on centralized capacity and more adaptable to East Africa's fragmented but emerging industrial landscape.

6.3.1 Sequenced Policy Layering: From Supply-Push to Demand-Pull

One of the most replicable features of China's PV strategy lies in the sequencing of industrial policy tools across the value chain and technology life cycle. Rather than applying all policy instruments simultaneously, Chinese authorities implemented supply-push mechanisms (e.g., tax exemptions, R&D grants, low-cost land) in the early stages, followed by demand-pull measures (e.g., feed-in tariffs, procurement incentives) as domestic manufacturing matured. This logic—aligning policy tools with the industry's capacity to absorb and respond—can be selectively adopted by East African countries.

For instance, countries such as Kenya or Ethiopia could begin with investment de-risking tools for component manufacturers and equipment importers, while gradually developing market-side incentives such as public procurement programs with local content requirements. Given the small size of national markets, these efforts would be more effective if coordinated at the regional level, with joint financing or pooled tenders under frameworks such as the EAC Power Pool or AfCFTA-linked industrial clusters.

6.3.2 Industrial Clustering and Infrastructure Planning

China's deployment of industrial parks and regional manufacturing clusters—especially in Jiangsu and Zhejiang provinces—played a crucial role in creating economies of scale and enabling firm specialization. While China's land and infrastructure decisions were often centrally orchestrated, the underlying principle of spatially concentrated, infrastructure-ready zones is applicable to East Africa, particularly in countries that have already begun experimenting with Special Economic Zones (SEZs) or industrial parks.

Ethiopia's Hawassa Industrial Park and Kenya's Konza Technopolis are examples of platforms that could be repurposed or expanded to accommodate solar manufacturing tenants, especially in upstream segments such as frame production, inverter assembly, or glass processing. Regional coordination could also help reduce duplication and enhance cross-border specialization, for example by promoting Rwanda as a hub for tin-based solder production or Tanzania for copper component processing.

6.3.3 Technical Standards and Quality Certification

A major bottleneck in East Africa's solar deployment ecosystem has been the widespread circulation of substandard products and the absence of harmonized testing and certification infrastructure. China addressed a similar challenge in the late 2000s by linking technical standards and certification requirements to financial support programs such as Golden Sun and Solar Roofs. This ensured that manufacturers upgraded their processes to meet defined performance benchmarks.

East African countries could adopt a similar strategy by tying public procurement or import licenses to minimum quality standards, enforced through regionally harmonized norms. Institutions such as the East African Standards Committee (EASC) under the EAC can serve as a platform for developing shared testing protocols. This approach would also support domestic manufacturers by helping build trust in locally produced components, a necessary step for regional value chain integration.

6.3.4 Public-Private and Academic Collaboration

While China benefited from centralized science-policy coordination, its solar PV firms also built capabilities through close interaction with universities, technical colleges, and research institutes, particularly in applied engineering and manufacturing process innovation. Although East Africa lacks large-scale R&D institutions dedicated to photovoltaics, several countries are undergoing TVET reforms and science policy restructuring.

Programs such as Kenya's Competency-Based Education and Training (CBET), Uganda's Presidential Initiative on Science and Technology, and Ethiopia's engineering capacity expansion under the Growth and Transformation Plan (GTP II) provide entry points for pilot collaboration platforms. These could link manufacturing firms, technical institutes, and donor agencies in targeted training or applied research projects focused on module assembly, system design, or local materials testing.

6.3.5 Performance-Linked Incentives and Investment Facilitation

Although East African states lack China's fiscal capacity for broad-based industrial subsidies, selective and transparent incentive structures remain feasible. For instance, local investment promotion agencies could offer performance-based tax holidays or import duty rebates tied to employment generation, export performance, or local value addition—similar to how certain Chinese provinces tailored support packages for PV firms.

Moreover, donor-backed financing tools (e.g., de-risking facilities, green credit lines) could be designed to function analogously to China's preferential bank loans, but in a fiscally sustainable manner. The emphasis should be on criteria-based targeting and sunset clauses, avoiding the inefficiencies and political lock-ins seen in some of China's subsidy programs.

In summary, China's experience provides not only a broad narrative of industrial catch-up but also a set of policy design principles—phased intervention, functional clustering, embedded quality control, and coordinated learning—that can inform East Africa's regional value chain strategies. These lessons are not prescriptive models but building blocks that can be selectively adapted to different national and regional contexts. The final section (6.4) now turns to the unintended consequences of China's PV development experience, offering cautionary guidance for East Africa's future trajectory.

