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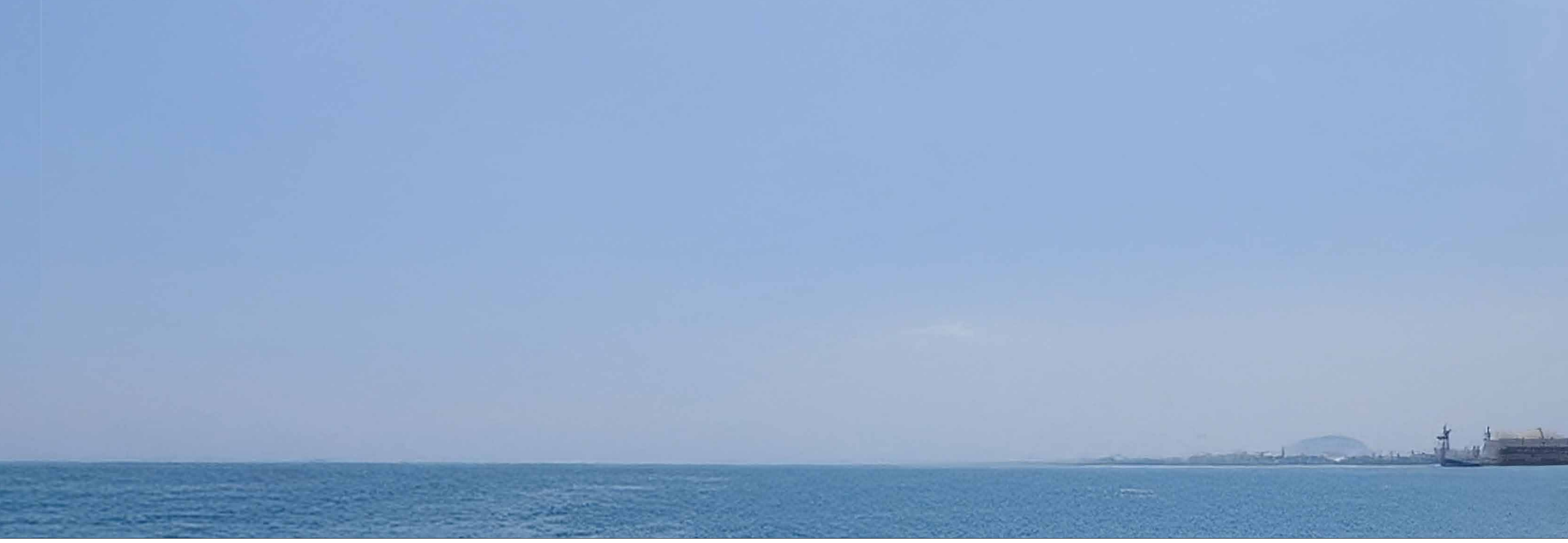
REPORT

Technical potential assessment of renewable energy projects developed in China's overseas industrial parks

Jing Song, Hong Miao, Yuchen Guo, Zhiqing Wen, Xiaofeng Ye, and Sihan Pan



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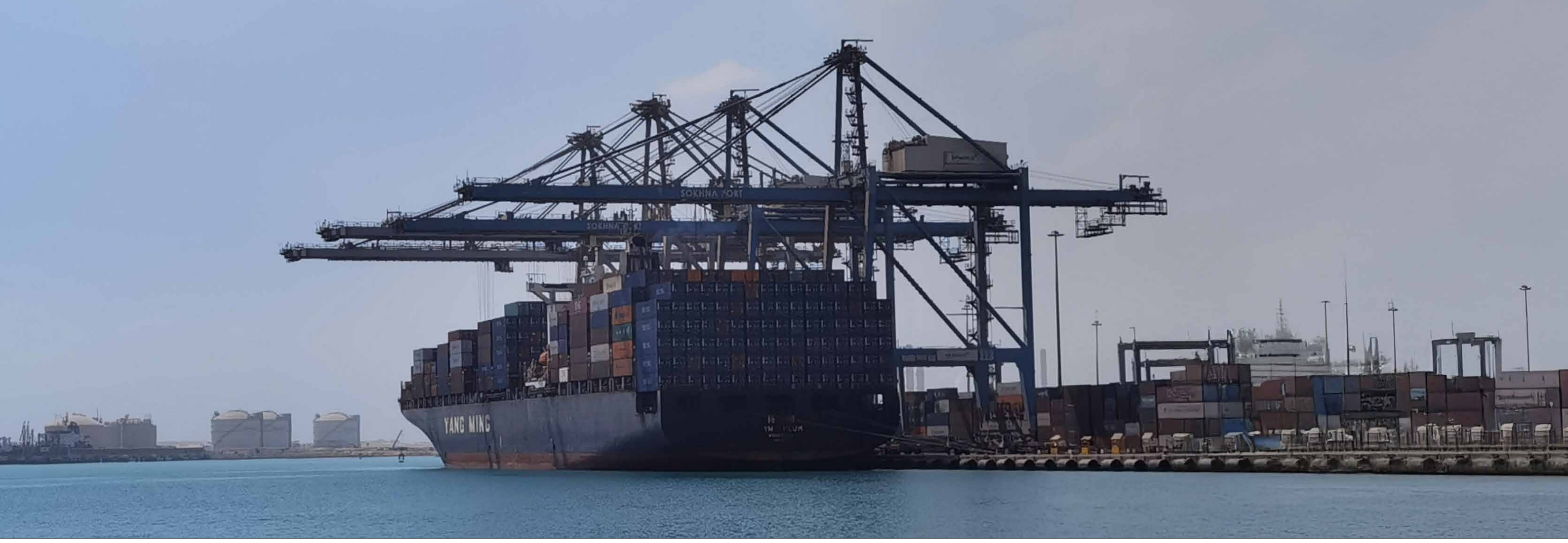

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Executive summary

Industrial parks are flourishing globally and are mostly equipped with a shareable energy infrastructure, which has a long service lifetime and thus locks in greenhouse gas (GHG) emissions. More importantly, such infrastructure plays a critical role in advancing energy transition efforts at both national and international levels. By 2050, fully harnessing the potential of solar and wind energy in China's overseas industrial parks could account for approximately 2% of the global renewable energy capacity required to achieve net-zero emissions. Accelerating this development by 2030 could raise this contribution to nearly 5%. Realizing this potential will require enhanced, science-based coordination and cooperation among all relevant stakeholders.

HIGHLIGHTS

- This report establishes a database of China's overseas industrial parks (hereinafter referred to as "COIPs") based on Geographical Information System (GIS) technology and scientifically evaluates the market size and technical potential of applying different renewable energy solutions within these parks. This research supports the formulation of policy and business decisions and helps quantify the scale of China's overseas green investments and their significance for the host countries' energy transitions.
- The database of China's overseas industrial parks (COIPD) includes 159 overseas parks. Nearly half of COIPs are located in Asia, while the COIPs in Africa and Europe make up the other half. Multifunctional integrated parks and agro-industrial parks constitute the majority of all COIPs.
- There is substantial technological potential and investment prospect for renewable energy (RE) projects developed in COIPs. The maximum installed capacity for photovoltaic (PV) solar projects can reach 419.66 GW, while it can reach 116.48 GW for wind power projects, bringing around CNY 2.064 billion of investment (in future-completion scenario).
- There are variations in the technological potential for developing RE projects in different types of COIPs. The technological potential for developing RE projects of COIPs in Asia and Africa stands out prominently.
- By 2050, if the PV systems (in future-completion scenario) and wind power systems in COIPs are fully developed, they will contribute approximately 2% towards RE installed capacity target of global net-zero emission. If the development timeline is moved up to before 2030, this contribution rate will reach nearly 5%.
- Establishing a multiple-stakeholder partnership with policymakers, business investors, industrial park operators and financial institutions is crucial for fully unlocking the RE technological potential of COIPs.

ABOUT THIS REPORT

China's overseas industrial parks (COIP) serve as a vital platform for promoting international capacities cooperation and innovative forms of outward investment. The decarbonization of COIPs also plays a significant role in facilitating global low-carbon transformation and sustainable development. As milestone policy documents, the "14th Five-Year Plan for Business Development" and the "Guidelines for Green Development in Overseas Investment and Cooperation" release the signal of guiding and directing the decarbonization efforts within these parks. Based on the working paper—*Evaluating Chinese Overseas Industrial Parks by Applying Low-carbon Development Indicator System*, World Resources Institute is conducting the research focused on "the scale of low-carbon development technological potential in COIPs", which aims to provide policymakers, COIP developers, RE project investors, financial institutions, and other stakeholders with a comprehensive landscape of RE development in COIPs. This research will encompass different countries and types of COIPs, offering preliminary insights for future policy and investment decision-making.

China is the world's largest manufacturer of RE equipment, possessing a strong market space and technological foundation for developing RE projects. This provides a technological advantage for the development of RE in COIPs. In addition, most COIPs are located in regions abundant in solar and wind energy resources, adding a resource advantage to the development of RE in these parks. There is tremendous technological potential for the development and application of RE in COIPs. However, to fully unlock and harness these potentials requires multiparty collaboration among stakeholders.

This report focuses on the issue of "analyzing the low-carbon development potential and scale of China's overseas industrial parks from a technical perspective." As China's investment in renewable energy projects in these overseas parks is still in its early stages, there is a lack of mature experience, and relevant decision-makers and stakeholders generally have a limited understanding of this market sector. This has led to many industry players, including renewable energy investors, overlooking the concentrated and large-scale application market that these overseas parks represent. Meanwhile, the limited understanding of the overall scale and current development status of these parks poses significant challenges for formulating targeted overseas green investment policies. It is essential to provide policymakers, industrial park developers and tenants, renewable energy project investors, and financial institutions with a scientific overview of this scale from an overall perspective, as it will serve as a fundamental reference for future micro-level investment decisions. This research comprehensively reviews the status quo of all COIPs established between 1992 and 2022, which were still operational as of the end of 2022. Based on this, a China's overseas industrial park database (COIPD) is established. These COIPs are distributed in 54 countries across six continents worldwide, covering a total area of approximately 6,772 square kilometers, and the total investment amounts to 652.3 billion CNY.

COIPs are classified into national-level COIPs, provincial-level COIPs, and other parks. They could also be categorized based on their 6 types, including processing and manufacturing parks, resource utilization parks, agro-industrial parks, trade and logistics parks, technology research and development parks, and multifunctional integrated parks.

In order to better differentiate the application characteristics and potential of various RE technologies in different types of parks, this research also categorizes COIPs into two major groups based on their land use types. The first category is the industrial and commercial parks, which include processing and manufacturing parks, resource utilization parks, trade and logistics parks, technology research and development parks, and multifunctional integrated parks that have a large number of industrial and commercial facilities. The second category is agricultural parks, which have a significant amount of arable land for cultivation.

- **Nearly half of COIPs are located in Asia, while the parks in Africa and Europe make up the other half.**

  The COIPD established in this research covers a total of 159 COIPs that were established between 1992 and 2022 and were still operational as of the end of 2022. Among them, there are 71 parks located in Asia, accounting for nearly half (45%) of the total. There are 44 parks located in Africa and 39 parks located in Europe.

- **Multifunctional integrated parks and agro-industrial parks constitute the majority of all COIPs.**

  According to the types of COIPs, there are 59 multi-functional integrated parks, 44 agro-industrial parks, 22 processing and manufacturing parks, and 15 resource utilization parks. Among these parks, the highest number is in the multifunctional integrated parks and agro-industrial development parks, accounting for 37% and 28% respectively.

- **There is substantial technical potential and investment prospect for RE projects developed in COIPs.** The maximum installed capacity for PV solar projects can reach 419.66 GW--the equivalent of 7.51 times the new PV installed capacity added by the EU in 2023, while the maximum installed capacity for wind power can reach 116.48 GW (in future-completion scenario)-- the equivalent of 7.19 times the new wind power installed capacity added by the EU in 2023. Specifically, the annual PV power generation in COIPs (industrial and commercial parks) is approximately 222,700 GWh, with a PV installed capacity of approximately 147.7 GW. In agro-industrial parks, the annual PV power generation is estimated to be around 371,800 GWh, with a PV installed capacity of approximately 271.96GW. The estimated annual wind power generation in COIPs ranges from 46,300 GWh to 112,000 GWh, with a wind power installed capacity of approximately 22.74 GW to 116.48 GW. Developing RE projects in COIPs could attract an investment of approximately CNY 2.064 billion. Under future completion scenario, the development of PV projects is expected to drive around CNY 552 million in investment. Ground PV projects in agricultural parks are anticipated to generate about CNY 1.129 billion in investment. Wind power projects in COIPs are expected to attract approximately CNY 383 million in investment.

- **There are variations in the technical potential for developing RE projects in different types of COIPs. In terms of geographical regions, the technical potential for developing RE projects of COIPs in Asia and Africa stands out prominently.**

  Among the various types of COIPs, multifunctional integrated parks have the greatest PV development potential, while agro-industrial parks have the greatest wind power development potential. Both industrial and commercial parks and agricultural parks have the greatest PV development potential in Southeast Asia. In terms of wind energy, COIPs located in the Nordic-Asian region have the greatest wind power development potential, followed by COIPs in Southeast Asia and Africa.

- **The emission reduction effects of RE projects in COIPs strongly highlight China's contribution to global efforts in combating climate change.**

  The direct installation of rooftop PV systems, ground PV systems, and wind power systems in COIPs will result in significant emission reductions. This not only helps the host countries achieve their climate change mitigation and RE development goals but also reflects China's substantial contribution to global emission reductions, considering its prominent role in international trade and investment. Developing RE projects in COIPs supports the global net-zero emission target. By 2050, if the PV systems in industrial, commercial, and agricultural parks, as well as wind power systems in these parks, are fully developed (under future completion scenario), they will contribute approximately 2% towards RE installed capacity target of global net-zero emission. If the development timeline is moved up to before 2030, this contribution rate will reach nearly 5%.

RESEARCH METHOD

Besides qualitative research methods such as literature review, case studies, and comparative analysis applied across the whole report, this research employs quantitative evaluation methods that cover three specific aspects. First is the development method of COIPD. Based on organizing and verifying existing relevant datasets of China's overseas industrial parks, a comprehensive collection and integration of information on the names and various types of overseas industrial parks were conducted using web and media-based data scraping methods, supplemented by manual cross-validation. The development potential of RE technologies is analyzed through two dimensions: power generation and installed capacity. Furthermore, separate assessments and analyses were conducted for the PV development potential and wind energy development potential of overseas industrial parks. The assessment method for PV development potential primarily utilizes geographic information system (GIS)-based methods to separately evaluate the industrial and commercial parks and agricultural parks in COIPs. Scenario analysis is employed to classify, assess, and analyze the evaluation results. The assessment method for wind power development potential uses direct calculation based on wind energy parameters and global valuation methods to estimate wind power generation and installed capacity. In the assessment of wind power generation, different scenarios of wind turbine placement are also discussed to analyze the range of power generation. The meso-level analysis of RE technology development potential in COIPs is conducted in this research, which is not suitable for application in economic performance and profitability studies of micro-level projects in individual parks.

DATA SOURCE

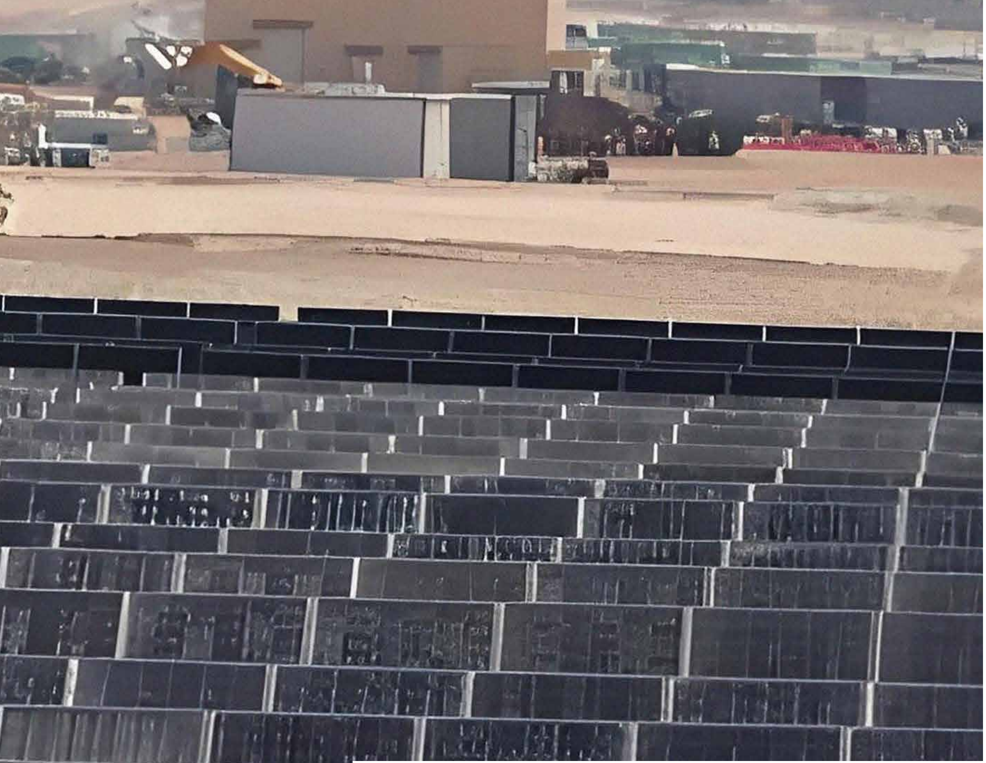
The data and information for the COIPD are sourced from public channels, primarily including the official website of the Ministry of Commerce of China, official websites of various industrial parks, the China Council for the Promotion of International Trade, the All-China Federation of Industry and Commerce, and relevant media sources. Solar radiation data for COIPs is obtained from the Global Solar Atlas photovoltaic system online platform. Wind-related parameters for COIPs are sourced from the Global Wind Atlas wind energy system online platform.

