For decades, location strategy was like playing chess: location decisions were based on financial and qualitative considerations in a relatively unrestricted way. When investigating where to best expand their geographic footprint, companies selected those destinations that offered the greatest value proposition for a specific business function—for example, their manufacturing operations, the regional corporate headquarters, or a software development hub. Technology and global trade agreements had enabled organisations to optimally locate each supply chain component where they would find the best mix of a high-caliber business environment—offering a broad pool of the required skill sets and expertise, suitable suppliers, strong transport connections, market access, etc.—while optimising their return on investment, in terms of input materials, labour, real estate, transportation, taxes and utilities [1].

In March 2020, however, COVID-19 shook up our globally interconnected marketplace: transportation halted, businesses closed, workers were sent home and supply chains were interrupted. The worldwide economy stalled. In addition to the pandemic, various other global events and uncertainties continue to impact business conditions, and a diverse set of technologies and innovations are transforming industries and global value chains at an unprecedented rate. Examples alongside pandemic risks and technological advancements, including AI and automation, also cover a wide spectrum of dynamics, such as climate change, scarcity of natural resources and materials, trade-related policy changes, the expectations of the next-gen workforce, competition for skills, and more. In combination, all these dynamics have significant implications on how and where value is created. It is also changing why, how and where companies are planning their investments and requires them to anticipate risks and build more resiliency into

Abstract
The COVID-19 pandemic and a subsequent string of global political and economic crises have forced companies to reassess how they operate in the face of constantly shifting policy and supply chain dynamics. This article explores how the PV industry can make informed decisions on choosing the best locations to base manufacturing operations in a world characterised by unpredictability.
their supply chain and operations. In this context, location strategies have become considerably more complex.

In response to these dynamics, and further accelerated by the global political and economic turmoil, companies need to clearly articulate how they want to position themselves in a global business climate characterised by increased volatility that is causing significant shifts in growth prospects and operating conditions within and across regions. The response of these companies requires a comprehensive review of their entire supply chain, from planning and sourcing all the way to making and delivering, aimed at building resiliency to address these ever-changing demand patterns and operating conditions. More concretely, these reviews are resulting in a restructuring of global production and distribution networks, with companies setting up new facilities or relocating existing capacity to meet future needs.

As such, we are witnessing a reconfiguration of global corporate activity across multiple manufacturing industries, as companies are seeking alternatives to some of the world’s traditional hotspots for production and assembly. More specifically, companies are particularly reducing their dependency on China as a global factory and export hub. This trend was initiated years ago as the country’s cost competitiveness started eroding and skill shortages emerged, but it has dramatically accelerated since the pandemic. This shift is clearly confirmed by recent foreign direct investment (FDI) trends, as illustrated in Figure 1.

While evaluating these trends, it is important to understand that the changes to a specific manufacturing footprint in response to modifications in operating conditions across the world do not automatically translate into a standard and uniform approach on how to best organise global production, such as purely through near- or re-shoring, or by standalone location decision-making focused exclusively on market access or resilience.

Rather, the corporate response to such changing circumstances not only depends on the specific requirements and strategic drivers of any particular production facility but should also assess how it fits within the wider supply chain and its associated competitiveness. When deciding on how to best respond to constantly evolving business conditions, companies must weigh a broad spectrum of qualitative operational considerations and cost parameters. This will in turn result in more complex networks of global value chains, with production activities likely to be more scattered across a range of geographies.

Of course, the interesting question now is: how does the above context impact investment patterns in the solar industry? While there has been a lot of focus on re-/near-/on-shoring as well as decoupling—from a China-dominant manufacturing base—in PV manufacturing, it is interesting to ascertain how the perceived changes in the operating environment are altering companies’ location decisions and, as a consequence, the global investment scene in the solar manufacturing industry.

![Figure 2. Historic investment trend in solar PV manufacturing by number of FDI projects globally (index, with 100 = average across the 12 years) [4].](image)
When looking at data on internationally mobile investment projects in the context of solar PV manufacturing globally, the graph in Figure 2 shows a rather volatile trend over 12 years and a significant and ongoing boost in investment activity since 2022. This upward trajectory is a clear indication of increased dynamism in the industry, potentially in response to changes in operating conditions.

When zooming in on the prime beneficiaries of newly created manufacturing jobs in solar PV, the USA managed to attract half the employment recently generated globally through foreign investment in the industry, with Vietnam, India and Malaysia jointly accounting for another third (Figure 3). Further on in this article, we will explore potential drivers contributing to these strong concentrations of FDI.