6.4 Risks and Cautionary Lessons from China's PV Boom

While China's emergence as a global leader in solar PV manufacturing offers valuable insights, its development trajectory also reveals a series of structural risks and unintended consequences that East Africa would be wise to avoid. These challenges were not incidental, but rather embedded within the dynamics of accelerated industrialization and state-led expansion. For East African countries seeking to build a competitive and sustainable regional value chain, learning from these pitfalls is just as important as emulating China's strengths.

One of the most prominent challenges was the problem of overcapacity. In the rush to scale up manufacturing, multiple provinces in China offered overlapping incentives and raced to attract investment, resulting in redundant capacity across the value chain. By the mid-2010s, production far exceeded global demand, leading to sharp price declines, margin compression, and widespread firm closures. Although this outcome lowered solar prices globally, it also generated instability for producers and undermined long-term profitability. For East Africa, where manufacturing capabilities and capital are scarce, replicating this pattern—even at a smaller scale—could quickly lead to unviable operations and wasted investment. Coordinated planning, both at the national and regional levels, is essential to avoid duplication and excessive competition among countries.

Closely related to this is the issue of policy-induced market distortions. In China, generous subsidies—including feed-in tariffs, tax holidays, and equipment grants—played a critical role in scaling the industry. However, they also created opportunities for rent-seeking behavior, inefficient firm survival, and misalignment between industrial output and actual market needs. In some cases, firms produced low-quality modules simply to qualify for subsidies, and performance metrics were inflated to meet administrative targets. East African countries, where oversight mechanisms are often weaker, must therefore approach subsidies and incentives with caution. Support schemes should be rule-based, transparent, and performance-linked, with clear sunset provisions and third-party verification to prevent misuse.

Another risk arises from political and institutional fragmentation. While China was able to coordinate industrial development through vertical alignment between central and provincial governments, East Africa is composed of multiple sovereign states with diverse policy environments and regulatory systems. Without strong mechanisms for regional coordination, there is a danger that each country will pursue isolated or duplicative strategies, diluting the potential for functional specialization and economies of scale. Past examples of inter-provincial competition in China—where local governments protected their own firms and offered conflicting incentives—offer a warning of what could happen if East African countries fail to align their efforts through platforms like the EAC or AfCFTA.

Environmental and social trade-offs also deserve close attention. Although solar energy is often seen as a green solution, its manufacturing processes—particularly upstream stages like polysilicon and ingot production—can be resource-intensive, involving high electricity and water consumption, chemical usage, and hazardous waste. In China, these issues were sometimes downplayed in favor of economic growth, leading to local environmental degradation and community resistance. As East African countries consider siting solar manufacturing zones near hydropower or mining hubs, they must proactively assess environmental risks and ensure that clean energy production does not come at the expense of ecological integrity or social license to operate.

Finally, despite rapid industrial scaling, China's PV sector initially remained highly dependent on imported technologies, equipment, and foreign expertise. The localization of core technologies—such as high-efficiency cell production and power electronics—took time and required substantial investment in R&D, standards, and technical education. For East Africa, the risk of technological dependence is even higher. Without early and sustained investment in workforce development, vocational training, and applied research, countries may become stuck in low-value segments of the value chain, with limited capacity for upgrading. Efforts to promote local content must therefore be accompanied by measures to build endogenous capabilities through TVET reform, university-industry collaboration, and knowledge transfer.

In summary, China’s solar PV boom provides a compelling case for how industrial policy can accelerate sectoral transformation—but it also offers clear warnings. Overproduction, poorly structured subsidies, regional disintegration, environmental neglect, and technological lock-in are not theoretical concerns; they are empirically documented outcomes that carry important implications for East Africa’s path forward. Anticipating these risks and designing preventive measures from the outset can help ensure that solar PV industrialization in the region is not only ambitious but also sustainable and inclusive.

7 Conclusion and Discussion

This chapter concludes the thesis by synthesizing the main findings and reflecting on their broader implications. It first revisits the five research questions introduced in Chapter 1 and explicitly answers each based on the analyses presented in Chapters 4 to 6. This provides a structured closure to the study's empirical and theoretical exploration. Subsequently, the chapter discusses how the findings contribute to the broader debates on green industrialization, regional economic integration, and latecomer development strategies, particularly in the African context. It also identifies key policy implications, methodological limitations, and potential avenues for future research.

As a starting point, it is worth recalling the overarching objective that motivated this research: to investigate whether regional cooperation can serve as a viable strategy for East African countries to develop a sustainable solar PV manufacturing value chain, and how lessons from China's experience can inform this regional ambition. The thesis responds to this objective by combining three complementary analytical lenses—the Technological Innovation System (TIS) framework, the regional integration approach to global value chains (GVCs), and the developmental regionalism perspective—alongside catch-up and policy transfer theory. These frameworks were selected to reflect the multi-level, multi-actor, and multi-scalar nature of industrial upgrading in late-industrializing regions.