RECOMMENDATIONS

For policymakers, it is recommended to issue clear guidelines and regulations for the construction of green COIPs, set up an official platform for standardized development on COIPs to promote low-carbon COIPs, establish innovative assessment, evaluation and incentive mechanisms for low-carbon development in COIPs, pilot leading COIPs to practice low carbon projects, and integrate existing bilateral and multilateral international cooperation mechanisms to facilitate the alignment and implementation of RE projects in COIPs.

For business investors/COIP operators, it is recommended to develop coordinated plans for power supply and energy systems of COIPs, including RE solutions, and timely update low-carbon plans based on the utilization of RE resources in the regions parks located, explore sustainable business cooperation and profit models by integrating various stakeholders, such as park development enterprises, tenant enterprises, and RE project investment enterprises, considering market factors and the RE potential of COIPs, explore the possibility of achieving emission reduction benefits through international and regional carbon market mechanisms, effectively recovering the initial costs of RE project development and investment, utilize key regions' COIPs layout to promote RE international capacity investment cooperation and green industries.

For financial institutions, it is recommended to supply financing support for low-carbon demonstration pilot projects in regions where key COIPs are located, establish a project pipeline pool for low-carbon investment and financing in COIPs, and create financing products and portfolios specifically for low-carbon projects in COIPs.



CHAPTER 1.

Renewable energy investment in China's overseas industrial parks and global climate goals

Investing in renewable energy projects within industrial parks holds significant potential, and effectively unlocking this potential is of critical importance. Mapping this potential across geographical and sectoral dimensions can provide a data-driven and scientifically grounded framework to inform and guide investment-related decision-making for a wide range of stakeholders.

China is presented with significant opportunities for overseas renewable energy (RE) investment. The global RE market shows great potential, especially as climate change becomes a more pressing issue worldwide. Over the past decades, the RE industry has seen impressive growth—technology keeps improving, costs are falling, and both installed capacity and annual power generation reach record levels.

The numbers tell a compelling story. Between 2010 and 2021, the global levelized cost of energy (LCOE) of newly commissioned utility-scale solar PV projects dropped by 88% (IRENA 2022). In 2021, annual renewable capacity additions grew 6% to a record high of almost 295 gigawatts (GW) (IEA 2022); and power generation increased 8% to 8,300 terawatt-hours (TWh), the fastest annual growth since the 1970s (Mastoi et al. 2022). The goal of tripling installed capacity of global RE by 2030 (IRENA 2024) offers greater opportunities for China, which holds an 80% share of the global solar photovoltaic (PV) product market.

The Chinese government has introduced supportive policies to encourage companies to invest in RE overseas. These include a series of guidance documents addressing financial services, information provision, risk mitigation, and operational management. The 14th Five-Year Plan for Commerce Development released by the Ministry of Commerce of the People's Republic of China (MOFCOM) in 2021, along with the Green Development Guidelines for Overseas Investment and Cooperation by MOFCOM and the Ministry of Ecology and Environment in the same year, serve as landmark policy documents, sending positive signals of China's support for low-carbon development in its overseas industrial parks (Song et al. 2022).

China's overseas industrial parks (COIPs) serve dual purposes. They act as key demonstration sites for overseas RE investment and provide practical settings for coordinating and integrating RE production capacity. The scale of these COIPs is significant, with a total investment of CNY 652.3 billion (US$89.7 billion) in 54 countries across six continents, meaning nearly 30% of countries worldwide host COIPs. In total, these parks cover an area of 6,772 square kilometers (km2), which is 2.6 times the size of Luxembourg. Further details on methodology and data sources can be found in "Identifying land use types and evaluating solar and wind potential through spatial remote sensing technology and modeling."

However, both policymakers and COIP developers require more specific information on the potential of RE. Studies by World Resources Institute, including the working

TABLE 1 | Existing datasets of China's overseas industrial parks (COIPs)

DATASET	STATISTICAL ENTITY	TIME	NUMBER	INFORMATION
China's major overseas ETCZs	China Council for the Promotion of International Trade https://oip.ccpit.org	As of 2018	103	▪ Name of ETCZ ▪ Host country ▪ Managing company ▪ Location of managing company
COIPs datasets	Humei Li and others (Li et al. 2019)	1992–2018	182	▪ Type of COIP ▪ Whether COIP host country has joined the AIIB ▪ Time of joining the AIIB ▪ Continent/region/country where the COIP is located ▪ Development level of the host country ▪ Name of COIP ▪ Managing company ▪ Type of managing company ▪ Company identification code ▪ Starting year of COIP construction
Appendix: China-built industry parks in BRI countries	Low-carbon and environmental assessment for China-built industry parks in BRI countries (Energy Foundation 2020)	As of the end of 2018	160+	▪ Name of COIP ▪ Country where the COIP is located ▪ Starting year of COIP construction ▪ Predominant industries in COIP

Notes: ETCZs = economic and trade cooperation zones. COIPs = China's overseas industrial parks. BRI = Belt and Road Initiative. AIIB = Asian Infrastructure Investment Bank.

paper "Evaluating Chinese Overseas Industrial Parks by Applying Low-Carbon Development Indicator System," have identified several key challenges. These include limited understanding of the low-carbon development, the absence of a unified database, and an urgent need for improved planning capabilities. Existing studies have not conducted a systematic assessment of low-carbon development in COIPs from the perspective of technical potential of renewables. Statistical data on COIPs is sparse, lacking verification or systematic review. The available information is mostly found in basic summary lists (see Table 1). Furthermore, current datasets on COIPs fail to include critical details, such as investment scale and operational status.

This underscores the need for a comprehensive database that reflects the current state of COIPs, ensures data accuracy through verification, and supports analysis of RE investment potential and further studies.

This report aims to address three key questions:

- What is the current status of COIPs in terms of their number, area, and land use types?
- What is the technical potential for solar PV projects in COIPs?
- What is the technical potential for wind power projects in COIPs?

COIPs in this report refer to the overseas economic and trade cooperation zones (ETCZs) established by China. The report focuses on two major RE technologies, solar PV and wind power, assessing their potential in terms of installed capacity and power generation. These factors serve as primary indicators of low-carbon development potential within COIPs. Other types of RE technologies are not included in this report.

The report categorizes COIPs into two main groups based on their land use types. The first category is the industrial and commercial parks, which include processing and manufacturing parks, resource utilization parks, trade and logistics parks, technology research and development (R&D) parks, and multifunctional integrated parks. All of them feature substantial industrial and commercial facilities. The second category is agro-industrial parks, which are characterized by extensive land dedicated to cultivation.

This report holds varying levels of significance for different stakeholders:

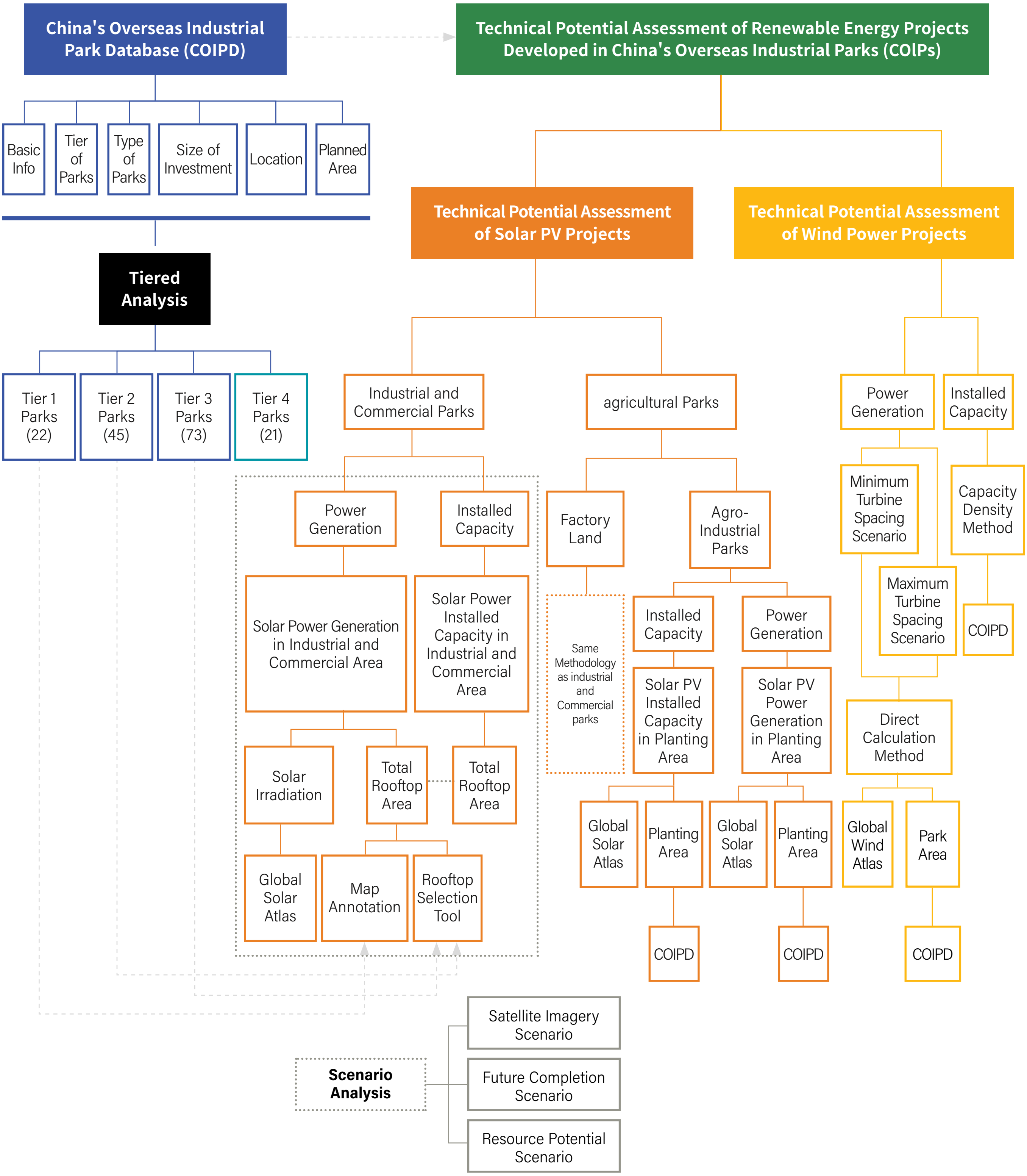
- **For park developers and investors.** The report provides valuable insights into the overall potential for RE development within COIPs, helping build investment confidence. Due to the limited experience in RE investment in COIPs, decision-makers and stakeholders often lack a clear understanding of the market size and potential. Therefore, it is essential to scientifically demonstrate its huge potential to policymakers, investors, industrial park operators, and financial institutions. The report also serves as a foundational reference for future investment decisions.
- **For host countries.** The report helps host countries build capacity and confidence in RE development, supporting their efforts to achieve their Nationally Determined Contributions under the Paris Agreement.
- **For global climate cooperation.** The report fosters greater confidence and ambition in global climate initiatives. Developing RE technologies like solar PV in COIPs not only helps host country reduce emissions and meet their RE goals, it also enables technology collaboration and potential business opportunities through park demonstrations.
- **For inclusive development in host countries.** The report encourages more inclusive social, economic, and environmental development. It facilitates stable and sustainable power supply within parks, improves local electricity accessibility, and increases tax revenue and economic benefits. Additionally, it promotes equitable, high-quality employment, gender equality, and other social benefits.

CHAPTER 2.

Identifying land use types and evaluating solar and wind potential through spatial remote sensing technology and modeling

This report evaluates the technical potential for photovoltaic (PV) project development through a land use type–based methodology. In parallel, the technical potential for wind power projects is assessed using an analysis grounded in turbine layout configurations.

FIGURE 1 | Report framework



Notes: For tiered analysis classification of China's overseas industrial parks in the framework, please refer to Appendix B.

Source: WRI

HOW MANY COIPS ARE THERE?

- Compiling available information and creating a comprehensive list of COIPs. The data are obtained from public sources, ranked by credibility in the following order (highest to lowest):
  - MOFCOM official website (http://www.mofcom.gov.cn/article/zt_jwjjmyhzq/) and COIPs official websites;
  - "Going Global" public service platform (http://fec.mofcom.gov.cn/article/fwydyl/tjsj/). China Council for the Promotion of International Trade's (CCPIT) overseas industrial parks platform (https://www.ccpit.org/maoyitouzicujin/zhongguoqiye/). All-China Federation of Industry and Commerce (ACFIC, https://www.acfic.org.cn/qlyw/201509/t20150915_82498.html), the Guide for Countries and Regions on Overseas Investment and Cooperation issued by MOFCOM (http://fec.mofcom.gov.cn/article/gbdqzn/index.shtml), local government reports on international cooperation and development (example: https://swt.fj.gov.cn/xxgk/jgzn/jgcs/dwtzyjjhzc/tpxw/202308/t20230830_6244900.htm);
  - China's official media; and
  - other media.
- Identifying and categorizing the number and distribution of COIPs. This study established a table-based database covering 159 COIPs established between 1992 and 2022 that remained operational as of 2022. The map of these parks is illustrated in Figure 4. The information was cross-verified across multiple sources to confirm the operational status of the parks as of 2022. The details of COIPD can be found in Appendix A.
- Identifying land use types and areas of COIPs, based on available information. Considering the varying data completeness for different parks in the database, we use different methods to acquire or estimate rooftop area data for parks in three tiers (Tier 1, Tier 2, and Tier 3). Due to missing data for Tier 4 parks, we were unable to estimate their rooftop areas. For detailed classification methods of tiered parks, please refer to Appendix B.
  - For Tier 1 parks, rooftop area data was collected through manual annotation of satellite maps. The satellite map data were primarily sourced from Google Maps, and annotations were made using Google Earth Engine (GEE). A detailed description of the methods is provided in Appendix C.
  - For Tier 2 and Tier 3 parks, given their larger number of rooftops, applying the same manual annotation method used for Tier 1 parks would be time-consuming and resource-intensive. Therefore, we used publicly available artificial intelligence–extracted rooftop datasets and obtained rooftop data through Microsoft Building Footprints (MBF). The specific methods and steps are detailed in Appendix C.

HOW TO EVALUATE TECHNICAL POTENTIAL OF SOLAR PV PROJECTS WITH IDENTIFIED LAND USE TYPES?

When evaluating the technical potential for the development of solar PV projects, this report employs methods based on Geographic Information System (GIS) to assess COIPs. These parks are mainly divided into two types: industrial and commercial parks and agricultural parks. We then analyze our assessment results through scenario analysis, examining the technical potential of COIPs from two key metrics: power generation and installed capacity (see Figure 1).

Calculation method for solar PV potential in industrial and commercial parks

This report evaluates the solar PV potential in industrial and commercial parks by focusing on rooftop solar installations. Studies show that urban rooftop solar power generation potential is largely determined by the available rooftop areas suitable for PV installation (Hong et al. 2016; Izquierdo et al. 2011; Kjellsson 1999; Min et al. 2021). Overseas parks are mostly processing and manufacturing parks, trade and logistics parks, and multifunctional integrated parks. These parks typically have numerous buildings with rooftops well suited for solar panel installation, making rooftop solar projects the optimal choice for solar energy development in these parks.

Generally, buildings in industrial and commercial parks are flat-roofed structures in relatively open areas, with minimal shadowing between buildings. In this situation, there is no need to consider factors such as building orientation, roof slope, and shadow effects when installing solar panels. Existing research has applied different methods to measure the available roof area (see Table 2).

This report adopts a GIS-based calculation method. Since overseas parks are scattered across many countries and regions, extensive data need to be dealt with. This GIS-based method is not only the most efficient way to obtain the available data but also the only viable method for evaluating land-use information on a global scale. While this method may sacrifice some accuracy and need verification through other methods before actual construction, it serves the purpose of this report well. Table 2 provides a detailed comparison of our GIS-based method with similar methodologies.

In general, while rooftop PV potential can be examined from a broad resource and geographic perspective, evaluating technical potential—which includes many technical factors like efficiency, capacity, stability, and performance—can more accurately reflect how technological advancements in solar PV systems influence power generation and installation capacity (Gassar and Cha 2021).

Accordingly, the report focuses on evaluating the technical potential for PV development in overseas parks. The analysis considers the upper limit of theoretical technical potential (i.e., resource potential) and includes resource potential as part of the scenario analysis. A brief overview of solar radiation assessment can be found in Appendix C.

To provide more targeted data support for different stakeholders and accurately present the variations in power generation across overseas industrial parks in different regions, the report uses a GIS-based calculation method to estimate power generation rather than simply converting it from installed capacity. For assessing installed capacity, we use a direct calculation method that is more closely tied to the technical parameters of the equipment. The former approach tends to explore the theoretical maximum PV power generation, and the latter shows the maximum installed capacity using the best-available solar PV system equipment.

Based on the actual solar PV power generation resources in host countries, this report evaluates the theoretical maximum annual power generation from rooftop PV systems,

$$E = (A_R \times RCR) \times r \times GHI \times PR \quad (1)$$

where:

E is the power generation (gigawatt-hours [GWh]/year);

A_R is the total rooftop area;

RCR is the roof cover ratio of PV modules, typically set at 0.85 (ADB 2014);

$A_{R \times RCR}$ yields the total area of PV modules (in square meters [m^2]);

r is the theoretical conversion efficiency of PV modules (%), determined by the type of PV modules used—typically 20% for polycrystalline silicon modules (CPIA 2023);

TABLE 2 | Calculation methods for rooftop solar PV installation

METHOD	RESEARCH SUBJECT	PARAMETERS
Proportion calculation method (Kjellsson 1999)	Regional potential of building integrated PV	▪ Ground area of the buildings
Social factor calculation method (Izquierdo et al. 2011)	Study on large-scale distributed solar PV installation potential in Spain	▪ Population, number of buildings, and land use information
Area exclusion calculation method (Hong et al. 2017)	Available rooftop area for solar PV installation in South Korea	▪ Mountain shadow areas, minimum installation area per kilowatt of solar PV systems
GIS-based calculation method (Min et al. 2021)	Development potential and vision for distributed RE in Yangtze River Delta region, China	▪ Geographic location information

Notes: GIS = Geographic Information System. PV = photovoltaic. RE = renewable energy.