A closer look at the investment data over a longer timeframe emphasises the recent successes of the US in securing solar PV investment and, while doing so, in forming a major driving force behind the substantial global growth of FDI in the industry (Figure 4). The analysis also confirms the continued strength of Southeast Asia as a manufacturing hub for solar PV, albeit with a shift from Malaysia to Vietnam.

Notwithstanding the continued dominance and benefits of China in terms of its PV manufacturing capacity, the FDI trends suggest a switch in investment strategies that is especially favoring the US as the prime market, in addition to existing strong destination countries including Vietnam, India and Malaysia.

To further investigate the rationale behind these recent geographic shifts in investment flows, it is relevant to understand the typical steps companies follow in their decision-making process to select a preferred and final location for their greenfield or expansion project, as shown below.

In this stepwise approach, a footprint strategy or a site-selection process always starts with an in-depth understanding of the investor company’s strategic
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Scope, its critical drivers and the main operational requirements for the planned facility. These specifications can be translated into (i) assumptions that constitute the operational cost structure, which influences the profitability of the future investment project, on the one hand, and (ii) location decision-making factors that will be prioritised to evaluate the suitability and associated risk of the future operating environment in the location candidates under consideration, on the other hand.

Specifically for solar PV manufacturing facilities, key metrics to assess expected return on investment of a future facility in possible location options include building and equipment CAPEX, components costs, fully loaded labour costs, electricity charges, transportation fees, import duties in destination markets, corporate taxation and the impact of potential cash grants or tax incentives.

Most of the essential location-assessment criteria to measure the suitability of the operating environment for a solar PV manufacturing facility are focused on local market potential and access to export markets, availability of and access to main components, presence and scalability of relevant skills, multimodal transport connections, and permitting regulations. Recently, in light of the growing sustainability agenda, increased emphasis is also placed on access to renewable energy sources.

Once the project scope and most-critical must-haves have been defined, they are used to screen a long-list of multiple candidates with the aim to rapidly filter down to a subset of best-suited locations that are worth investigating further, based on their integrated cost/profitability performance and their fit with the qualitative requirements. The outcomes of such analysis can be visualised in a so-called cost-quality map, which will often show a trade-off between financial factors (on the horizontal axis) and suitability of the operating environment (on the vertical axis).

Depending on a company’s strategic drivers, the optimal choices based on this two-dimensional evaluation may concentrate on high-caliber solutions (i.e., high quality)—for example, when topics such as innovation, low risk or resilience are most critical. Similarly, for other projects, saving potential may be the primary focus, hence prioritising the most cost-competitive candidates. Ideally, the best solutions combine an attractive business environment at an interesting cost level.
The short-list of locations selected on the basis of such high-level assessment can then be assessed in more detail to further validate the dynamics in the locations’ labour market, transportation networks they provide, local presence of potential partners or suppliers, industrial sites that can accommodate the plant specifics, governmental support and incentives that may be granted to the project, etc., as input for a solid decision on the final location and preferred site to establish the operations.

When we now apply the analytical approach, as outlined above, to quickly screen a long list of location candidates for a sample of options that would typically be considered for a solar PV manufacturing facility serving the US market, it is interesting to observe how this supports the recent shift in investment flows that we highlighted previously.

We have represented below the cost-quality proposition of various location options for a US-serving solar PV plant, comparing their performance pre- and post-pandemic, as a means to illustrate the implications of recent (post-pandemic) policy changes with respect to the introduction of the Inflation Reduction Act (IRA) as well as the revision of the list of countries falling under the safeguarding import tariff regime.

While the charts in Figure 7 refer to countries, the analysis is typically performed at the level of realistic labour-drawing areas. This means that for each country plotted on the map, the analytical focus is on those regions with most relevant strengths for solar PV manufacturing in terms of their supplier base, labour pool, cluster presence and market access. As such, key reference areas in the US, for instance, could include Texas, Arizona or Georgia.

It is evident that prior to the pandemic, Southeast Asian (SEA) countries offered a strong value proposition to existing and new PV plants based on their competitive cost profile coupled with a reasonable quality level. This explains why Malaysia, Vietnam and Thailand are the main import sources for PV modules into the US [2]. It is interesting to note that China-based operations serving the US, while benefiting from a well-developed operating environment for PV manufacturing, at the same time are suffering from low profitability levels, which is exclusively driven by the anti-dumping and countervailing duties on direct imports from China.

Post-pandemic, due to the impact of IRA incentives and safeguarding duties applied on a different range of countries, operating US-based facilities has clearly become considerably more attractive, which nicely underscores why companies are choosing to invest in the US to serve the domestic market. In addition, the cost-quality evaluation also illustrates that appealing new options are emerging, such as Morocco, which...
offers a highly competitive financial profile, albeit at weaker overall operating quality.