Through the lens of TIS, the study diagnosed the structural and functional weaknesses of solar PV innovation systems in 12 East African countries, highlighting the systemic constraints that hinder industrial emergence. The GVC and regional competitiveness analysis in Chapter 5 shifted focus to the spatial division of labor and examined how countries could move from isolated national efforts to a coordinated regional manufacturing strategy based on comparative advantages. Chapter 6 then contextualized these regional possibilities by drawing lessons from China's experience, while critically assessing their applicability to the East African context under current global and domestic constraints.

By integrating these perspectives, the thesis argues that although East African countries individually face formidable challenges in developing a competitive solar PV manufacturing sector, regional cooperation—if strategically structured—can offer a realistic pathway toward industrial upgrading. This chapter now turns to systematically answer each of the five research questions before engaging in a broader reflection on what these findings mean for the theory and practice of green development in Africa.

7.1 Addressing the Research Questions

To provide a clear and structured synthesis of this study's empirical findings, this section directly answers the five research questions introduced in Chapter 1. Each sub-section corresponds to one research question and draws upon the analytical evidence presented in Chapters 4, 5, and 6. This step-by-step approach not only offers an explicit closure to the study's investigative arc, but also reinforces the internal coherence between the research objectives, theoretical frameworks, and empirical analyses. Together, these answers demonstrate how a combination of regional cooperation, strategic specialization, and selective policy learning can enable East Africa to move from solar PV deployment toward sustainable industrial participation.

7.1.1 Addressing RQ1: What is the current state of solar PV value chain development in East Africa?

Chapter 4 addressed this question by applying the Technological Innovation System (TIS) framework to twelve East African countries, aiming to evaluate the extent to which the core structural and functional components necessary for solar PV manufacturing are in place. The findings reveal that solar PV development in the region remains overwhelmingly concentrated at the deployment end of the value chain—primarily in system installation, distribution, and off-grid O&M—while upstream and midstream manufacturing activities are either nascent or entirely absent in most countries.

Among the twelve countries assessed, only Kenya and Ethiopia demonstrate early-stage industrial participation beyond deployment. Kenya hosts a module assembly facility (Solinc), supported by relatively advanced logistics, financial institutions, and policy awareness. Ethiopia has attracted foreign investment in solar cell production, though local integration and technological upgrading remain limited. The rest of the countries—including Uganda, Rwanda, Tanzania, and others—largely rely on imported modules, with local firms engaged primarily in retail, installation, or last-mile delivery.

From a structural perspective, the actor landscape is fragmented and dominated by international development agencies, NGOs, and donor-supported enterprises, with minimal involvement from domestic industrial actors or research institutions. Key infrastructure such as testing laboratories, certification bodies, and specialized technical training centers are largely missing. Financial and policy support mechanisms remain oriented toward deployment rather than local production.

Functionally, the innovation system exhibits several critical weaknesses. Knowledge development and diffusion are weak due to underinvestment in R&D and the absence of university-industry linkages. Entrepreneurial experimentation is limited to low-barrier service provision rather than technological innovation. Resource mobilization, both financial and human, is insufficient to support capital-intensive manufacturing. Most importantly, the system lacks a coherent guidance of the search—that is, a shared strategic vision that prioritizes domestic or regional solar PV manufacturing as a development goal.

In sum, the current state of solar PV value chain development in East Africa is characterized by deployment-led growth, donor-driven innovation dynamics, and underdeveloped production capabilities. While the region is experiencing a rapid expansion in solar access, this has not yet translated into industrial value creation or structural transformation. The findings confirm that in its present form, the East African solar PV sector is ill-equipped to move up the value chain without significant changes in institutional coordination, policy orientation, and regional integration.

7.1.2 Addressing RQ2: What are the main constraints preventing East African countries from developing competitive solar PV industries individually?

As outlined in Section 4.4, the cross-country TIS diagnoses reveal five persistent and interrelated systemic bottlenecks that hinder the emergence of a coherent solar PV manufacturing innovation system in East Africa.

First, knowledge development and diffusion are severely limited. While basic skills in installation and distribution are gradually spreading, advanced technical know-how related to component manufacturing, system design, and quality assurance is largely absent. Institutional and industrial capacity to absorb or adapt upstream PV technologies remains minimal. Research–industry linkages are virtually nonexistent, with Kenya being the sole exception through limited involvement in an externally driven international initiative (REACH-PSM).