GHI is the annual global horizontal irradiance on PV panels (GWh/m^2); and

PR is the system's performance ratio, representing its operational efficiency.

In practice, PV system output power falls below its peak power due to various losses, including those caused by changes in temperature, angle, and spectrum, as well as system losses in inverters and cables. The system's performance ratio (PR) represents the ratio between actual output and theoretical output (IEC 1998; Šúri et al. 2007). Since 2000, technological advances have enabled PV system to achieve PR value typically ranging from 0.75 to 0.9. In regions with advanced technological capabilities, the PR value is approximatley 0.85, which is the value adopted for calculations in this report (Khalid et al. 2016). The parameters selected for this analysis are based on the best available literature.

However, due to the rapid advancements in technology, the latest technological developments may not be reflected in the analysis.

Based on the parameters of PV module equipment, this report estimates the installed capacity of rooftop PV systems,

$$C_R = (\frac{C_m}{1000}) \times (\frac{A_R \times RCR}{A_m}) \qquad (2)\ )$$

where:

C_R is the installed capacity of the solar PV rooftop system (kilowatt-peak [kWp]);

C_m is the individual PV module rated capacity (watt peak [Wp]);

A_R is the total rooftop area;

RCR is the roof cover ratio of PV modules, typically set at 0.85 (ADB 2014);

$A_{R \times RCR}$ yields the total area of PV modules (m^2); and

A_m is the area of one PV module.

The rated capacity of a single PV module is typically taken as 500 Wp, with an area of 2.5 m^2 (Longi Green Energy Technology 2023).

COIPs are at different stages of development, ranging from planning to partially built to fully constructed. These stages significantly impact the rooftop area calculation for potential assessment. To estimate the technical potential for RE development in industrial and commercial parks, this report uses scenario analysis, taking into account the current construction status of COIPs.

- **Resource potential scenario**

Considering that the final building area in COIPs will not exceed their current total planned area, this scenario calculates the resource-side potential for PV development. It uses the total planned area, the local annual average GHI values, and an assumed maximum RCR of 0.85 for PV modules, accounting for area fragmentation. Theoretically, the potential calculated in this scenario represents the maximum achievable value under optimal technical conditions, serving as a reference for other scenario assessments.

- **Future completion scenario**

Remote sensing images and media reports indicate that most COIPs are still under construction. This report explores the technical potential for PV development in a future completion scenario. According to the Land Use Control Indicators for Industrial Project Construction issued by the Ministry of Natural Resources of China (Ministry of Natural Resources 2023), the building coefficient (i.e., total area of buildings, structures, and storage yards ÷ total project land area × 100%) for various industrial projects should be higher than 40%. Considering most industrial parks in China maintain a building coefficient between 40% and 60%, this scenario assumes that 45% of the total planned COIP area will be available for rooftop PV installations.

- **Satellite imagery scenario**

The satellite imagery scenario uses GIS-based data to calculate the PV system development potential with existing rooftop area available for installations. It reflects the most realistic technical potential for PV development in COIPs under current conditions.

Calculation method for PV potential in agricultural parks

Agricultural parks usually consist of farmland and industrial facilities. In this report , the PV potential calculation for industrial buildings follows the same methodology as industrial and commercial parks. Therefore, it is included in the technical potential assessment for industrial and commercial parks, while farmland PV potential is assessed separately.

This report evaluates the technical potential of agrivoltaic systems on farmland in agricultural parks. Globally, farmland offers the highest solar PV generation potential at 28 megawatts per square kilometer (MW/km^2) (Adeh et al. 2019). Generation varies by region due to different solar radiation levels, from 30 kilowatt-hours per square meter (kWh/m^2) in Sweden (Campana et al. 2021) to 600 megawatt-hours (MWh) per acre (148 kWh/m^2) in Phoenix, Arizona (Majumdar and Pasqualetti 2018). Installation methods (ground-mounted or elevated) and densities of agrivoltaic systems also affect power generation, as shown in a Kansas City lettuce farm case study where power generation ranged from 40 to 108 kWh/m^2 under various installation conditions (Dinesh and Pearce 2016).

BOX 1 | Practices in agrivoltaics

Over the past decade, agricultural photovoltaics (agrivoltaics) have shown promising results in research and practice. In China, agrivoltaic farms have been installed in 2,300 impoverished villages, with a total of 1.3 GW across 1,600 hectares of land. These projects have successfully generated power while maintaining high crop yields (including rice, wheat, corn) for seven consecutive years. France, Germany, and other European countries have also launched demonstration projects to explore the potential of agrivoltaics.

Notes: WRI authors.

Current research has mostly analyzed agrivoltaic project data at specific test plots. These studies track different agricultural products and PV system configurations, to assess the combined benefits from crop yield and power output (Fraunhofer ISE n.d.; SETO 2022; Trommsdorff et al. 2021). While these micro-level studies provide valuable insights, comprehensive large-scale research is still lacking.

Based on the solar resources in host countries, this report evaluates the theoretical maximum annual power generation from agrivoltaic systems on farmland within agricultural parks,

$$E = (A_{ag} \times CCR) \times r \times GHI \times PR \tag{3}$$

where:

E is the power generation (GWh/year);

A_{ag} is the farmland area (m^2);

CCR is the coverage ratio of PV modules on farmland (%); and

$A_{ag \times CCR}$ is the total area of PV modules (m^2).

All the other parameters are the same as in equation 1.

Based on the parameters of PV module equipment, this report estimates the installed capacity of PV systems on farmland within agricultural parks,

$$C_R = (\frac{C_m}{1000}) \times (\frac{A_{ag} \times RCR}{A_m}) \tag{4}$$

where:

CR is the installed capacity of PV systems (kWp); and

A_{ag} and CCR have the same meanings as in equation 3.

All the other parameters are the same as in equation 2.

The agricultural parks are at different stages of implementing agrivoltaics, requiring differentiated analyses of their development potentials. Unlike the calculation method for industrial and commercial parks, where scenarios are based on construction status, the analysis for farmland within agro-industrial parks focus on two scenarios: the resource potential scenario and the future completion scenario. The reason for this is that there is no data available on farmland in COIPs, making it unfeasible to use GIS-based calculation methods as applied to industrial and commercial parks.

- **Resource potential scenario**

In this scenario, the solar radiation within a planned region is calculated based on the farmland area of China's overseas agricultural parks. Given the fragmented nature of park areas, a maximum RCR of 0.85 for PV modules is assumed. This assumption is used to estimate the resource potential for PV development on the farmland. Theoretically, the potential calculated under this scenario represents the highest achievable value under optimal technical conditions and serve as a reference for other scenarios.

- **Future completion scenario**

Remote sensing images and media reports reveals that, at present, none of the China's overseas agro-industrial parks employ agrivoltaic methods for planting. This report explores the technical potential for PV development in farmland under a future completion scenario. According to the Solar Energy Technologies Office (SETO 2022), a US Department of Energy office, solar greenhouses account for up to 30% of the total horticultural area in China. Based on this figure, we assume that the same proportion of farmland in China's overseas agro-industrial parks could be used for installing PV systems for agrivoltaics.

HOW TO EVALUATE TECHNICAL POTENTIAL OF WIND POWER PROJECTS BASED ON TURBINE LAYOUTS?

This report evaluates the technical potential of wind power development in COIPs by analyzing both power generation and installed capacity under different turbine layout scenarios.

Wind power generation

Wind power generation refers to the usable wind energy within a specific area and time period, accounting for technical requirements and limitations such as turbine conversion efficiency, spacing requirements, and the wake effect between turbines. There are four main methods to assess wind power generation: global valuation, minimum LCOE, integrated parameters, and direct calculation (see Table E-1).

This report uses the direct calculation method to assess wind power generation in overseas parks for the following reasons:

- **Global valuation method.** This method requires standardizing potential values based on park area ratios. It is better suited for macro-level studies with less focus on precise analysis of individual parks.
- **Minimum LCOE method.** This method is most effective for large geographic areas over 30,000 km2 (Jäger et al. 2016), which exceeds the size of most overseas parks. Therefore, it is not applicable in this report.
- **Integrated parameters method.** This method is used by platforms like the Global Wind Atlas to obtain resource-side wind parameters (e.g., wind speeds). Since this method typically does not produce quantifiable outputs, it cannot be used for quantitative analysis.
- **Direct calculation method.** This method evaluates wind power potential by considering the impact of different turbine types, providing a comprehensive assessment of wind energy potential based on current turbine technologies. It also allows for future projections as technology advances. Unlike the global valuation method, which scales wind potential proportionally to park area, the direct calculation method incorporates wind speed and total park area, reflecting the unique wind resource characteristics of each park. This method can also provide detailed insights for micro-level energy project investment decisions for specific park(s).

This report uses direct calculation to estimate annual wind power generation in overseas parks,

$$E = WPD \times S \times t \tag{5}$$

where:

> E is power generation (watt-hours [Wh]);
>
> WPD is wind power density (watts per square meter [W/m^2], calculation method in Appendix E);
>
> S is total swept area of wind turbines (m^2); and
>
> t is annual utilization hours, fixed at 2,246 hours (NEA 2022).

The total swept area of wind turbines can be calculated in the following equation,

$$S = N \times S_{turbine} \tag{6}$$

where:

> S is total swept area of wind turbines (m^2);
>
> N is the number of wind turbines; and
>
> $S_{turbine}$ is the swept area per turbine (m^2/turbine), a fixed value available from turbine manufacturers.

The number of wind turbines (N) depends on the total area of industrial parks and the spacing between turbines. Turbine layout significantly impacts the wind power potential of a given area:

- **Close spacing.** Overly close placement reduces wind speed and the total power generation of the area. It also increases turbulence, which can lead to higher dynamic mechanical loads on downwind turbines.
- **Distant spacing.** Excessive spacing results in fewer turbines being installed, wasting available land and reducing the total wind power generation.

Optimal turbine spacing ensures efficient use of the wind farm area, avoids turbine overload, and maximizes wind energy resource utilization. Recent studies on the optimization of onshore wind farms use combined sampling, modeling, and machine learning approaches to maximize power generation through optimal turbine layout (Kwong et al. 2012; Yang et al. 2014).

Usually, the optimum spacing of wind turbines is 8 to 12 times rotor diameter in the dominant wind direction (Patel 2006) and 3 to 5 times rotor diameter in the crosswind direction (Pookpunt and Ongsakul 2016). China's national standard Code for Design of Wind Farm (GB 51096-2015) also requires that wind turbines be arranged in a grid pattern, with rows perpendicular to the dominant wind direction. The spacing between turbines in the same row should be no less than 3 times rotor diameter (3D), and spacing between rows no less than 5 times rotor diameter (5D).

This report sets up two simulation scenarios to determine the number of wind turbines:

- **Minimum turbine spacing scenarios.** This scenario assumes the spacing between turbines is 8D in the dominant wind direction and 3D in the crosswind direction.
- **Maximum turbine spacing scenario.** This scenario assumes the spacing between turbines is 12D in the dominant wind direction and 5D in the crosswind direction.

For both scenarios, four turbines are placed at the corners of the grid formed by the dominant wind direction and the crosswind direction (see Figure 2). The number of the grids (Ngrid) can be calculated,

Minimum turbine spacing scenario:

$$N_{grid} = S_0 / (8D \times 3D)$$

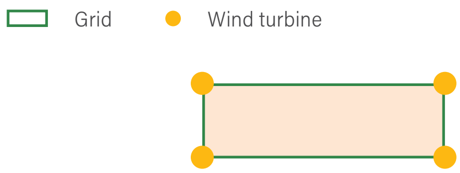
Maximum turbine spacing scenario:

$$N_{grid} = S_0 / (12D \times 5D)$$

where:

> S_0 is the total available area for wind turbine placement (m^2). For industrial and commercial parks, this value is the area excluding building space (in the future completion scenario); for agricultural parks, this value is the planting area.

FIGURE 2 | Turbine layout 1



The first grid contains four turbines. Since adjacent grids share one edge, each additional grid will have two more turbines (see Figure 3). Therefore, under single-row grid arrangements (multiple-row grids follows the same principle), the number of turbines (N) could be calculated by the number of grids (Ngrid) in the following equation:

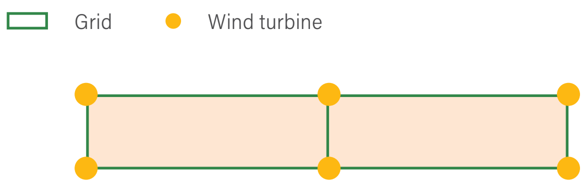
Minimum turbine spacing scenario:

$$N = 4 + 2(N_{grid} - 1) = (2 + \frac{S_0}{12D^2})$$

Maximum turbine spacing scenario:

$$N = 4 + 2(N_{grid} - 1) = (2 + \frac{S_0}{30D^2})$$

FIGURE 3 | Turbine layout 2



In conclusion, this report evaluates the technical potential of wind power projects in COIPs with the direct calculation formula as follows,

Minimum turbine spacing scenario:

$$E = (2 + \frac{S_0}{12D^2}) \times s_{turbine} \times \frac{1}{2} \rho \int_0^{\infty} U^3 f(U) dU \times t$$

$$= (2 + \frac{S_0}{12D^2}) \times s_{turbine} \times s_{turbine} \times \frac{1}{2} \times 0.955 \rho U^3 \times t$$

Maximum turbine spacing scenario:

$$E=(2+\frac{S_0}{30D^2})\times s_{turbine}\times\frac{1}{2}\rho\int_0^{\infty}U^3 f(U)dU\times t$$
$$=(2+\frac{S_0}{30D^2})\times s_{turbine}\times s_{turbine}\times\frac{1}{2}\times 0.955\rho\overline{U}^3\times t$$

where:

E is the wind power generation in COIPs (Wh);

$S0$ is the total available area for turbine placement (m^2);

D is rotor diameter of the wind turbine (m);

Sturbine is the swept area per turbine (m^2/turbine);

ρ is the air density (fixed value), typically 1.225 kilograms per cubic meter (kg/m^3);

$\overline{U}$ is the annual average wind speed at turbine hub height (meters per second [m/s]); and

t is the annual utilization hours (fixed value), set to 2,246 hours (based on International Energy Agency data).

The selection of wind turbines will impact related parameters and the calculation of wind energy technical potential. This report chose the Goldwind 5S turbine (D = 165 m, Sturbine = 21,382 m^2; see Table 3), with the average wind speed taken from the Global Wind Atlas, at a height of 100 meters above the center of each COIPs.

TABLE 3 | Goldwind 5S wind turbine parameters

PARAMETER	VALUE
Hub height	100 m
Swept area per turbine (Sturbine)	21,382 m^2
Rotor diameter (D)	165 m

Installed wind power capacity

Unlike annual wind power generation, the installed capacity refers to the sum of rated effective power of all installed generator units in the system. This report uses the capacity density method to estimate the installed wind power capacity,

$$C_Z = S_Z \times \delta \quad (7)$$

where:

C_z is the wind power installed capacity (megawatts [MW]);

S_z is the total available area for turbine layout in the industrial park (km^2), which is the same as S0 in the turbine spacing scenario equations;

δ is the installed capacity density (MW/km^2).

Installed capacity density can quantify the achievable power generation capacity per unit area. It is a core component in the modeling of technical potential, along with wind resources, system performance and site-specific constraints. This study uses the capacity density method for estimation. Since different methods are used to represent installed capacity density, the values obtained in studies can vary (Harrison-Atlas et al. 2021).

In this report, considering the wide geographic distribution of COIPs, we use the maximum installed capacity density values from research worldwide: 19.8 MW/km^2 for Europe and 20.5 MW/km^2 for regions beyond (Enevoldsen and Jacobson 2021), as well as the minimum value of 4 MW/km^2 (Hoogwijk et al. 2004) for estimations.

BOX 2 | Vietnam Singapore Industrial Park rooftop solar project

The Vietnam Singapore Industrial Park (VSIP) was established in 1996 in Binh Duong Province, Vietnam. It is an integrated complex of industrial, commercial, and residential areas, committed to sustainable development through green initiatives. Vietnam-Singapore Smart Energy Solutions (VSSES), one of VSIP's joint ventures, aims to provide sustainable energy solutions and supplies rooftop solar PV systems to multiple enterprises within the park.

In December 2021, the rooftop solar system of II-VI Vietnam was commissioned by VSSES successfully. The system has an installed capacity of 636 kWp and generates 890 MWh of electricity annually, reducing carbon dioxide emissions by over 812 tons—equivalent to planting 9,811 trees. II-VI Vietnam is committed to long-term sustainable development and actively works to reduce its global carbon footprint, aiming to be a role model in sustainability.

In May 2021, VSSES also successfully implemented the rooftop solar system for Green Cross Vietnam in the VSIP Binh Duong, using the Zero Capex Model. The system, with an installed capacity of 578 kWp, generates over 800 MWh annually and reduces carbon dioxide emissions over 738 tons each year. Green Cross Vietnam uses the green energy generated by the rooftop solar PV system for both production and administrative purposes. Remarkably, the system was installed before the outbreak of the COVID-19 pandemic in Vietnam, helping the company lower its electricity cost during the challenging period.

Notes: WRI authors; VSIP official website.