Simulating a similar assessment for the EU market reveals a very different situation (Figure 8). In this context, without anti-dumping duties in place, the strengths of China-based manufacturing operations remain obvious, which justifies why the country accounts for more than 90% of PV-module imports into the EU [3].

In the EU, the main post-pandemic change can be attributed to the EU Green Deal, allowing for a more lenient approach to state aid. This creates the potential for Central and Eastern European countries (such as Poland in our example) to substantially improve their financial proposition and compete with China. While still lagging behind this global PV giant in terms of its skill pool and supplier base, such location options can become interesting alternatives to China-based facilities given the cost sensitivity of PV-module procurement, in combination with the increased importance attached to decoupling and strategic independence (China plus X approach). In Germany, operational strengths are clearly on a par with those of a plant serving the EU market from China, but cost levels remain substantial despite the impact of state aid for renewable energy manufacturing projects.

Overall, financial support in itself may not be sufficient to close the competitiveness gap with China-based manufacturing operations. To further increase the potential for European locations to successfully attract solar PV manufacturers, it will
therefore be essential to expand the region’s local supply base, develop the required skill sets, support local-for-local procurement and boost innovation, both at product level and certainly also at the manufacturing process level through automation.

In summary, the US, the EU and China all adopt distinct approaches to their respective solar PV manufacturing industry development, which can greatly affect location decisions in this segment. Extensive support measures in the US are definitely generating a lot of investment activity and associated jobs in the short to medium term, while at the same time building increased resilience in supply and strategic independence for this key product. The favorable impact these incentives have on the cost-quality trade-off offered by US-based options versus their international competitors clearly supports such on-shoring decisions. However, in the longer run, this trend may also contribute to higher domestic installation costs, which could slow down the energy transition, and may lead to global manufacturing overcapacity and associated risks for the players involved, especially in a rapidly evolving policy environment.
Thus far, the EU approach has not yet translated into a major re- or on-shoring investment trend, and in the absence of further policy changes this is unlikely to occur any time soon. This context could mainly enable a faster and more cost-effective energy transition while opening the door for funding to be focused primarily on product and process innovation, the development of a supplier base for raw materials and components, and as mechanisms for the recycling of decommissioned installations. This in turn may contribute to the growth of a sustainable local solar manufacturing base.

Time will tell which approach is most appropriate to address the various strategic objectives at play. From a corporate perspective, consistently monitoring dynamics and risks—whether technological, political, economic, societal, environmental, or a combination of these—as input for a constant rebalancing act of capabilities and capacities will allow companies to continue to thrive in this diverse and complex global policy and business environment, and to successfully navigate the future.

References

About IBM-Plant Location International

IBM-Plant Location International (PLI) is a global service of IBM Consulting, specialising in corporate location and economic development strategies. With a global center of excellence in Brussels, Belgium, IBM-PLI provides footprint strategy and location selection services to corporate clients, analyzing international business locations to help expanding or consolidating companies define their optimal global footprint. IBM-PLI also advises economic development organisations on improving their areas’ competitiveness through dedicated policy measures, as well as on strategic marketing by developing value propositions and marketing tools.

IBM-PLI’s Global Location Trends database
Since 2002, IBM-PLI has been developing its Global Location Trends database as a leading corporate investment tracking database, registering mobile investment projects around the world on an ongoing basis to enable representative and up-to-date location trend analysis on various geographic scales. Corporate executives use the Global Location Trends database to monitor where peer companies are planning operations and which locations are being selected for specific functions, enabling more informed strategic decisions on whether these locations should be considered for their own projects. As we are constantly evaluating further improvements to our database, we have recently entered into a multi-year collaboration initiative with Bureau van Dijk, a Moody’s Analytics company.

About the Authors
Koen Gijpers, Managing Consultant with IBM-PLI, has 15+ years of cross-functional experience in regional economic development and inward investment strategies and research, along with location, footprint and supply chain strategy and feasibility studies. His project work includes scenario building and assessment, business-case development, operational environment analysis, trend and risk assessment, competitive analysis and strategy formulation. He is an established contributor to IBM’s annual Global Location Trends report.

Patsy Van Hove, Global Leader of IBM-PLI, with 25+ years of experience in location advisory services, has been involved in a wide range of strategic location studies for major international clients, assessing locations worldwide. She has gained extensive expertise in advising corporate clients on where to establish manufacturing facilities around the world, helping clients prepare for the future in an ever-evolving world and in disruptive operating environments.

Enquiries
Plant Location International (PLI)
IBM Consulting
Visit us on the web at
https://www.ibm.com/consulting/pli

Patsy Van Hove – Global Leader
Patsy.Van.Hove@be.ibm.com

Koen Gijpers – Managing Consultant
Koen.Gijpers@be.ibm.com