Second, the direction of search is narrowly framed. Policy agendas across the region continue to prioritize rural electrification and off-grid deployment, largely in response to donor objectives and short-term access targets. These signals fail to incentivize industrial upgrading or investment in higher-value segments such as module production, inverter assembly, or productive-use applications.

Third, entrepreneurial experimentation is concentrated in downstream services like retail, installation, and PAYG. Very few ventures attempt upstream manufacturing, and those that do—such as Solinc in Kenya—operate in isolation and face significant barriers. In parallel, resource mobilization remains uneven. Kenya and Ethiopia are the only countries with any significant concentration of financial capital, technical expertise, or enabling infrastructure, while most others remain almost entirely dependent on donor-led deployment funding.

Fourth, functional networks are weak or nonexistent. There is little collaboration between firms, research institutions, and government agencies. Existing industry associations tend to focus on downstream market development rather than facilitating coordination for manufacturing or technology upgrading. This fragmentation hampers collective learning, shared investment, and long-term strategic alignment.

Fifth, legitimation is growing but incomplete. Although solar PV is increasingly accepted as a tool for rural energy access, its potential role in industrialization and regional value creation is still underrecognized. Most countries lack formal standards, certification schemes, or policy mandates that would embed solar manufacturing within broader industrial strategies. This limits the sector's credibility and ability to attract long-term investment or policy prioritization.

In sum, these five bottlenecks—insufficient knowledge capability, narrow policy orientation, weak entrepreneurial base, fragmented networks, and underdeveloped institutional legitimacy—collectively prevent any single East African country from building a viable solar PV manufacturing system on its own. Addressing them requires deliberate and coordinated regional action, as explored in the next chapters.

7.1.3 Addressing RQ3: What enabling factors exist for building regional solar PV value chains in East Africa?

As demonstrated in Chapter 5.2, although no single East African country currently possesses the full set of capabilities needed to support a vertically integrated solar PV manufacturing industry, several countries display clear, segment-specific comparative advantages that align with distinct stages of the value chain.

Specifically, Rwanda, Uganda, Tanzania, and Eritrea possess commercially relevant deposits of minerals critical to PV manufacturing—such as tin, copper, and niobium—indicating upstream potential in raw material extraction and processing. Their mining sectors, while still underdeveloped, offer a foundation for value-added activities if coupled with investment in refining and transport infrastructure.

Ethiopia stands out for its abundant and low-cost hydropower, making it particularly well-positioned to host electricity-intensive manufacturing processes such as polysilicon, ingot, or wafer production. Its central geographic location also presents potential logistical advantages for cross-border supply coordination.

Kenya, by contrast, demonstrates the most advanced industrial and logistical ecosystem in the region. It hosts the only operational module assembly facility (Solinc), benefits from relatively mature manufacturing capabilities in related sectors (e.g., electronics, cables), and offers superior access to ports and financial services. These factors position it to lead downstream activities such as module assembly, inverter integration, and possibly final system configuration.

In addition, Rwanda and Uganda—while smaller markets—show relatively stronger institutional capacity and infrastructure quality (e.g., SEZ frameworks, vocational training centers), which could support specialized roles in certification, standards testing, or regional coordination platforms.

Taken together, these country-specific strengths do not substitute for full national capabilities, but they do provide the basis for functional specialization under a coordinated regional approach. The enabling conditions identified in Chapter 5.2 demonstrate that such specialization is not only technically feasible, but also aligns with developmental regionalism principles and the logic of task-sharing within global value chains.

7.1.4 Addressing RQ4: How can East African countries position themselves within different segments of the solar PV value chain through regional specialization?

Building on the country-level potential identified in Chapter 5.2, Chapter 5.3 and 5.4 together develop a regionally coordinated strategy for positioning East African countries within the solar PV manufacturing value chain. Rather than each country attempting to build an entire value chain domestically, the analysis emphasizes the need to develop a distributed manufacturing system that aligns different stages of the production process with the comparative strengths of specific countries, while addressing the systemic fragmentation challenges discussed earlier.

The process begins by identifying the critical stages of the solar PV value chain—ranging from upstream raw material processing to midstream component manufacturing (e.g., polysilicon, ingots, wafers), and downstream module assembly and system integration—and asking which countries are best suited to take on what roles, based on their existing capabilities and potential. The analysis proposes that:

Countries with critical mineral resources, such as Rwanda, Uganda, and Tanzania, could focus on developing mining and early-stage mineral processing for inputs like tin, copper, and niobium. However, this will require substantial investment in upgrading refining infrastructure and introducing basic environmental and industrial regulation to enable these resources to feed into regional supply chains. Ethiopia, due to its low-cost and abundant hydropower, is positioned to take on energy-intensive processes, such as the production of polysilicon, ingots, or wafers. To realize this potential, Ethiopia would need to leverage existing industrial zones and improve coordination between its energy and industrial ministries to attract investment into solar-specific manufacturing. Kenya, with its relatively developed manufacturing base, logistics networks, and financial infrastructure, is well suited for module assembly and system integration. Rather than replicating upstream capabilities, Kenya’s role would be to anchor downstream production and serve as a regional hub for product distribution and export.