CHAPTER 3.

China's extensive network of overseas industrial parks

Based on Geographic Information System (GIS) technology, this report establishes a database of China's overseas industrial parks, comprising 159 parks in total. Approximately half are located in Asia, with the remainder distributed across Africa and Europe. Among the various types, multi-functional integrated parks and agro-industrial parks represent the largest proportions.

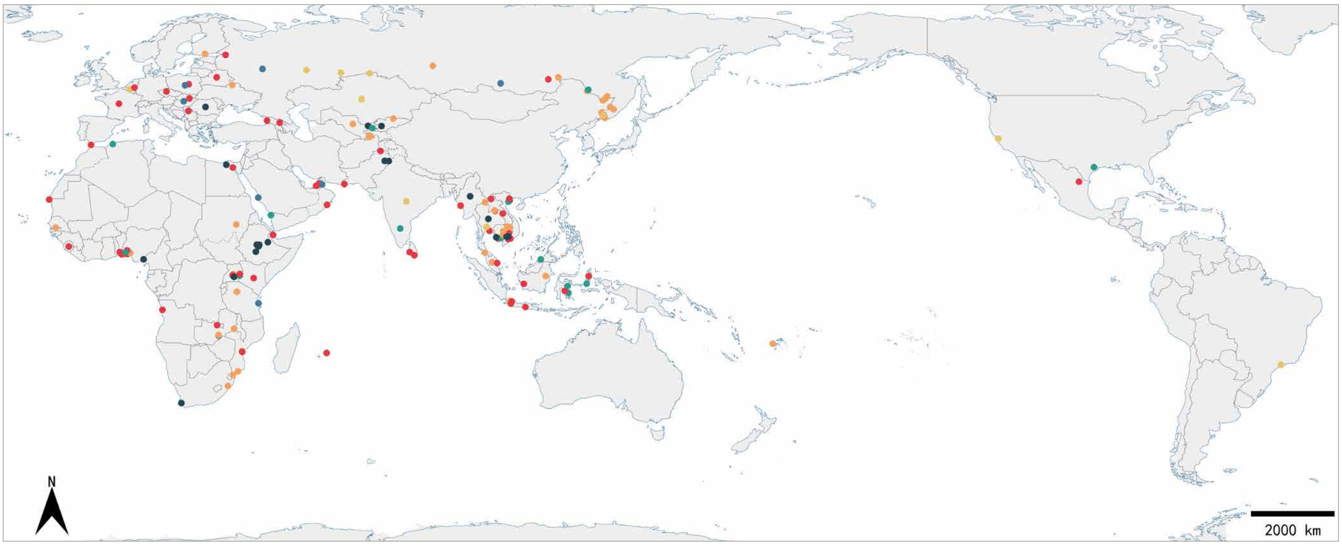
The database in this report covers 159 COIPs that were established between 1992 and 2022 and were still in operation in 2022 (see Appendix A). The geographic distribution is as follows: 71 parks are located in Asia (45%), 39 in Europe (25%), 44 in Africa (28%), 3 in North America, and 1 each in South America and Oceania.

In terms of park type, there are 59 multifunctional integrated parks, 22 processing and manufacturing parks, 15 resource utilization parks, 44 agro-industrial parks, 10 technology R&D parks, and 9 trade and logistics parks. Among these, multifunctional integrated parks (37%) and agro-industrial parks (28%) account for the largest share, while technology R&D parks (6%) and trade and logistics parks (6%) represent the smallest portions (see Figure 4).

The majority of these parks were established after 2000, with 63% built after 2013.

FIGURE 4 | Map of COIPs (As of the end of 2022)

Type of Parks Multifunctional Integrated, Trade & Logistics, Resource Utilization, Processing & Manufacturing, Agro-Industrial, Technology R&D



Notes: WRI authors
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BOX 3 | Overview of provincial-level overseas economic and trade cooperation zones evaluation and management policies

Four provinces in China have established evaluation and management measures for provincial-level overseas economic and trade cooperation zones (ETCZs) through their departments of commerce, either independently or jointly with their finance departments:

- **Shandong (2018):** Evaluation and Management Measures for Shandong Overseas ETCZs (Lushangzi [2018] No. 205).
- **Zhejiang (2022):** Notice of Zhejiang Department of Commerce and Zhejiang Department of Finance on the Issuance of Evaluation Measures for Zhejiang Overseas ETCZs (Zheshangwulianfa [2022] No. 146), specifying principles and evaluation requirements.
- **Guangdong (2021):** Evaluation Measures for Guangdong Overseas ETCZs (Yueshangwuguizi [2021] No. 1), its first-ever assessment plan.
- **Hubei (2021):** Recognition and Evaluation Measures for Hubei Overseas ETCZs (Trial) (Eshangwufa [2021] No. 2).

Notes: WRI authors, MARA official website.

BOX 4 | Overseas agricultural cooperation demonstration zones recognized by the Ministry of Agriculture and Rural Affairs of China

In 2017, China's Ministry of Agriculture (now known as the Ministry of Agriculture and Rural Affairs [MARA]) initiated the recognition progress for overseas agricultural cooperation demonstration zones and agricultural opening-up cooperation pilot zones, based on two key documents, the Construction Plan for Agricultural Overseas Cooperation "Two Zones" (Nongwaifa [2016] No. 3) ("农业部关于印发《农业对外合作'两区'建设方案》的通知" n.d.) and the Notice on Organizing the Pilot Construction of Overseas Agricultural Cooperation Demonstration Zones and Agricultural Opening-Up Cooperation Pilot Zones (Nongwaifa [2016] No. 4)("农业部关于组织开展境外农业合作示范区和农业对外开放合作试验区建设试点的通知" n.d.). As a result, a total of 10 parks were recognized as the first batch of overseas agricultural cooperation demonstration zones.

Notes: WRI authors, MARA official website.

CHAPTER 4.

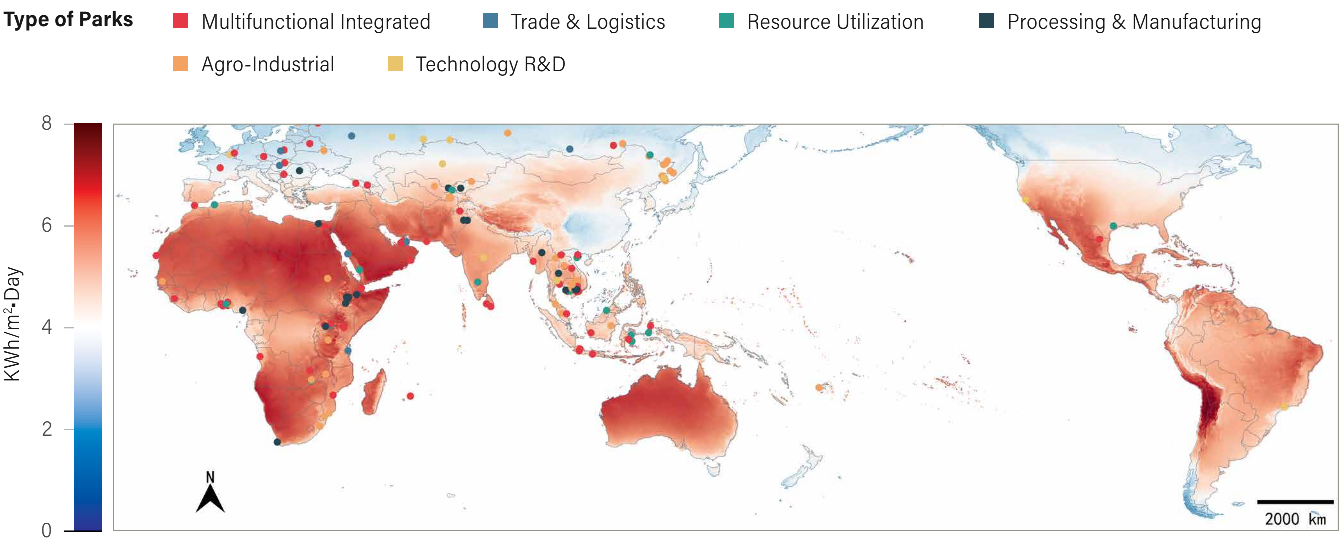
Evaluating technical potential of solar PV projects in COIPs

The estimated annual electricity generation from rooftop photovoltaic (PV) systems in industrial and commercial parks is approximately equivalent to the European Union's total PV generation in 2023. Such rooftop PV projects could stimulate around CNY 552 million in investment. For agro-industrial parks, the annual electricity generation potential from ground-mounted PV systems on cultivated land is estimated to be 1.78 times that of the EU's 2023 PV generation, with the potential to drive approximately 1.129 billion CNY in investment.

China's RE industry is mature, with well-developed technology and significant price advantages. Most COIPs are located in mid- to low-latitude regions with strong solar radiation, making them ideal for solar energy development (see Figure 5).

COIPs provide significant opportunities for solar projects, as they have abundant rooftop area for PV panel installations, requiring no additional land. This approach can mitigate the negative impacts of unstable power supply on production. It also lowers electricity costs and improves the overall energy efficiency of the park. Agro-industrial parks can adopt the agrivoltaics model, installing solar systems above farming areas to increase land utilization and per-unit land output.

FIGURE 5 | Global Presence of COIPs and Global Horizontal Irradiance (GHI)



Notes: COIPs = China's overseas industrial parks. GHI = global horizontal irradiance. R&D = research and development. kWh/m^2 = kilowatt-hours per square meter.
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BOX 5 | The renewable energy project of Deep C Industrial Zones in Vietnam

The Deep C Industrial Zones, located in the northern port city of Haiphong, Vietnam, installed a 2.15 megawatt (MW) rooftop photovoltaic (PV) system. Feasibility studies for the project began in 2016 with international consultants, followed by small-scale testing in 2017. In 2018, an operational performance analysis was conducted based on data collected over the previous 12 months. The construction took place during 2019 to 2021, with one warehouse rooftop as a pilot project.

A total of 12 suppliers participated in the bidding, with quotes ranging from \$490–\$700 per kilowatt-peak. The construction took six months to complete; the system's first-year power generation is expected to reach 2,360 megawatt-hours, with annual operation and maintenance costs accounting for about 1.5% of the PV system's total investment.

The rooftop PV system is connected to Deep C's internal power grid without disrupting its operations and distributes green electricity to all tenants. The industrial park plans to expand to 120 MW of solar and wind power capacity, incorporating energy storage systems and smart grid technology. By 2030, the park aims to meet half of its power demand with renewable energy.

Notes: WRI authors; cases provided by Clean Energy Investment Accelerator.

TECHNICAL POTENTIAL OF PV PROJECTS IN COMMERCIAL AND INDUSTRIAL PARKS

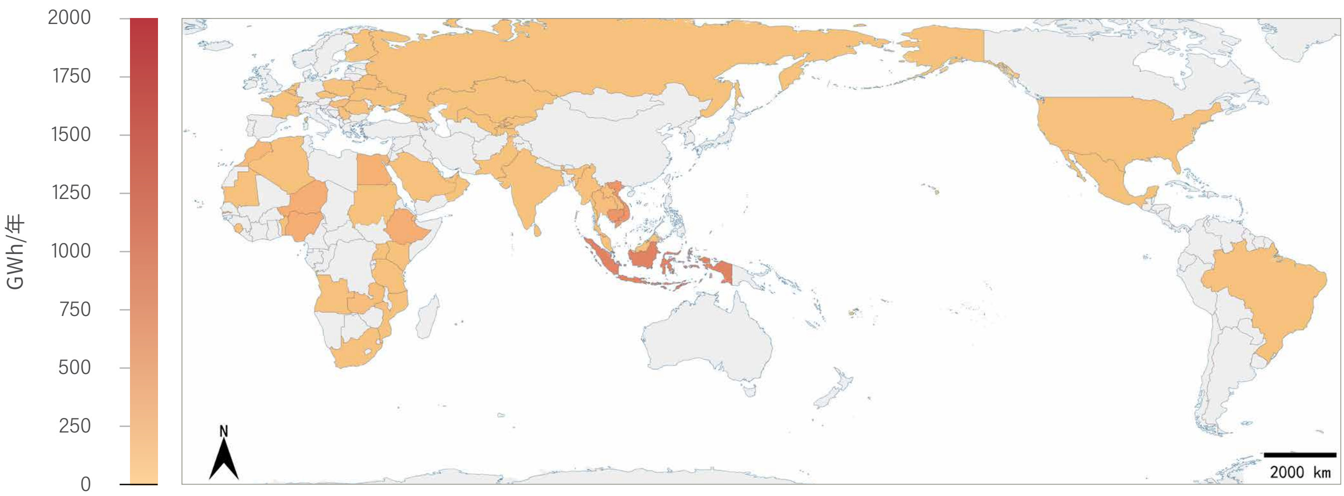
This section includes calculations for industrial and commercial parks, as well as industrial facilities within agro-industrial parks.

In the future completion scenario, the annual PV power generation of industrial and commercial parks is estimated 2.23×105 GWh, which equals EU total PV power generation in 2023 (Ember 2024); the PV installed capacity could be around 147.7 GW, equivalent to 2.64 times the European Union's 2023 PV capacity additions (Solar Power Europe 2023). Based on the investment costs of distributed PV systems in China's industrial and commercial sectors (CPIA 2023), developing these PV projects could attract an investment of CNY 552 million ($75.9 million).

In the satellite imagery scenario (see Figure 6), the annual PV power generation for industrial and commercial parks is estimated at 3,789.39 GWh, with an installed capacity of 2.54 GW. Following the current satellite imagery scenario, the PV power generation is about 2% of the European Union's 2023 PV output (Ember 2024).

In the satellite imagery scenario, Indonesia, Cambodia, and Vietnam rank as the top three countries in terms of PV power generation in industrial and commercial parks (see Figure 7).

FIGURE 6 | Power Generation Assessment of Solar PV Projects in Commercial and Industrial Parks (Satellite Imagery Scenario)



Notes: Gray indicates no data or not applicable (same below).

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FIGURE 7 | Power Generation Assessment of Solar PV Projects in Commercial and Industrial Parks (by country)

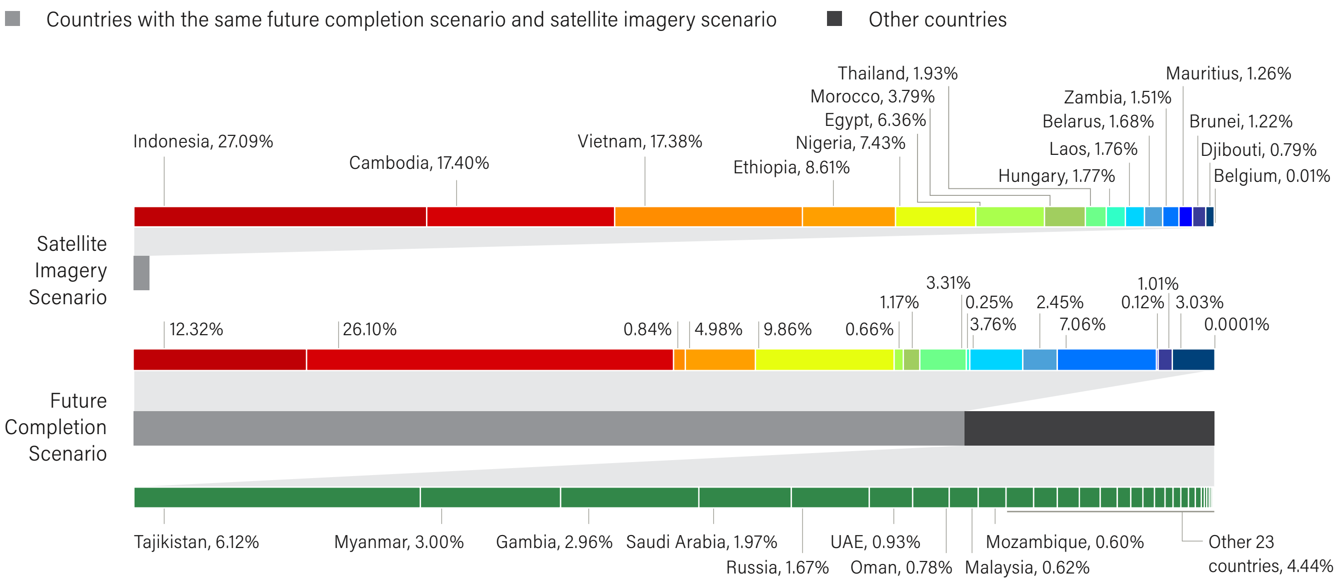
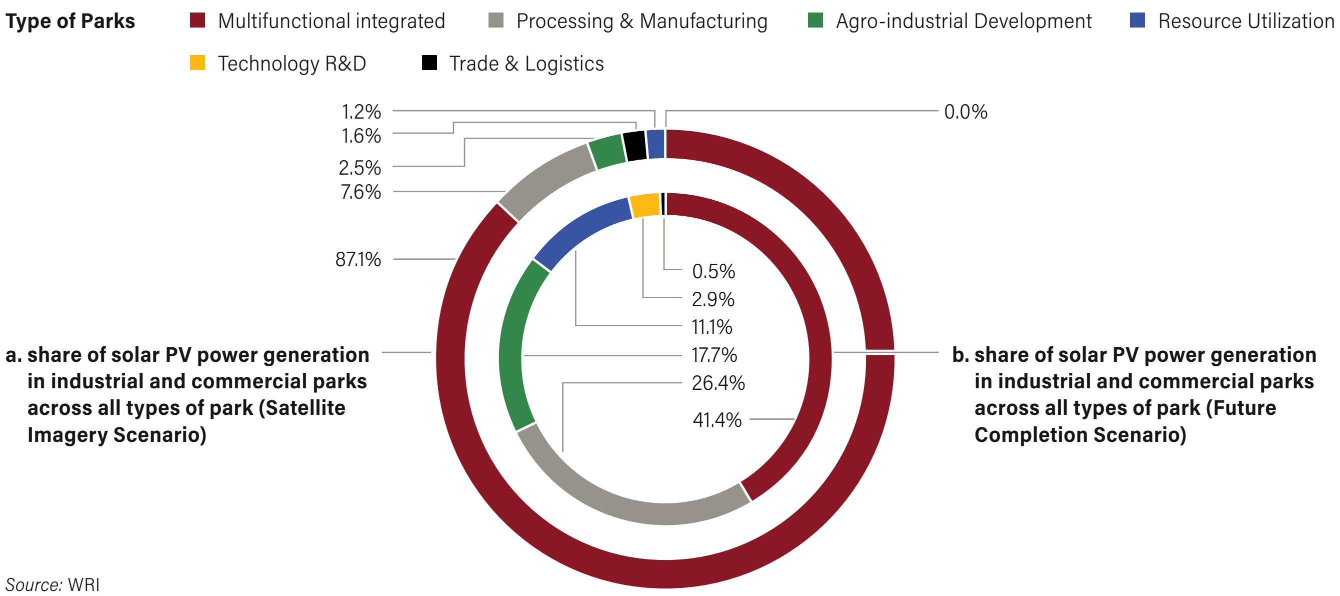


FIGURE 8 | Power generation assessment of solar PV projects in commercial and industrial parks (by type of park)



Source: WRI

By type of park, multifunctional integrated parks dominate with 87.1% of PV power potential due to their large number and extensive land area, followed by processing and manufacturing parks at 7.6%. Technology R&D parks have the smallest share at less than 1% (see Figure 8).