In addition, supporting functions such as quality control, certification, training, and logistics could be taken up by countries with relatively stronger governance and institutional infrastructure. For instance, Rwanda could develop itself as a regional node for standards harmonization and certification, while Uganda and others could host regional technical training centers to address the shared labor skills gap.

To move from potential to implementation, Chapter 5.2 and 5.3 emphasizes the need for intentional policy coordination across borders. This includes aligning trade and industrial policies, leveraging regional frameworks such as the EAC and AfCFTA to eliminate tariff and logistical barriers, and establishing regionally governed investment strategies that avoid duplication and instead encourage complementary specialization.

Furthermore, investment in infrastructure connectivity—including transport corridors, regional grid expansion, and shared testing facilities—will be essential to integrate these fragmented capabilities into a functioning production system. Without such coordination, early signs of industrial emergence, such as Kenya's Solinc or Ethiopia's cell production facility, risk remaining isolated and economically vulnerable.

In short, regional specialization is not a static description of what countries already have, but a deliberate process of coordinating national efforts toward complementary roles in a shared industrial strategy. This requires strategic planning, institutional collaboration, and cross-border investment in both hardware (e.g., infrastructure) and software (e.g., regulation, skills). As Chapters 5.2 to 5.4 collectively argue, it is only through such proactive coordination that East Africa can move beyond its fragmented industrial base and establish a viable solar PV manufacturing value chain.

7.1.5 Addressing RQ5: How can China's solar PV industry development experience inform the establishment of a competitive and context-adapted regional value chain (RVC) for East Africa under current global market dynamics?

Chapter 6 explores this question by drawing on catch-up theory and policy transfer literature to analyze the extent to which China's trajectory in solar PV manufacturing offers relevant insights for East Africa. The analysis reveals both opportunities for selective policy learning and limits to applicability due to structural, institutional, and geopolitical differences.

In terms of broad relevance, China's rise as the global leader in solar PV manufacturing underscores the importance of long-term state coordination, sequenced industrial policy, investment in innovation systems, and strategic integration into global markets. Chapter 6.1 highlights how China leveraged its latecomer position by using policy tools such as feed-in tariffs, export credit, public procurement, and domestic content requirements—not all at once, but through phased layering of incentives that evolved alongside the industry's maturity.

However, Chapter 6.2 makes clear that direct replication of the Chinese model is neither feasible nor desirable in the East African context. The two regions differ substantially in terms of market scale, governance capacity, fiscal space, and central-local policy alignment. For example, East African countries lack China's large and unified domestic market, its centralized industrial planning apparatus, and its capacity for sustained public R&D financing. Furthermore, regional fragmentation makes it difficult to execute coordinated national champions or large-scale production mandates.

Despite these differences, Chapter 6.3 identifies several policy mechanisms that can be meaningfully adapted to support a regional PV manufacturing strategy in East Africa. These include:

- **Policy sequencing: Starting with supply-push tools** (e.g., targeted investment incentives, preferential loans for upstream projects), then gradually incorporating demand-pull mechanisms such as local content requirements or regional procurement schemes.
- **Cluster and zone-based development**: Leveraging existing industrial parks and SEZs to attract solar-specific manufacturing investment, particularly in Kenya and Ethiopia.
- **Standards and certification infrastructure**: Establishing regionally harmonized quality standards and testing facilities to reduce technology risk and transaction costs.
- **Skills and innovation platforms**: Building collaborative public–private–academic networks to address skill shortages and support applied R&D, especially in module design, inverter technology, and materials processing.
- **Performance-based investment facilitation**: Providing support to firms contingent on technology transfer, workforce localization, or participation in regional value chains.

Finally, Chapter 6.4 offers cautionary lessons from China's PV boom, including the dangers of overcapacity, weak environmental enforcement, and uncoordinated local subsidy competition. These experiences underscore the need for East African policymakers to pursue industrial development in a sustainable, regionally coordinated, and demand-sensitive manner, avoiding the pitfalls of fragmented expansion or subsidy-driven bubbles.

In conclusion, while East Africa cannot and should not seek to replicate China's exact path, China's experience offers a valuable repertoire of tools, sequencing logic, and institutional mechanisms that can be selectively adapted to local conditions. The key lies in integrating these lessons into a regionally embedded strategy—one that aligns with East Africa's political realities, market size, and institutional diversity, while remaining responsive to global market dynamics and technological change.

7.2 Policy recommendations

This thesis finds that while no single East African country possesses the full capabilities required for a complete solar PV manufacturing chain, a regionally coordinated approach—anchored in functional task-sharing and policy alignment—could enable the emergence of a viable Regional Value Chain. Drawing on the comparative analysis in Chapter 5 and the lessons from China discussed in Chapter 6, the following policy recommendations are proposed:

1. **Align National Industrial Strategies to Enable Regional Task Division**
   Governments in East Africa should identify and formally commit to complementary roles along the PV manufacturing chain, based on their existing resource endowments and capabilities. For example, countries with mineral processing capacity (e.g., Ethiopia, Tanzania) can focus on upstream segments, while those with stronger logistics and institutional readiness (e.g., Kenya, Rwanda) can take on downstream functions like module assembly and regional distribution.
2. **Institutionalize Cross-Border Coordination Mechanisms**
   The East African Community (EAC) and other regional bodies should establish dedicated coordination units to oversee industrial planning, monitor investment flows, and align policy instruments across member states. This could include joint feasibility assessments, synchronized investment promotion, and co-managed industrial parks serving multiple countries.
3. **Use Public Procurement and Regional Demand to Anchor Early-Stage Manufacturing**
   Public institutions—including utilities and rural electrification agencies—should design procurement schemes that prioritize regionally manufactured solar components, where

available. Such demand-side coordination can lower market uncertainty for early-stage manufacturers and justify domestic investment.

4. **Prioritize Infrastructure that Supports Cross-Border Production Networks**
   Targeted investment in regional transport corridors, power interconnections, and logistics platforms will be essential to enabling intra-regional trade in intermediate goods and materials. Special economic zones or industrial clusters with a regional mandate could serve as hubs for specific stages of the value chain.
5. **Invest in Workforce Development as a Strategic Long-Term Asset**
   East Africa's demographic profile gives it a potential labor advantage, especially in downstream manufacturing stages that remain labor-intensive. Regionally coordinated technical and vocational education programs can ensure that this advantage is translated into skilled, industry-ready workers.
6. **Apply Lessons from China through Contextualized Policy Design**
   Rather than replicating China's centralized industrial model, East African countries can learn from its strategic sequencing, coordinated infrastructure investment, and use of domestic demand to build manufacturing capabilities. However, such lessons must be adapted to the political and institutional realities of the region, emphasizing distributed governance and flexible cooperation.

7.3 Discussions

7.3.1 Main findings and scientific contributions

This thesis contributes to the broader literature on latecomer industrialization, green transition strategies, and regional development by demonstrating that the establishment of a solar PV manufacturing base in East Africa—though difficult at the national level—can become viable through strategic regional coordination, selective policy learning, and targeted integration into global value chains. The findings challenge the prevailing assumption that African economies can only participate in global clean energy transitions through raw material exports or end-user deployment, offering instead a pragmatic vision for value-creating regional industrialization.

From a theoretical standpoint, the study advances a multi-framework approach that integrates the Technological Innovation System (TIS) framework with Bamber et al.'s value chain competitiveness dimensions, developmental regionalism, and insights from catch-up and policy transfer theories. This composite lens allows for a more nuanced analysis of the barriers and pathways to green industrial development in structurally constrained regions. Whereas TIS highlights internal system failures, the value chain perspective surfaces exogenous structural constraints and interdependencies, while developmental regionalism adds the necessary political-economic layer for coordinated upgrading in fragmented regions.

Importantly, the thesis demonstrates that regional integration and industrial policy must be conceived together. Value chain development is not merely a function of private investment or technology transfer, but also of how state and regional institutions shape markets, build linkages, and guide the allocation of productive resources. The case of East Africa shows that industrial upgrading in the renewable energy sector will not emerge organically from solar deployment but must be actively organized—through aligned policy mandates, infrastructure co-investment, and inter-country coordination of specialized roles.

The findings also hold relevance for development partners and international organizations. Much of the donor discourse in Africa's energy sector remains focused on energy access and climate mitigation, often through market-based deployment models. While this has improved access metrics, it has not translated into industrial deepening or technological learning. Supporting regionally embedded industrial strategies—through concessional finance, capacity-building, and regulatory harmonization—could generate far greater developmental multipliers.

7.3.2 Can East Africa learn from China? Could Africa Compete with China in the PV Industry?

This study draws lessons from China's solar PV development, but it is important to recognize that China's success was shaped not only by policy and planning, but also by specific global and domestic conditions that may no longer exist today. China rose as a solar manufacturing leader during a time of rapidly growing global demand, rising concerns over climate change, and generous subsidies in key export markets like Europe. These unique external factors—combined with China's large domestic market and centralized governance—created a favorable window that may be difficult for others to replicate.