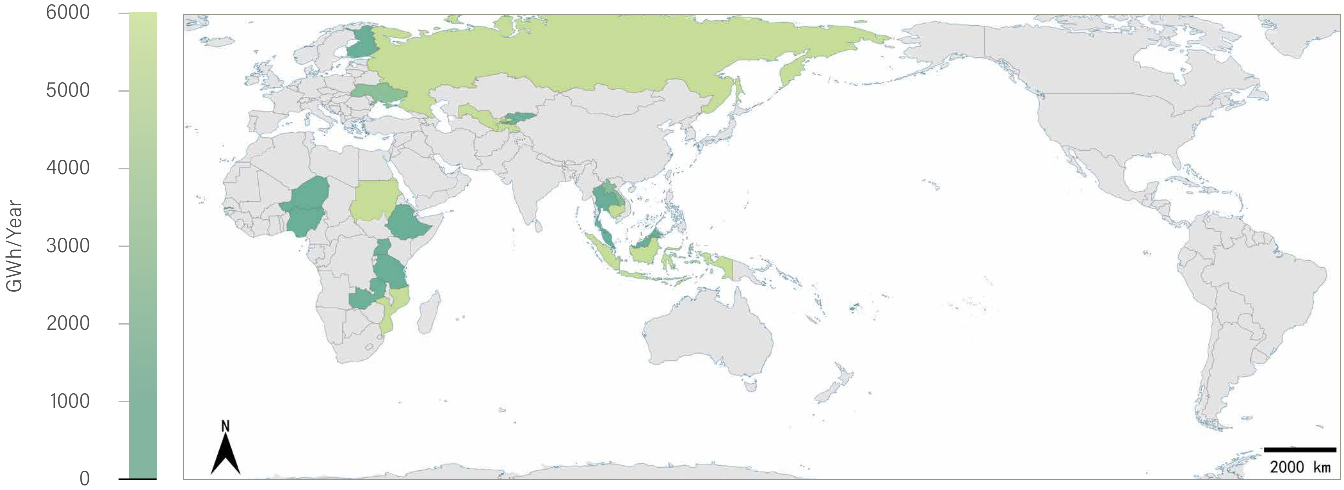
In the future completion scenario, the countries with top PV power generation in industrial and commercial parks are Cambodia, Indonesia, and Nigeria (see Figure 7). By type of park, multifunctional integrated parks remain dominant with 41.4% of PV power potential, followed by processing and manufacturing parks at 26.4% (see Figure 8).

TECHNICAL POTENTIAL OF PV PROJECTS IN AGRICULTURAL PARKS

The 38 agro-industrial parks in this report cover a total planting area of 4,533 km^2. In the resource potential scenario, the annual PV power generation of these farmlands could reach 6.20×106 GWh, with an installed capacity of 770.54 GW. In the future completion scenario (see Figure 9), the annual PV power generation of these farmlands is estimated at 3.72×105 GWh, which is 1.78 times the European Union's total PV output in 2023 (Ember 2024); the PV installed capacity is projected to be 271.96 GW, or 4.86 times the European Union's 2023 PV capacity additions (Solar Power Europe n.d.). Using China's ground-mounted PV investment costs as a reference, this represents potential investment of CNY 1.129 billion ($155.29 million).

By country, Russia leads with 39.1% of PV power generation potential in agro-industrial parks (see Figure 10), followed by Indonesia and Cambodia. Russia's dominance reflects its approximately 50% share of total agricultural area. By region, Southeast Asia shows the highest PV potential for agro-industrial parks, followed by Eastern Europe and Northern Eurasia (see Figure 11). However, the actual deployment of PV panels will depend on factors such as park layout, economic feasibility, and technical accessibility.

FIGURE 9 | Technical potential of PV projects in agricultural parks (future completion scenario)



Source: WRI
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FIGURE 10 | Power generation assessment of solar PV projects in agricultural parks (by country)

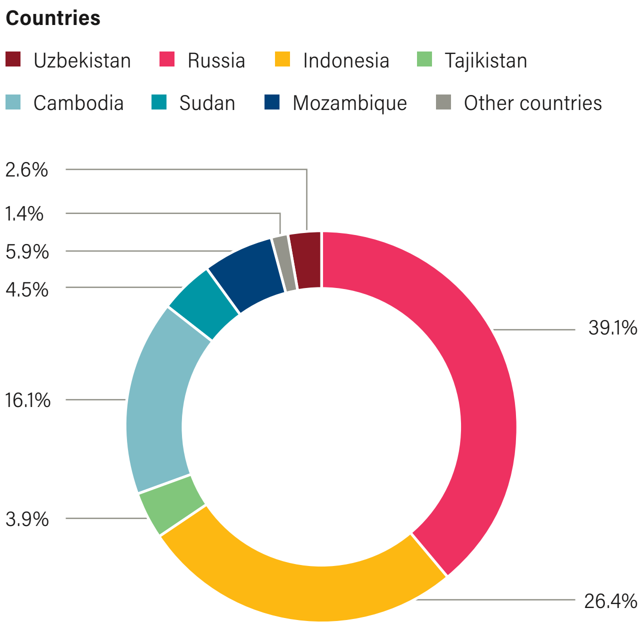
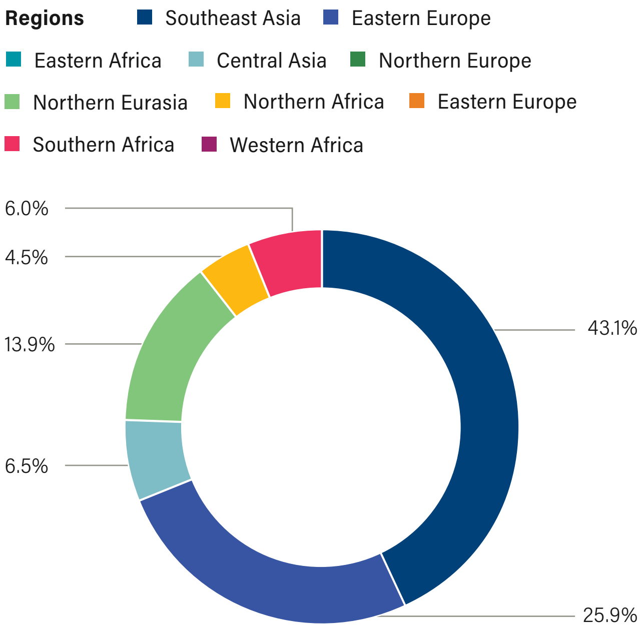
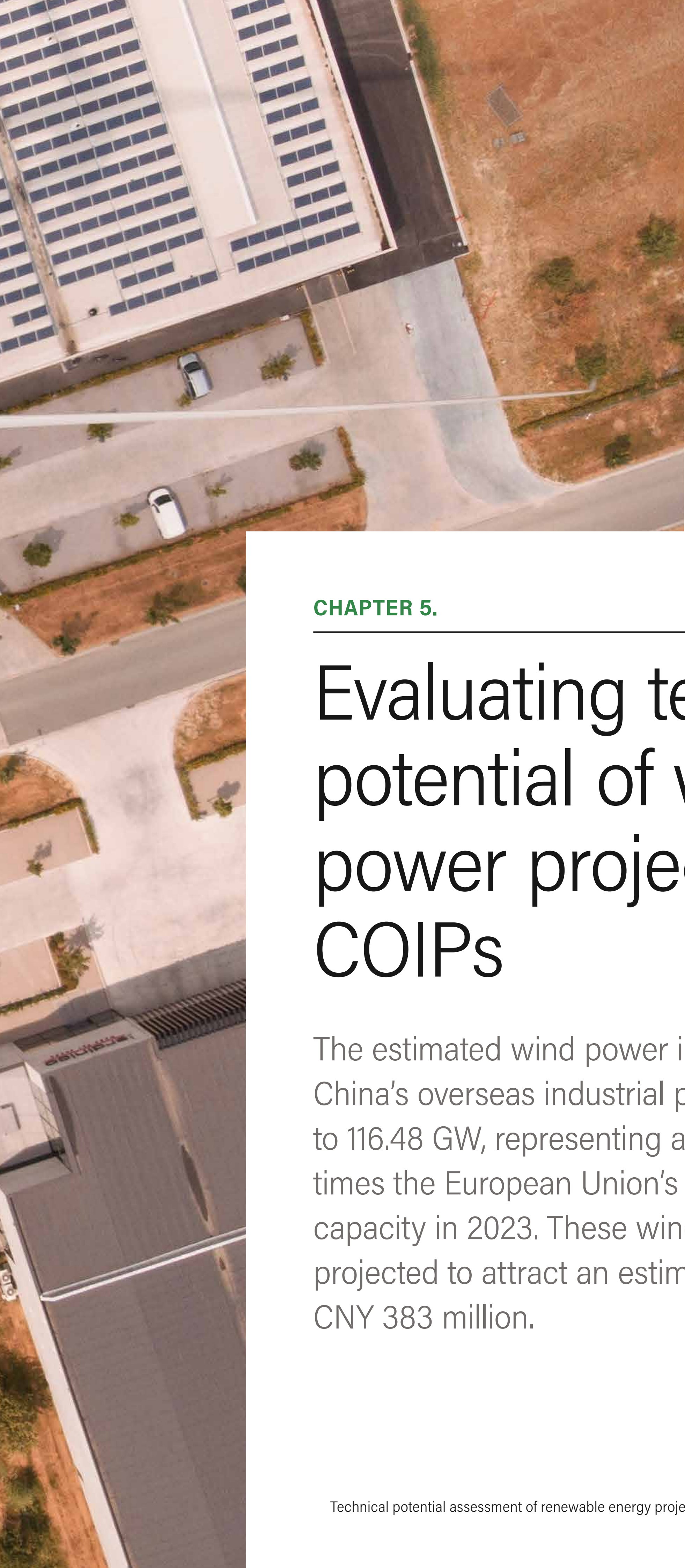


FIGURE 11 | Power generation assessment of solar PV projects in agricultural parks (by region)





CHAPTER 5.

Evaluating technical potential of wind power projects in COIPs

The estimated wind power installed capacity across China's overseas industrial parks ranges from 22.74 to 116.48 GW, representing approximately 1.4 to 7.19 times the European Union's newly installed wind capacity in 2023. These wind power projects are projected to attract an estimated investment of CNY 383 million.

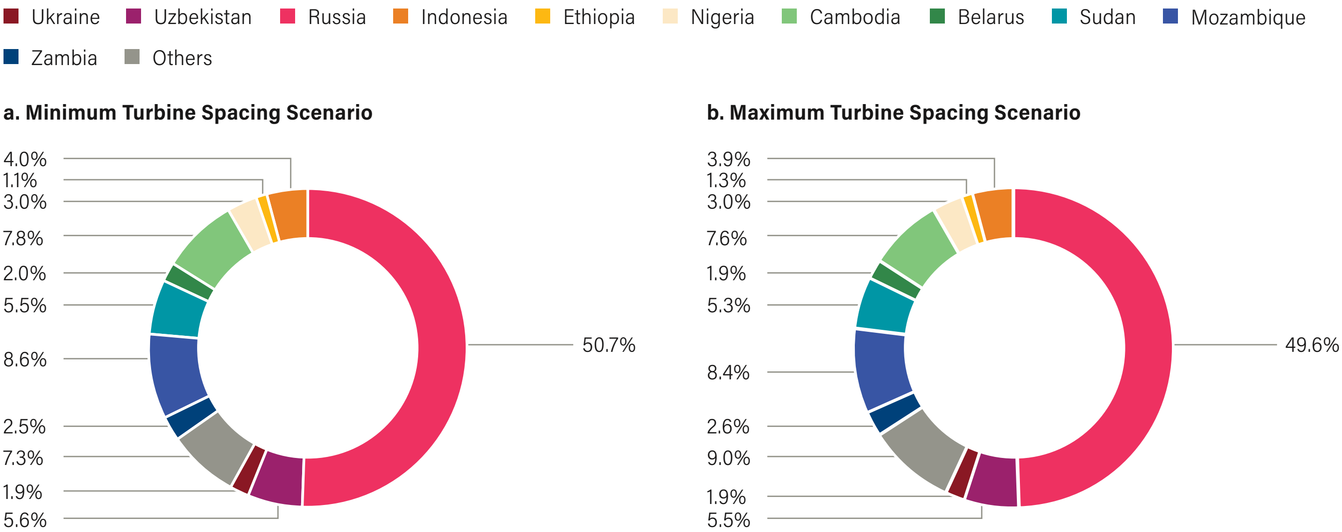
With the advancements in wind energy technology and decreasing power generation costs, wind energy is showing tremendous investment potential. Many regions hosting COIPs have abundant wind resources, providing favorable conditions for wind energy development in these parks.

In the minimum turbine spacing scenario, the annual wind power generation of COIPs could reach 4.36×104 GWh. In the maximum turbine spacing scenario, the figure could be 1.12×105 GWh. The installed capacity of wind power in COIPs ranges from 22.74 GW to 116.48 GW (see Figures 14 and 15), which is 1.4 to 7.19 times the European Union's wind capacity additions in 2023 (Wind Europe 2024).

By country, the COIPs in Russia generate the highest annual wind power, followed by Mozambique and Cambodia (see Figure 12). By region, COIPs in Northern Eurasia account for the largest share of annual wind power generation, reaching 50.7% and 49.6% in the two scenarios, respectively, followed by Southeast Asia (13.4%) and Southern Africa (11.2%) (see Figure 13).

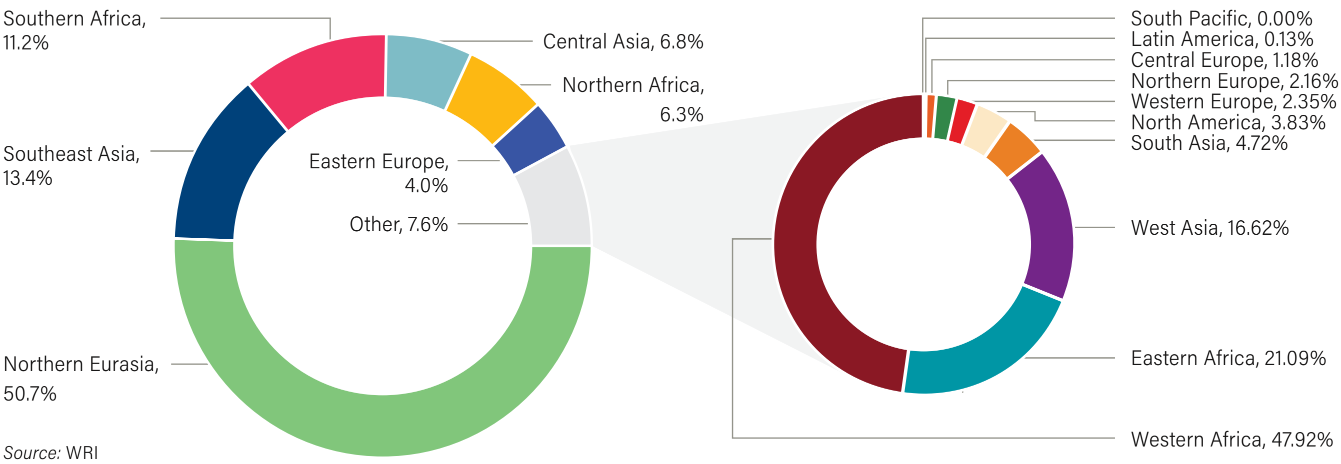
By type of parks, agro-industrial parks demonstrate the highest annual wind power generation, followed by technology R&D parks and multifunctional integrated parks (see Table 4). Based on the assessment results and using China's onshore wind power investment costs (CPIA 2023), wind power projects in COIPs are expected to attract investments of CNY 383 million ($52.68 million.

FIGURE 12 | Power Generation Assessment of Wind Power Projects in COIPs (by country)



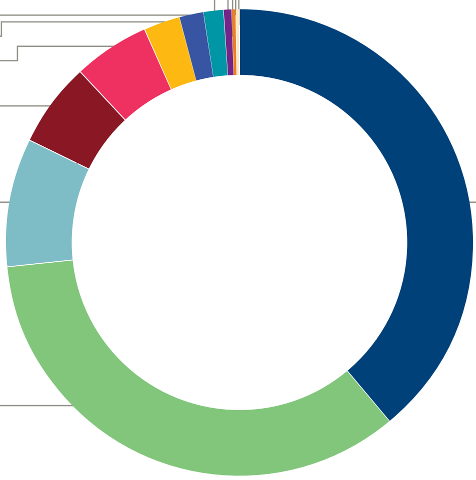
Notes: COIPs = China's overseas industrial parks.