Despite this, East Africa can still learn selectively from China's experience. Instead of trying to copy China's entire model, East African countries should focus on adapting the strategic thinking behind it: long-term planning, strong public-private coordination, and using domestic demand to support local production.

When it comes to direct competition with China, it is unlikely that East Africa will match China's scale or cost in the upstream segments such as polysilicon or wafers. China's decades of investment, integrated supply chains, and deep industrial base give it a lasting advantage.

However, that does not mean East Africa has no space to develop. From the author's perspective, labor will be a key factor shaping future competitiveness. While China's labor force is shrinking and aging, East Africa has a young and growing population. In the long run, this could give the region an edge in labor-intensive stages of PV manufacturing, such as module assembly and system integration.

Although automation and robotics are developing fast in China, not all parts of PV production can be easily automated. The closer to the end of the value chain, the more flexibility, judgment, and human skills are needed. In these areas, human labor is still very important. If East African countries invest in technical training and skills development, they can take advantage of this opportunity—especially for serving regional markets where speed and service matter more than just price.

To be clear, this opportunity will not last forever. As automation becomes cheaper and more widespread, the labor advantage may weaken. That is why timing matters: East Africa needs to act quickly, and act together, to make use of this window.

Moreover, this window of opportunity may not be limited to the PV industry alone. Other manufacturing sectors that share similar features—such as relatively low capital intensity in the final production stage, high employment potential, and growing regional demand—may also benefit from the same strategy. These include sectors like battery assembly, electrical appliance manufacturing, or processing equipment. The key is to identify which stages of which industries align best with regional strengths, and to respond with tailored, practical strategies, rather than waiting for fully built global value chains to arrive.

In summary, East Africa cannot compete with China in its own game, but it can build its own position in the global solar industry—and possibly in other strategic sectors—by focusing on its strengths, especially labor and regional integration, and by learning strategically, not copying blindly.

7.3.3 Limitations of the research

This thesis also acknowledges several important limitations. First, the analysis relies heavily on secondary data sources and national-level policy documents, which, while useful for building a regional comparative overview, lack the granularity and first-hand insights that field-based interviews or stakeholder engagement could provide. As such, the findings may underrepresent political economy frictions, informal negotiation dynamics, and real-world implementation gaps that often shape industrial policymaking in practice.

Second, some of the statistical data—particularly those used in value chain mapping and infrastructure comparisons—are not fully up to date. While the study has made efforts to use the most recent and reliable sources available, data availability across countries and stages remains highly uneven. For certain indicators, the most cited reports remain from 2013–2016, which may no longer reflect current realities in rapidly changing sectors such as solar PV and energy access. This may affect the precision of country-level assessments and the validity of some policy inferences.

Third, although the study proposes a functional regional division of labor across different stages of the PV value chain, it does not include a formal economic or spatial model to test the cost-efficiency or trade feasibility of such a configuration. As a result, the proposed industrial vision remains largely qualitative and conceptual. Future research would benefit from techno-economic modeling or simulation-based validation of cross-border production scenarios under different energy prices, logistics costs, and market assumptions.

Finally, while the thesis introduces a multi-framework approach—combining Technological Innovation System (TIS), Global/Regional Value Chain (GVC/RVC), and elements of catch-up theory—it does not fully resolve the methodological tensions between these frameworks. Their analytical boundaries sometimes overlap, and their application across diverse East African contexts requires further theoretical refinement. In this sense, the current study represents a starting point for more integrated and methodologically coherent approaches to studying green industrialization in developing regions.

7.3.4 Future research directions

Future research could extend this study in several meaningful directions. First, firm-level studies—through interviews, surveys, or case analysis—could help clarify how actual business decisions respond to regional policy incentives, infrastructure gaps, and institutional constraints. Such micro-level data would complement this thesis's macro-regional perspective and provide grounded insights into the real drivers and barriers of industrial participation.

Second, the feasibility of proposed regional production configurations could be tested through spatial analysis or techno-economic modeling. Simulations incorporating variables such as trade costs, electricity prices, transport networks, and mineral processing efficiencies would help assess whether the envisioned regional division of labor is not only desirable but also economically viable under different scenarios.

Third, further engagement with regional institutions—such as the East African Community (EAC) Secretariat, Afreximbank, or the African Trade Observatory—could shed light on the actual institutional capacity, governance dynamics, and political commitment needed to implement coordinated industrial strategies. Understanding these institutional foundations is crucial for translating conceptual models into policy reality.