FIGURE 13 | Power Generation Assessment of Wind Power Projects in COIPs (by region)



Source: WRI

FIGURE 14 | Installed Capacity Assessment of Wind Power Projects in COIPs (by region)



Notes: COIPs = China's overseas industrial parks.

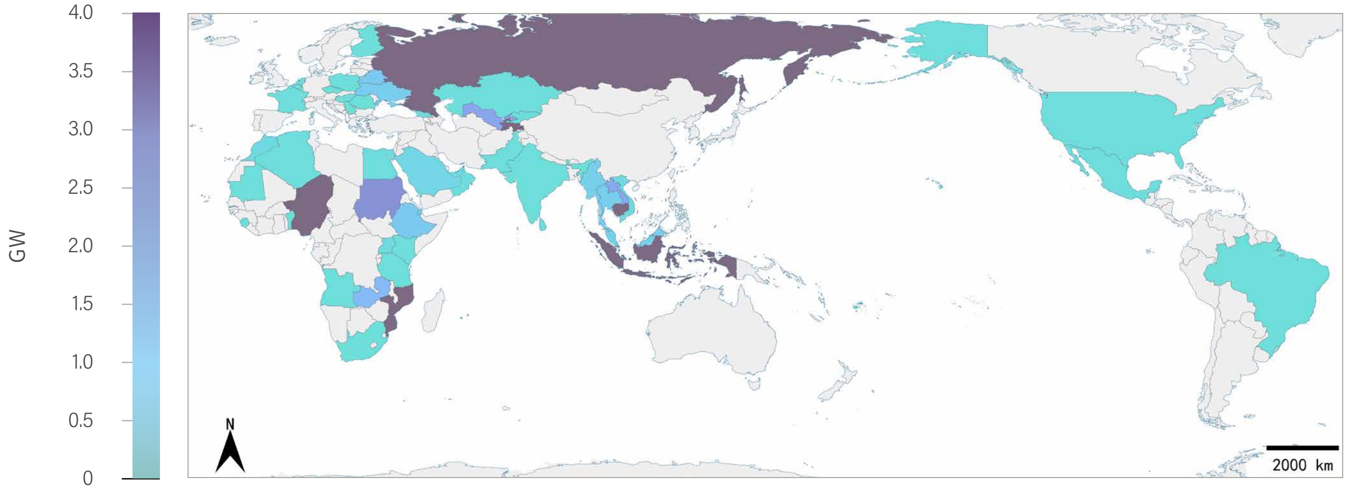
TABLE 4 | Estimated annual wind power generation in COIPs (by type of parks)

TYPE OF COIP	Minimum turbine spacing scenario (GWh)	Maximum turbine spacing scenario (GWh)
Multifunctional integrated parks	1.01×10^4	0.47×10^4
Trade and logistics parks	0.024×10^4	0.017×10^4
Agro-industrial parks	9.43×10^4	3.81×10^4
Processing and manufacturing parks	0.36×10^4	0.16×10^4
Technology R&D parks	0.052×10^4	0.033×10^4
Resource utilization parks	0.32×10^4	0.14×10^4

Notes: COIPs = China's overseas industrial parks. GWh = gigawatt-hours. R&D = research and development.

FIGURE 15 | Technical Potential of Wind Power Projects in COIPs

a. Installed Capacity of Wind Power (Minimum Turbine Spacing Scenario)



b. Installed Capacity of Wind Power (Maximum Turbine Spacing Scenario)

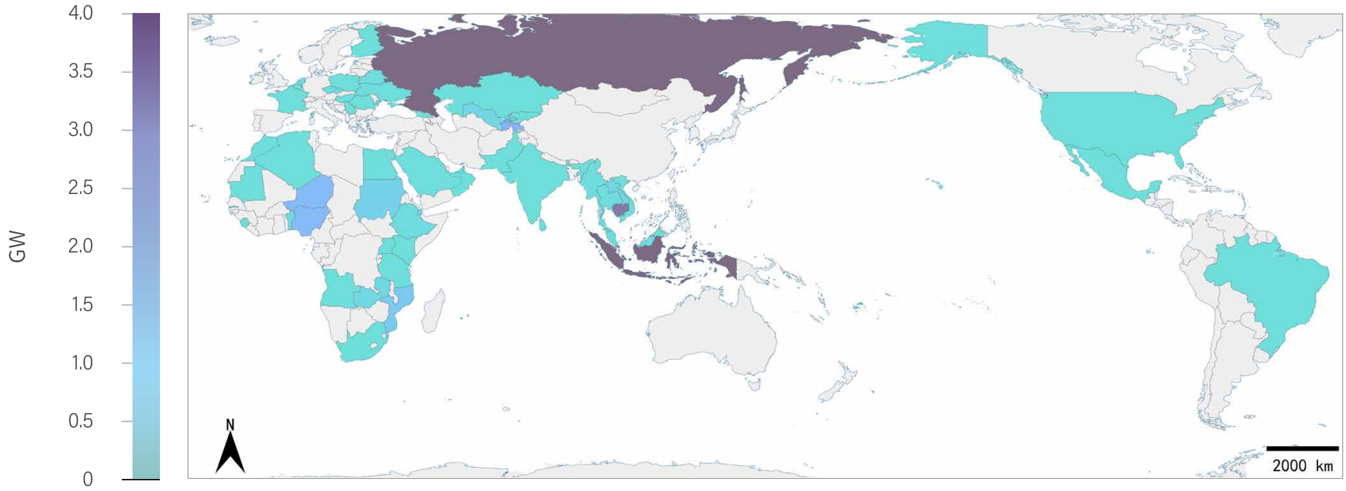
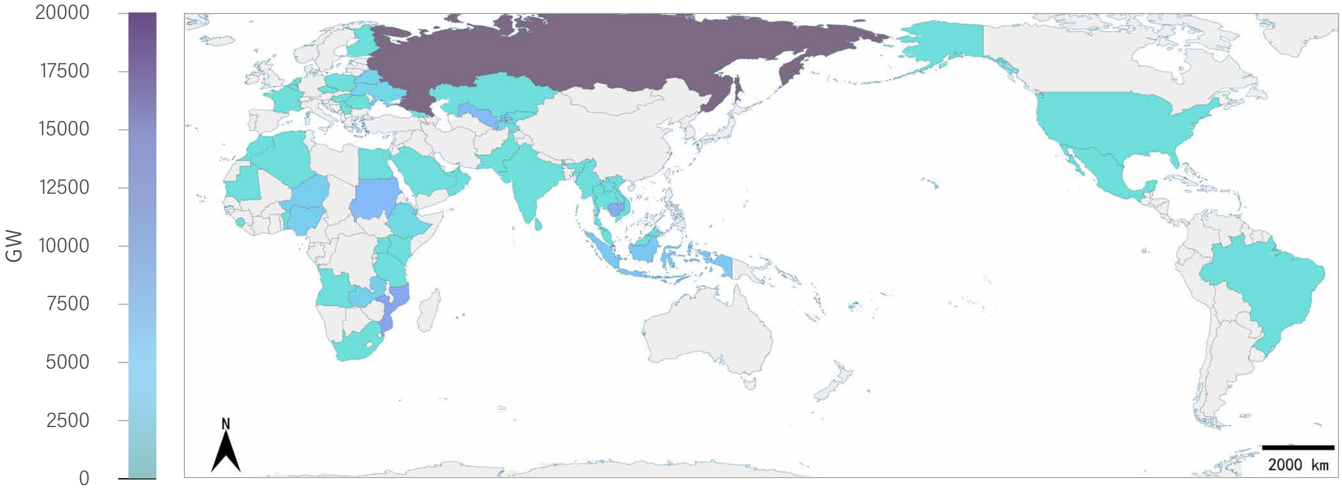
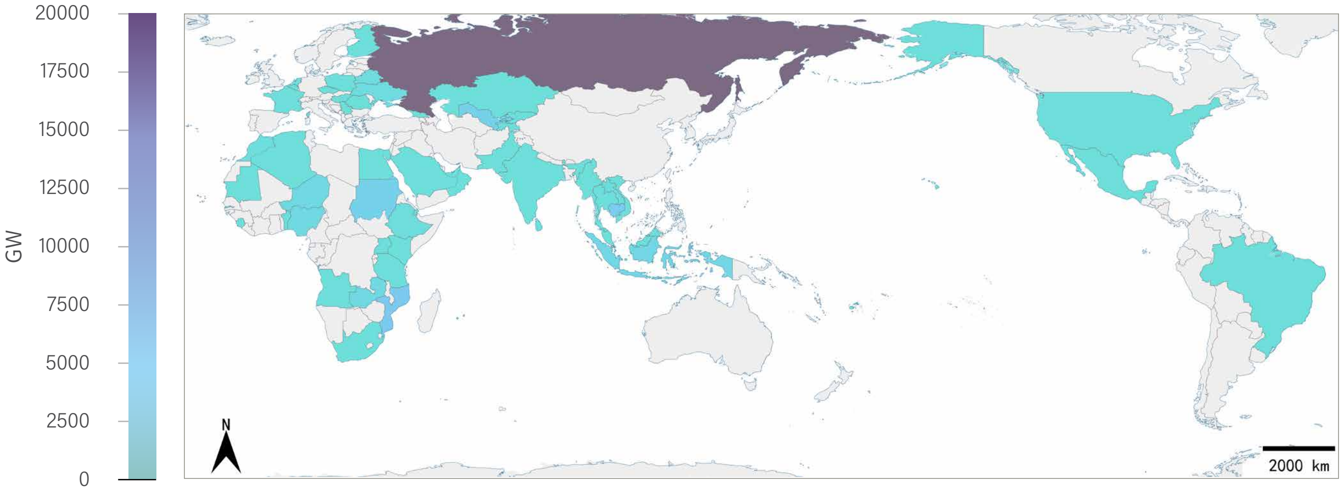


FIGURE 15 | Technical Potential of Wind Power Projects in COIPs (cont.)

c. Annual Wind Power Generation (Minimum Turbine Spacing Scenario)



d. Annual Wind Power Generation (Maximum Turbine Spacing Scenario)



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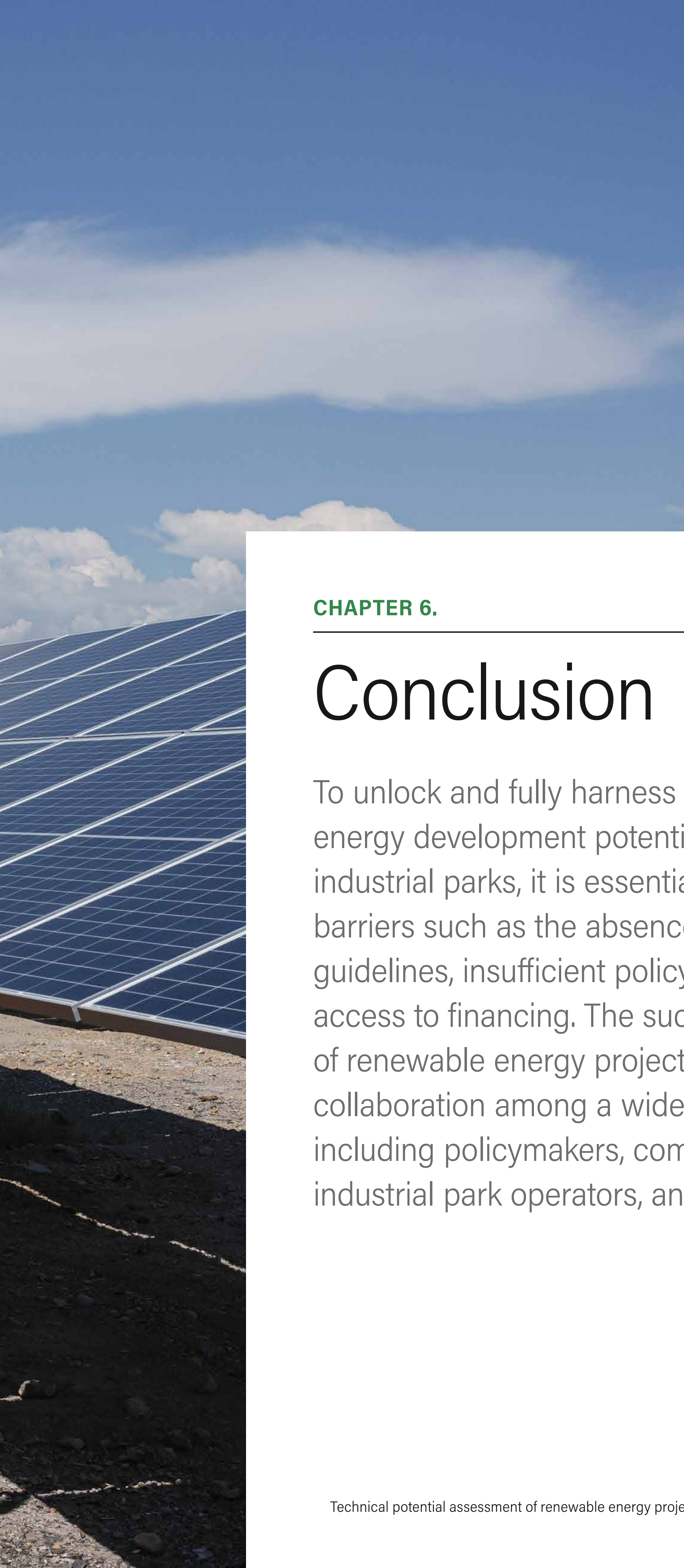


CHAPTER 6.

Conclusion

To unlock and fully harness the significant renewable energy development potential embedded within industrial parks, it is essential to overcome key barriers such as the absence of standardized guidelines, insufficient policy incentives, and limited access to financing. The successful implementation of renewable energy projects requires coordinated collaboration among a wide range of stakeholders, including policymakers, commercial investors, industrial park operators, and financial institutions.

COIPs distribution mainly in Asia, Africa, and Europe; multifunctional integrated and agro-industrial parks being the most numerous

According to the database COIPD established in this report, as of 2022, there were 159 COIPs in operation worldwide. Among these parks, 71 are located in Asia (45%), 39 in Europe (25%), and 44 in Africa (28%). The remaining parks include 3 in North America, 1 in South America, and 1 in Oceania.

In terms of park type, the distribution includes 59 multifunctional integrated parks, 22 processing and manufacturing parks, 15 resource utilization parks, 44 agro-industrial parks, 10 technology R&D parks, and 9 trade and logistics parks. Multifunctional integrated parks and agro-industrial parks are the most common, accounting for 37% and 28% respectively, while technology R&D parks and trade and logistics parks represent the smallest, each representing 6%.

The vast majority of these COIPs were established after 2000, with 63% being built after 2013.

RE projects in COIPs demonstrate both technical and investment potential

Land availability has been a major challenge for large-scale RE deployment. COIPs, utilizing noncompetitive land use, can serve as ideal locations for RE development. For COIPs located in regions rich in wind and solar resources, developing RE projects such as rooftop solar PV system not only has significant technical potential but can also offer substantial opportunities for emission reductions, thereby demonstrating competitive investment potential.

Investment in RE projects in COIPs could reach CNY 2.064 billion, which is equivalent to 1.24 times China's direct investment in Egypt in 2022 (MOFCOM 2023). In the future completion scenario, annual PV power generation in industrial and commercial parks could be the same as the European Union's 2023 solar power output, with potential investment of about CNY 552 million. The figure on farmland in agro-industrial parks could reach 1.78 times the European Union's 2023 PV power output, attracting potential investment of about CNY 1.129 billion. Wind power projects in COIPs could generate investments of approximately CNY 383 million in total.

The technical potential for RE development varies across different regions where COIPs are located. For solar power, under current satellite imagery scenarios, the industrial and commercial parks with the highest solar PV development potential are in Southeast Asia (Cambodia and Indonesia) and the Middle East (United Arab Emirates). Considering resource potential or future completion scenarios, the top potential regions are Southeast Asia (Cambodia and Indonesia) and Africa (Nigeria). Agro-industrial parks show the highest solar PV potential in Southeast Asia, followed by Northern Eurasia and Central Asia. For wind power, COIPs in Northern Eurasia exhibit the greatest potential, followed by Southeast Asia and Africa.

Different types of COIPs also demonstrate varied technical potential for RE development. Multifunctional integrated parks have the highest solar PV development potential, followed by processing and manufacturing parks, while technology R&D parks show the lowest potential. For wind energy, agro-industrial parks lead in wind power potential, followed by technology R&D parks and multifunctional integrated parks.

RE projects in COIPs highlight China's commitment to global decarbonization efforts

The large-scale deployment of RE projects in COIPs—including rooftop PV systems, ground-mounted PV systems, and wind power systems—not only attract direct investment but also reduce tremendous carbon emissions. Fully unlocking these potentials will support host countries in achieving their targets in climate change and RE. As a key player in international trade and investment, China shows its contribution to global decarbonization efforts through COIPs green initiatives while pursuing its domestic "dual carbon" goals of peaking carbon emissions and achieving carbon neutrality.

The deployment of RE projects in COIPs contributes to global net zero emissions target. By 2050, if the solar and wind power potential in COIPs is fully developed under the future completion scenario, it would contribute about 2% to the global RE installed capacity needed for net zero emissions. If this development is completed before 2030, the contribution could significantly increase to nearly 5% (IEA 2023).

Fostering multistakeholder cooperation to unlock and transform RE potential in COIPs

COIPs operate under the principles of government guidance, enterprise leadership, international rules, and market-driven operation. However, apart from a few pilot projects developed through bilateral and multilateral international cooperation mechanisms, there have been few solar and wind power projects initiated by park developers.

To unlock the substantial RE potential within COIPs, several key barriers must be addressed, including the lack of standard guidelines, incentives, and funding. It is crucial to establishing a multiple-stakeholder partnership among policymakers, investors, industrial park operators, and financial institutions throughout the project life cycle.

FOR POLICYMAKERS

COIPs serve as key platforms for China's overseas RE development and vital contributors to global climate efforts. Policymakers should guide low-carbon development by refining policies with clear guidance and actionable pathways.

These industrial parks facilitate the rapid overseas deployment of China's advanced clean energy technologies and strengthen the domestic RE sector through experience gained abroad. The emission reductions in COIPs also help host countries achieve their climate and low-carbon goals, underscoring China's contributions to global decarbonization.

- Refining policies for green COIPs

  Developing detailed guidelines for green COIPs based on existing frameworks such as the 14th Five-Year Plan for Commerce Development, Green Development Guidelines for Overseas Investment and Cooperation, and national/provincial regulations for overseas ETCZs or industrial parks. These policies should encourage parks to establish scientific low-carbon plans, increase RE consumption, and quantify emission reductions.

- Establishing standardized platforms and indicators

  Creating platforms like a standardized committee for COIPs low-carbon development, to coordinate standards on investment, development, construction, and operations. This includes publishing official standards such as a low-carbon development indicator system.

  It is also crucial to share best practices from domestic industrial and low-carbon parks and align with international standards to provide unified and clear guidance.

- Innovating evaluation and incentive mechanisms

  Developing an innovative evaluation mechanism with long-term and predictable incentive policies for COIPs' low-carbon development. Given the years-long timeline from project approval to operation, incentives must extend across the park life cycle. Current assessment methods focus on construction and economic indicators but lack specific low-carbon metrics. The Evaluation Measures for Zhejiang Overseas Industrial Parks is a noteworthy example of including green development as a key indicator.

- Leveraging international cooperation mechanisms

  Using existing bilateral and multilateral cooperation mechanisms to support pilot low-carbon COIPs. Public funding can cover the initial costs of RE projects. Leading industrial parks should be encouraged to pioneer low-carbon practices. Initiatives such as low-carbon demonstration zones under the South-South Climate Cooperation framework offer valuable examples of scalable and replicable models.

FOR BUSINESS INVESTORS AND COIP OPERATORS

- Developing strategic plans based on local context

  This involves understanding host countries' low-carbon policies and RE targets, such as Egypt's Integrated Sustainable Energy Strategy 2035, which aims for 42% of its electricity to come from renewables by 2035. COIP operators should analyze local commercial power pricing policies and energy supply dynamics, while referencing international best practices and standards. Based on this analysis, they should develop comprehensive energy plans for COIPs, including power supply plans with RE solutions, coordinated energy system planning, specialized low-carbon initiatives, and regular updates to the green sections of the existing overall park development plan.

- Maximizing resource and market opportunities

  Most COIPs are strategically located in regions rich in renewable resources and close to end markets of renewable products like PV panels. Developers should take full advantage of these market conditions and the RE potential to explore sustainable business partnerships and profit models. These collaborations could involve industrial park developers, tenant companies, and RE investors, with various operational models such as self-consumption, partial grid connection, or full grid connection. For example, in the China-Egypt TEDA Suez Industrial Park, tenant company Jushi has partnered with local stakeholders to launch a 7 MW rooftop solar PV project for its manufacturing operations.

- Transforming COIPs from fossil fuels to renewables

  Developers can replace fossil fuels like diesel with RE in COIPs. By participating in carbon market mechanism, such as EU Emissions Trading System or voluntary carbon markets, they can reduce carbon emissions and recover initial investments for RE projects.

- Fostering RE collaboration

  COIPs should be positioned as key hubs for RE investments, combining application and production. For example, RE companies targeting European markets could prioritize setting up projects in COIPs located in Africa, the Middle East, and Eastern Europe to maximize strategic and operational advantages.

FOR FINANCIAL INSTITUTIONS

- Recognizing COIPs as key platforms for China's overseas investment and international cooperation

  As COIPs transition toward greater sustainability, financial institutions can draw on valuable insights from China's climate finance pilot projects. They can select COIPs in key regions to develop low-carbon demonstration projects, such as small-scale rooftop solar PV systems, and provide essential financial support.

- Developing a project pipeline pool for low-carbon investment projects in COIPs

  Based on the findings of this report, financial institutions can develop a comprehensive pipeline pool for identifying low-carbon investment opportunities in COIPs. This pool could include indicators such as preferred industrial park types, regions, and compatibility with RE projects. These criteria would enable financial institutions to map and support promising low-carbon projects within COIPs more effectively.

- Adopting tailored energy strategies and blended financing models

  Financial institutions can adopt tailored energy strategies that align with their specific priorities, such as profitability, pay period, emission reductions, and social impacts. For example, the China-Africa Development Fund's investment in Nigeria's Lekki Free Trade Zone demonstrates its focus on enhancing sustainable capacity in Africa.

  In addition, financial institutions can explore blended financing models, which combine public and private sector funding to scale up projects, enabling broader implementation of low-carbon initiatives. These efforts can be further supported with technical assistance and capacity-building programs, fostering successful low-carbon development in COIPs through collaboration and policy frameworks.


CHAPTER 7.

Discussions

This report primarily investigates China's overseas industrial parks from a holistic perspective, with a focus on assessing the technical potential for developing renewable energy projects within these sites. Accordingly, the analysis adopts a meso-level research approach and, to a certain extent, relaxes the precision of the assessment, such as electricity demand for specific park.

Meso-level research perspective

This report takes a distinctive approach by focusing on COIPs. Previous studies either evaluate the technical potential of RE development from a macro perspective—such as a global, regional, or national scale—or concentrate on specific solar or wind power projects at the micro-level. In contrast, our research examines the expected technical potential for RE development across these industrial parks, requiring different evaluation methods and level of detail.

Throughout the research process, we applied either top-down or bottom-up calculation methods for different indicators, depending on specific conditions. Since the estimation methods for power generation and installed capacity are different, it is not appropriate to make direct comparisons between solar and wind power technical potentials. Future research could undertake comparative studies of solar and wind power generation and installed capacity within specific COIPs once more data on the industrial parks becomes available.

This report focuses specifically on technical potential rather than economic potential. We made this choice because the profitability of RE projects in COIPs is closely tied to the host country's power pricing and regulations. It is recommended that future research select representative COIPs to conduct economic potential and financial performance evaluations.

Moderate ease over accuracy of assessment

COIPD developed in this report uses web-based information research methods. However, some of the data and information for certain parks may not be accurate. To address this issue, we improve the data quality through manual cross-checking and classification of the industrial parks. When collecting GIS-based data, we dealt with missing boundary data by using manual image recognition.

This report evaluates the technical potential of solar and wind power separately, without considering the feasibility of wind-solar hybrid projects, which will require further studies.

In assessing the technical potential of PV development, we assumed flat rooftops across all COIPs, without accounting for possible variations in roof angles that may exist in different overseas parks. During the evaluation of PV potential in agro-industrial parks, we did not assess how the yields of different crops would be affected, as it was beyond our research scope.

For the technical potential of wind power, we simplified several factors. We did not consider the issue of dispersed park areas that could affect wind turbine installations. We also simplified turbine layout calculation without incorporating wake effect estimations. These aspects could be explored in more detail through future case studies of specific COIP renewable projects, based on comprehensive field data.

Further research needed on specific power demand

This report examines the technical potential for RE from the supply-side perspective, focusing on the possible development with current technology. However, the actual power demand of COIPs is also a key investment consideration. If power consumption is lower than power generation, it becomes necessary to reconsider the business models and collaboration strategies among multiple stakeholders, including the COIP operators, tenant companies, and the RE developers. Managing the excess power—whether by feeding it into the grid or finding alternative uses—can be best addressed through detailed case studies of specific industrial parks. These issues deserve further investigation in future research.

Appendices

APPENDIX A

Overview of 159 COIPs in this report

TABLE A-1 | Overview of 159 COIPs in this report

NO.	NAME OF COIP	TIERED ANALYSIS CLASSIFICATION	TYPE OF PARK
1	Sino-Hungarian Borsod Industrial Park	Tier 1	Multifunctional integrated park
2	Central European Trade and Logistics Cooperation Zone in Hungary	Tier 1	Trade and logistics park
3	PT Kawasan Industri Terpadu Indonesia China, or Guangxi-Indonesia Economic and Trade Zone in Wonogiri	Tier 1	Multifunctional integrated park
4	Djibouti International Free Trade Zone	Tier 1	Multifunctional integrated park
5	China-Egypt TEDA Suez Economic and Trade Cooperation Zone	Tier 1	Multifunctional integrated park
6	China-Ethiopia Huajian Light Industrial Town	Tier 1	Multifunctional integrated park
7	Ethiopia Eastern Industrial Zone	Tier 1	Multifunctional integrated park
8	Ogun Guangdong Free Trade Zone, Nigeria	Tier 1	Multifunctional integrated park
9	Lekki Free Zone (China-Nigeria Economic and Trade Cooperation Zone)	Tier 1	Multifunctional integrated park
10	Mohammed VI Tangier Tech City, Morocco	Tier 1	Multifunctional integrated park
11	Hengyi Industries Pulau Muara Besar Petrochemical Complex	Tier 1	Resource utilization park
12	Sihanoukville Special Economic Zone in Cambodia	Tier 1	Multifunctional integrated park
13	Cambodia Kampot Special Economic Zone/Fulongsheng Industrial Park/Kampot China-Cambodia Industrial Special Economic Zone	Tier 1	Multifunctional integrated park

TABLE A-1 | Overview of 159 COIPs in this report (cont.)

NO.	NAME OF COIP	TIERED ANALYSIS CLASSIFICATION	TYPE OF PARK
14	Mauritius Jin Fei Economic and Trade Cooperation Zone	Tier 1	Multifunctional integrated park
15	Thai-Chinese Rayong Industrial Zone	Tier 1	Multifunctional integrated park
16	Great Stone China-Belarus Industrial Park	Tier 1	Multifunctional integrated park
17	Vientiane Saysettha Development Zone	Tier 1	Multifunctional integrated park
18	Zambia-China Economic and Trade Cooperation Zone (Lusaka park)	Tier 1	Multifunctional integrated park
19	Zambia-China Economic and Trade Cooperation Zone (Chambishi park)	Tier 1	Multifunctional integrated park
20	China-Vietnam (Shenzhen-Haiphong) Economic and Trade Cooperation Park	Tier 1	Processing and manufacturing park
21	Linh Trung Export Processing Zone and Industrial Park, Vietnam	Tier 1	Multifunctional integrated park
22	Longjiang Industrial Park, Vietnam	Tier 1	Multifunctional integrated park
23	China-Uzbekistan Modern Agricultural Science and Technology Demonstration Park	Tier 2	Agro-industrial park
24	Uzbekistan Pengsheng Industrial Park	Tier 2	Processing and manufacturing park
25	Uganda-China (Guangdong) Free Zone of International Industrial Cooperation	Tier 2	Resource utilization park
26	China-Uganda Agricultural Cooperation Industrial Park	Tier 2	Agro-industrial park
27	China-Russian Modern Agriculture Industrial Cooperation Zone (Primorsky Krai)	Tier 2	Agro-industrial park
28	China-Russia Tomsk Wood Industry Trade Cooperation Zone	Tier 2	Agro-industrial park
29	Ussuriysk Economic and Trade Cooperation Zone, Russia	Tier 2	Processing and manufacturing park
30	Russia Longyue Forestry Economic and Trade Cooperation Zone	Tier 2	Agro-industrial park
31	Gambia (Hubei) Overseas Economic and Trade Cooperation Zone	Tier 2	Agro-industrial park
32	Hisense South Africa Industrial Park in Atlantis Special Economic Zone, Cape Town	Tier 2	Processing and manufacturing park
33	China-Indonesia Julong Agricultural Industry Cooperation Zone	Tier 2	Agro-industrial park

TABLE A-1 | Overview of 159 COIPs in this report (cont.)

NO.	NAME OF COIP	TIERED ANALYSIS CLASSIFICATION	TYPE OF PARK
34	PT Indonesian Morowali Industrial Park	Tier 2	Resource utilization park
35	Obi Industrial Park, Indonesia	Tier 2	Resource utilization park
36	Indonesia Weda Bay Industrial Park	Tier 2	Multifunctional integrated park
37	Asia Star Agricultural Industry Cooperation Zone, Kyrgyzstan	Tier 2	Agro-industrial park
38	Comprehensive Service Cooperation Zone of East Africa Commercial & Logistics Industrial Park	Tier 2	Trade and logistics park
39	Jiangsu-Shinyanga Agricultural Industrial Park	Tier 2	Agro-industrial park
40	China-Tajikistan Agricultural Cooperation Demonstration Park	Tier 2	Agro-industrial park
41	Serbia Belmax Trade and Logistics Park	Tier 2	Trade and logistics park
42	Hofusan Industrial Park, Mexico	Tier 2	Multifunctional integrated park
43	Angola Aode Industrial Park	Tier 2	Multifunctional integrated park
44	Nigeria Belt and Road Initiative Industrial Park	Tier 2	Multifunctional integrated park
45	Nigeria Weindustry Park	Tier 2	Agro-industrial park
46	Pakistan Haier-Ruba Economic Zone	Tier 2	Processing and manufacturing park
47	Czech (Zhejiang) Economic and Trade Cooperation Zone	Tier 2	Multifunctional integrated park
48	China-Fiji Comprehensive Multifunctional Fishery Industrial Park	Tier 2	Agro-industrial park
49	China-Cambodia International Agricultural Cooperation Demonstration Zone	Tier 2	Agro-industrial park
50	Huaxin (Cambodia) Building Material Industrial Park (Chakrey Ting Factory)	Tier 2	Resource utilization park
51	Holley Cambodia Agro-ecological Park	Tier 2	Agro-industrial park
52	Cambodia-China Tropical Eco-agriculture Cooperation Demonstration Zone	Tier 2	Agro-industrial park
53	Cambodia Kratié Special Economic Zone	Tier 2	Multifunctional integrated park
54	China-Belgium Technology Center	Tier 2	Technology R&D park
55	TCL Poland Plant	Tier 2	Multifunctional integrated park
56	Guangken Thai Hua Natural Rubber Processing Economic and Trade Cooperation Zone	Tier 2	Agro-industrial park
57	Myotha Industrial Park City in Mandalay, Myanmar	Tier 2	Processing and manufacturing park
58	Hangzhou Silicon Valley Innovation Center (Q Bay Center)	Tier 2	Technology R&D park
59	Hailiang Copper Texas Inc.	Tier 2	Resource utilization park
60	Laos-China Modern Agricultural Technology Demonstration Center	Tier 2	Agro-industrial park
61	China-Sudan Agricultural Cooperation Development Zone	Tier 2	Agro-industrial park

TABLE A-1 | Overview of 159 COIPs in this report (cont.)

NO.	NAME OF COIP	TIERED ANALYSIS CLASSIFICATION	TYPE OF PARK
62	China-Mozambique Agricultural Technology Demonstration Center	Tier 2	Agro-industrial park
63	Lianhe Economic and Trade Cooperation Zone in Mozambique	Tier 2	Agro-industrial park
64	Centre Chinois de Developpement Economique et Commercial au Benin	Tier 2	Multifunctional integrated park
65	Zambia Agricultural Products Processing Cooperation Park	Tier 2	Agro-industrial park
66	Phuoc Dong Business Park-Ningbo Park	Tier 2	Processing and manufacturing park
67	Dubai Yiwu Market	Tier 2	Trade and logistics park
68	East Kalimantan Agricultural and Industrial ETCZ, Indonesia	Tier 3	Agro-industrial park
69	Russia Taiyuan Agriculture and Husbandry Cluster	Tier 3	Agro-industrial park
70	Cambodia-China Comprehensive Investment and Development Pilot Zone	Tier 3	Processing and manufacturing park
71	Dongning Huayang Overseas Green Agriculture Cooperation Park	Tier 3	Agro-industrial park
72	Mozambique Wanbao Rice Farm	Tier 3	Agro-industrial park
73	Heihe Beifeng Sino-Russia Amur Agriculture (Husbandry) Industrial Park	Tier 3	Agro-industrial park
74	Zhongtai (Dangara) New Silk Road Agriculture and Textile Industrial Park, Tajikistan	Tier 3	Agro-industrial park
75	CNBM Zambia Industrial Park	Tier 3	Resource utilization park
76	Hanking-Makmur Industrial Park	Tier 3	Multifunctional integrated park
77	Laos Yunxiang Industrial Park	Tier 3	Agro-industrial park
78	China-ASEAN Beidou Technology City	Tier 3	Technology R&D park
79	China-Laos Khammouane Potash Salt Comprehensive Development Zone	Tier 3	Multifunctional integrated park
80	Polaris Pacesetter Free Trade Zone (Nigeria)	Tier 3	Multifunctional integrated park
81	China-Ukraine Fanda Agricultural Technology Demonstration Park	Tier 3	Agro-industrial park
82	China-Saudi Arabia Jazan Industrial Zone	Tier 3	Resource utilization park
83	Hengrui Park in Cambodia	Tier 3	Agro-industrial park
84	Ethiopia China Communications Construction Company (CCCC) Industrial Park (Arerti Industrial Parks by CCCC)	Tier 3	Processing and manufacturing park
85	Jiangxi (Malaysia) Modern Agricultural Technology Industrial Park	Tier 3	Agro-industrial park
86	Delong Industrial Park, Indonesia	Tier 3	Resource utilization park
87	Boten Specific Economic Zone, Laos	Tier 3	Multifunctional integrated park
88	Adama Industrial Park, Ethiopia	Tier 3	Processing and manufacturing park
89	China-Tajikistan (Henan) Agriculture Technology Demonstration Center	Tier 3	Agro-industrial park

TABLE A-1 | Overview of 159 COIPs in this report (cont.)