In addition to empirical and institutional extensions, future work may also build on the multi-framework approach proposed in this thesis. While this study combines perspectives from Technological Innovation Systems (TIS), Global and Regional Value Chains (GVC/RVC), and catch-up theory, further research could explore how these frameworks may be more formally integrated—for instance, through a unified analytical model or comparative case typologies. Doing so could help clarify their complementarities and address the analytical overlaps observed in this study.

Finally, the approach developed here may also be applied to other green manufacturing sectors that share similar characteristics with solar PV—such as battery assembly, electric mobility components, or low-voltage grid infrastructure. These adjacent sectors may offer additional opportunities for regional value chain development and technological upgrading in East Africa.

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Appendix A: Key Public Institutions Relevant to Solar PV Development in East Africa

Country	Relevant Institutions	Role in PV Manufacturing	Website
Kenya	Ministry of Investments, Trade and Industry (MITI)	Industrial policy and SEZ planning	https://www.industrialization.go.ke
	Kenya Investment Authority (KenInvest)	Promotion of renewable energy investment	https://www.invest.go.ke
	Rural Electrification and Renewable Energy Corporation (REREC)	Procurement and technical standards	https://www.rerec.co.ke
Ethiopia	Ministry of Industry (MoI)	Strategic promotion of solar equipment manufacturing	https://moi.gov.et
	Ethiopian Investment Commission (EIC)	FDI attraction in renewable energy	https://www.investethiopia.gov.et
	Ethiopian Electric Power (EEP)	Coordinates generation-side projects	http://www.eep.gov.et
Rwanda	Rwanda Development Board (RDB)	SEZ and solar manufacturing promotion	https://www.rdb.rw
	Ministry of Infrastructure (MININFRA)	Oversees national energy strategy	https://www.mininfra.gov.rw
Uganda	Ministry of Energy and Mineral Development (MEMD)	Energy policy including off-grid solar	https://memd.go.ug/
	Uganda Investment Authority (UIA)	Industrial zone development, solar FDI support	https://www.ebiz.go.ug/
Tanzania	Ministry of Industry and Trade	National industrialization strategy	https://www.mit.go.tz
	Tanzania Investment Centre (TIC)	Promotes clean energy industrial investment	https://www.tic.go.tz
	Rural Energy Agency (REA)	Administers solar mini-grid procurement	https://www.rea.go.tz
Burundi	Ministry of Hydraulics, Energy and Mines	Oversees energy programs including solar	*(No functioning website)*[1]

[1] Source of information: Lighting Global (2020), *Burundi Market Assessment for Off-Grid Solar and Improved Cooking Technologies for Households*, https://www.lightingglobal.org/wp-content/uploads/2020/07/Burundi-off-grid-market-energy-assessment-EN.pdf

	Agence Burundaise d’Électrification Rurale (ABER)	Rural electrification implementation	*(No functioning website)*[2]
South Sudan	Ministry of Energy and Dams	Early-stage policy development	*(No verified website)*[3]
Somalia	Ministry of Energy and Water Resources	Post-conflict energy sector recovery	https://moewr.gov.so
Djibouti	Ministry of Energy and Natural Resources	RE-focused energy planning	https://www.mern.dj/
Eritrea	Ministry of Energy and Mines	Oversees AfDB-funded solar initiatives	*(Limited online presence)*[4]
Comoros	Ministry of Energy, Water and Hydrocarbons	Partner in solar + storage projects	*(No verified website)*[5]
Seychelles	Ministry of Agriculture, Climate Change, and Environment	Oversees solar hybrid and RE strategy	https://macce.gov.sc/

[2] Source of information: GET.invest (2023), *Burundi: Small Hydropower and Rural Development*, https://www.get-invest.eu/wp-content/uploads/2023/10/GET.invest-Market-Insights_Burundi_Developer-Guide_Sept-2023.pdf

[3] Source of information: Gender-Based Violence Assessment: South Sudan Energy Sector Access and Institutional Strengthening Project (P178891, 2023). https://www.mofp.gov.ss/doc/Gender-BasedViolenceGBVAssessmentSouthSudanEnergySectorAccessandInstitutionalStrengtheningProjectP178891.pdf

[4] Source of information: https://www.afdb.org/en/documents/eritrea-dekemhare-30-mw-solar-pv-grid-connected-project-ipr-november-2024

[5] Source of information: World Bank. (2022). *Comoros Solar Energy Access Project (Project Appraisal Document No. P-COM-005).* https://documents1.worldbank.org/curated/en/975231653594135953/pdf/Comoros-Solar-Energy-Access-Project.pdf