NO.	NAME OF COIP	TIERED ANALYSIS CLASSIFICATION	TYPE OF PARK
90	Dire Dawa Industrial Park, Ethiopia	Tier 3	Processing and manufacturing park
91	China-UAE Industrial Capacity Cooperation Demonstration Zone, UAE	Tier 3	Multifunctional integrated park
92	Malaysia-China Kuantan Industrial Park	Tier 3	Multifunctional integrated park
93	China-Oman (Duqm) Industrial Park	Tier 3	Multifunctional integrated park
94	Kyaukphyu Special Economic Zone, Myanmar	Tier 3	Multifunctional integrated park
95	Manga-Mungassa Special Economic Zone in Beira, Mozambique	Tier 3	Multifunctional integrated park
96	Irkutsk Chenglin Agricultural Products Trade and Logistics Park, Russia	Tier 3	Trade and logistics park
97	Polaris Forestry Trade Zone, Russia	Tier 3	Agro-industrial park
98	Pearl River Special Economic Zone, Kenya	Tier 3	Multifunctional integrated park
99	CFLD Karawang New Industry City	Tier 3	Multifunctional integrated park
100	Indonesia Ketapang Smart Home Industrial Cooperative Park	Tier 3	Multifunctional integrated park
101	Astana Motors Manufacturing Kazakhstan	Tier 3	Technology R&D park
102	China Jiangling Economic and Trade Cooperation Zone, Algeria	Tier 3	Resource utilization park
103	Hualing International Special Economic Zone, Georgia	Tier 3	Multifunctional integrated park
104	Sino France Economic Cooperation Zone, now named EuroSity	Tier 3	Multifunctional integrated park
105	Liao Shen Industrial Park, Uganda	Tier 3	Multifunctional integrated park
106	Qilu (Cambodia) Special Economic Zone	Tier 3	Processing and manufacturing park
107	Rashakai Special Economic Zone in Khyber Pakhtunkhwa, Pakistan	Tier 3	Multifunctional integrated park
108	Hualing Free Industrial Park in Kutaisi, Georgia	Tier 3	Multifunctional integrated park
109	Hunan Industrial Park, Thailand	Tier 3	Processing and manufacturing park
110	Ethiopia-Hunan Industrial Park	Tier 3	Multifunctional integrated park
111	Ningbo Industrial Park, Nigeria	Tier 3	Resource utilization park
112	Serbia-China Industrial Park	Tier 3	Multifunctional integrated park
113	China Egypt Mankai Textile Industrial Park	Tier 3	Processing and manufacturing park
114	Hawassa Industrial Park, Ethiopia	Tier 3	Processing and manufacturing park
115	Gwadar Free Zone, Pakistan	Tier 3	Multifunctional integrated park
116	Zhongyang (Zambia) Ecological Agriculture Industrial Park	Tier 3	Agro-industrial park
117	Kilinto Industrial Park, Ethiopia	Tier 3	Processing and manufacturing park
118	Port City Colombo, Sri Lanka	Tier 3	Multifunctional integrated park
119	Sino-Uganda Mbale Industrial Park	Tier 3	Multifunctional integrated park

TABLE A-1 | Overview of 159 COIPs in this report (cont.)

NO.	NAME OF COIP	TIERED ANALYSIS CLASSIFICATION	TYPE OF PARK
120	Hunan Agricultural Industrial Park, Northern Europe	Tier 3	Agro-industrial park
121	Cambodia-Shandong Sunshell (Svay Rieng) Special Economic Zone	Tier 3	Processing and manufacturing park
122	Pearl of the Baltic Sea Economic and Trade Cooperation Zone in St. Petersburg, Russia	Tier 3	Multifunctional integrated park
123	China-Russia Dalnerechensk Timber Processing Economic and Trade Industrial Park	Tier 3	Agro-industrial park
124	Alabuga Harbin Industrial Park, Russia	Tier 3	Technology R&D park
125	Ajman China Mall, UAE (also known as the Middle East China Commodity Purchasing Center)	Tier 3	Multifunctional integrated park
126	Huayu Economic and Trade Cooperation Zone in Primorsky Krai, Russia	Tier 3	Multifunctional integrated park
127	China-Mauritania (Hongdong) Marine Economic Cooperation Park	Tier 3	Multifunctional integrated park
128	Chery Brazil Industrial Park (Chery Automobile Industrial Park)	Tier 3	Technology R&D park
129	Hongda Logistics Industrial Park in Vladimir, Russia	Tier 3	Trade and logistics park
130	Naili Forestry Industrial Park, Russia	Tier 3	Agro-industrial park
131	China-Tajikistan Industrial Park	Tier 3	Resource utilization park
132	Yun Zhong Industrial Park in Bac Giang, Vietnam	Tier 3	Multifunctional integrated park
133	TBEA (India) Green Energy Park	Tier 3	Resource utilization park
134	China-UAE (Dubai) Food Industrial Cluster	Tier 3	Multifunctional integrated park
135	China-Africa Modern Animal Husbandry Circular Economy Industrial Zone	Tier 3	Agro-industrial park
136	Shengli Vietnam Special Steel Co. Ltd. Industrial Park	Tier 3	Resource utilization park
137	Midea Technology Industrial Park	Tier 3	Technology R&D park
138	Industrial Innovation Park in Chelyabinsk, Russia	Tier 3	Technology R&D park
139	China-UAE (Fujairah) Trade and Logistics Park	Tier 3	Trade and logistics park
140	Africa (Uganda) Shandong Industrial Park	Tier 3	Processing and manufacturing park
141	Uzbekistan Anjiyan Textile Park	Tier 4	Processing and manufacturing park
142	China-Russia Agriculture and Husbandry Demonstration Park	Tier 4	Agro-industrial park
143	Nizhneleninskoye Wood Processing Park, Russia	Tier 4	Agro-industrial park
144	Bashmakovo Wood Processing Park, Russia	Tier 4	Agro-industrial park
145	Grodekovo New North Wood Processing Park, Russia	Tier 4	Agro-industrial park
146	Berezovka Petrochemical and Building Materials Processing Park in Amur Oblast, Russia	Tier 4	Resource utilization park
147	Amur Comprehensive Park, Russia	Tier 4	Multifunctional integrated park

TABLE A-1 | Overview of 159 COIPs in this report (cont.)

NO.	NAME OF COIP	TIERED ANALYSIS CLASSIFICATION	TYPE OF PARK
148	Suifenhe Yuejin Industrial Park	Tier 4	Technology R&D park
149	Pengrui Overseas Forestry Cutting and Processing Zone	Tier 4	Agro-industrial park
150	China Minsheng Investment Indonesia Industrial Park	Tier 4	Multifunctional integrated park
151	China-Kazakhstan Jintudi High-Tech Industrial Park	Tier 4	Technology R&D park
152	Sierra Leone Guoji Industry and Trade Park	Tier 4	Multifunctional integrated park
153	Yuemei Nigeria Textile Industrial Park	Tier 4	Processing and manufacturing park
154	ICBC-Ruyi Masood Textile and Garment Industrial Park, Pakistan	Tier 4	Processing and manufacturing park
155	Hambantota Port Industrial Park, Sri Lanka	Tier 4	Multifunctional integrated park
156	HuaYue Cambodia Green Agriculture Industrial Park	Tier 4	Agro-industrial park
157	Saudi Arabia (Jeddah) China Town	Tier 4	Trade and logistics park
158	Central European Logistics Hub in Lodz, Poland	Tier 4	Trade and logistics park
159	Maidao Industrial Park, Romania	Tier 4	Processing and manufacturing park
160	Sino-Europe Logistics Park Venlo Region	Tier 4	Multifunctional integrated park

Notes: The Zambia-China Economic and Trade Cooperation Zone consists of one zone with two industrial parks, counted as one. Therefore, the actual number of COIPs is 159. COIPs = China's overseas industrial parks. R&D = research and development. ETCZ = economic and trade cooperation zone. CNBM = China National Building Material Group. ASEAN = Association of Southeast Asian Nations. UAE = United Arab Emirates. ICBC = International Commercial Bank of China.

APPENDIX B

China's overseas industrial parks database

Basic information of industrial parks

The basic information of COIPs includes the park name, the continent where the COIP is located, its host country, the development level of the host country, its managing companies in China, company type, and the starting year of construction.

Type of park

COIPs can be categorized into six types based on their primary business focus:

- Processing and manufacturing parks. These focus on light manufacturing, textiles, building materials, and metal processing.
- Resource utilization parks. These specialize in the development and processing of resources like mineral, forest, oil, and gas.
- Agro-industrial parks. These engage in agriculture, including planting, breeding, developing, processing, purchasing, and warehousing of products like grains, economic crops, and livestock.
- Trade and logistics parks. These center on product display, transportation, warehousing, distribution, information processing, and distribution processing.
- Technology R&D parks. These focus on rail transit, automotive, communications, engineering machinery, and marine engineering.
- Multifunctional integrated parks. These aim for diversified and multifaceted development.

Park classification levels

The level of a COIP is determined by official assessments:

- National level. These are parks approved as overseas economic and trade cooperation zones by MOFCOM or recognized as overseas agricultural cooperation demonstration zone by the Ministry of Agriculture and Rural Affairs (MARA).
- Provincial level. These are parks evaluated by provincial commerce departments (either alone or with provincial finance departments), currently involving Zhejiang, Shandong, Hubei, and Guangdong provinces.
- Other parks. Those parks are not included in national or provincial approval lists.

If an industrial park receives national-level approval, it automatically qualifies as a provincial-level park.

The information of classification level is sourced from the official websites of China's State Council, MOFCOM, and the provincial commerce authorities. According to the database in this report, there are 29 national-level parks, 31 provincial-level parks, and 101 other parks.

The Asia Star Agricultural Industry Cooperation Zone in Kyrgyzstan is recognized both by MOFCOM as an overseas ETCZ and by MARA as an overseas agricultural cooperation demonstration zone.

Total investment and planned area

The total investment amount refers to all the planned investment across multiple phases (if applicable) for the industrial park. The planned area refers to the total park area across multiple phases (if applicable), including both industrial and agricultural land uses. The information comes from various official sources like MOFCOM, COIPs official websites, Going Global public service platform, CCPIT's overseas industrial parks platform, ACFIC, the Guide for Countries and Regions on Overseas Investment and Cooperation issued by MOFCOM, local government reports on international cooperation and development, and authoritative media reports. If reliable data is not available, this section will be left blank.

Tiered analysis classification

The 159 overseas industrial parks are categorized into four tiers for analysis based on research requirement and information completeness:

- Tier 1 (22 parks). Leading parks including 11 recently approved national-level parks and the other 11 parks (including 4 provincial-level and 7 other parks) that were either previously recognized as national-level or established/visited by national leaders. (The Zambia-China Economic and Trade Cooperation Zone is considered as one zone with two parks, so it is counted as one.)
- Tier 2 (45 parks). Remaining national and provincial-level parks not included in Tier 1.
- Tier 3 (73 parks). Parks with sufficient public data for further analysis, excluding Tier 1 and Tier 2 parks.
- Tier 4 (20 parks). Remaining parks beyond Tier 1, 2, and 3, with basic establishment and investment records but lacking critical detailed information.

Location information

Geographic information of COIPs was obtained through internet map data scraping and verified through two rounds of manual cross-checking. In this process, first, we gather the latitude and longitude coordinates from the map. Considering differences of park names in English and local languages, as well as possible location errors of online maps, we verify the country/regional consistency and the accuracy of land use types. Second, if the initial search results have errors, we try different translations of the park names for search and review. For parks with unclear locations, we check the park's website or other official sources for the address. If an address is provided, we use it. If only an approximate location is available, we make estimates based on descriptions. If the location remains unclear after all these steps, the location is marked as "unknown." The database includes 31 parks with estimated coordinates and 4 with unknown locations.

It is worth noting that 6 COIPs involve multiple parks. While the Zambia-China Economic and Trade Cooperation Zone's two parks (Lusaka and Chambishi) are listed separately due to their complete information, for other multipark zones, only the main park's location is recorded in the database.

APPENDIX C

Rooftop area data collection method for COIPs

Rooftop area data collection method for Tier 1 parks

For Tier 1 parks, the data collection process begins with entering park location information into GEE. Once the park location is identified, polygons are drawn on Google Map's high-resolution satellite imagery layer to mark rooftops within the park. The GEE is then used to calculate and sum individual rooftop areas to obtain the total rooftop area for each park. The specific steps are illustrated in Figure C-1.

MBF roof drawing tool development and application steps

MBF is a global building footprint dataset released by Microsoft under the Open Database License. To quickly obtain rooftop area data for COIPs, this report developed an interactive roof drawing tool based on GEE with an MBF dataset. This tool only requires park location information to outline the park area and extract rooftop information, by which the total rooftop area of each park can be calculated. Compared to the manual selection process used for Tier 1 parks, this tool enables fast selection of rooftops for Tier 2 and Tier 3 parks, while maintaining comparable data quality.

To evaluate the data quality of the roof drawing tool, this report conducted a comparison for the Tier 1 parks. Of the 22 Tier 1 parks, 4 parks were excluded for data missing in the tool. We then compared manually annotated rooftop areas with tool-generated measurements for the remaining 18 parks. The results are shown in Figure C-2.

FIGURE C-1 | Interactive Manual Annotation Process in Google Earth Engine (GEE)

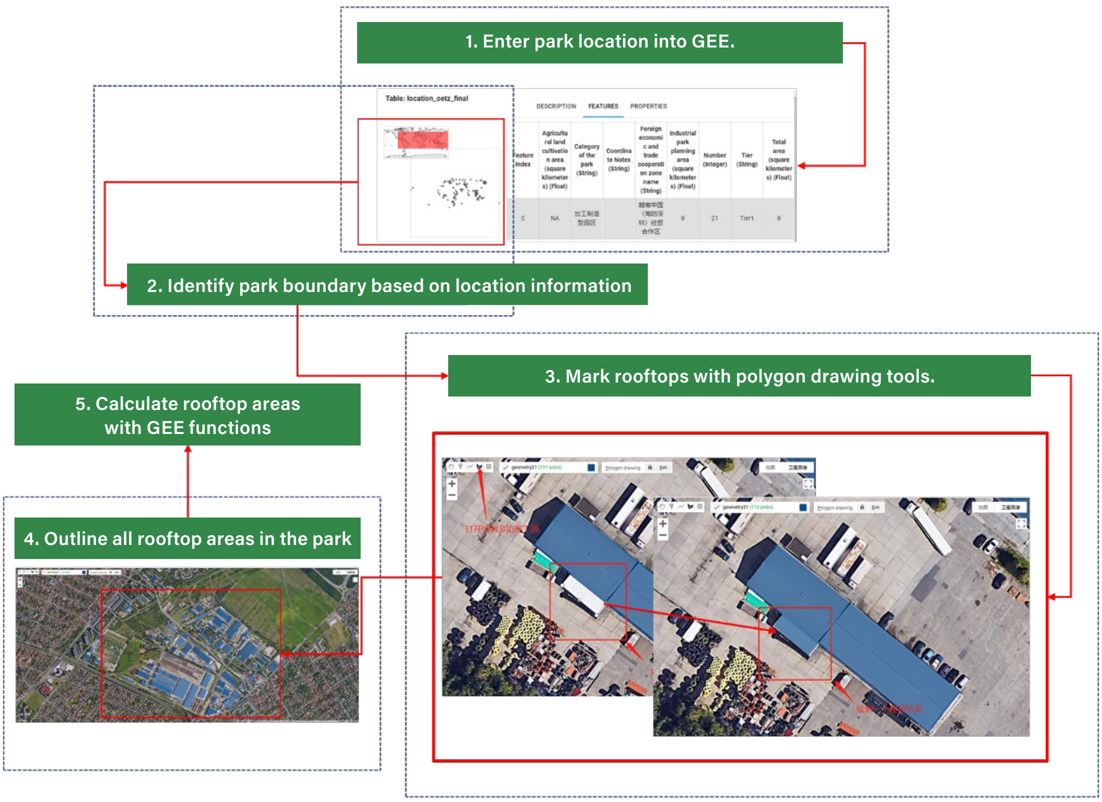
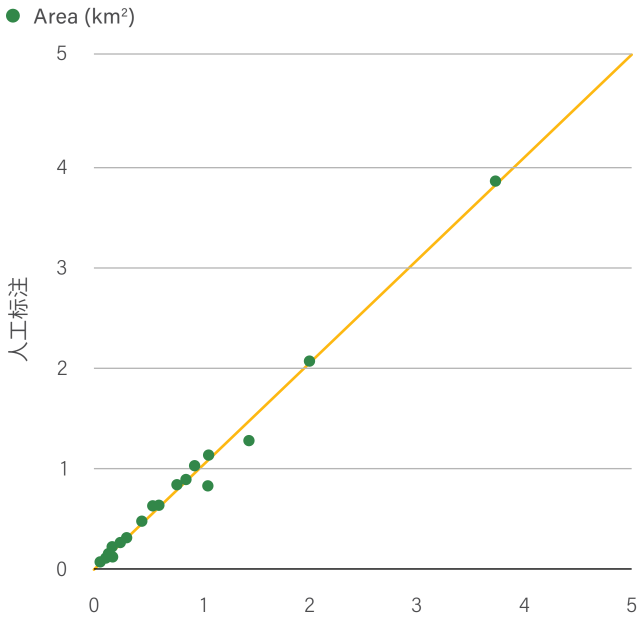


FIGURE C-2 | Rooftop Area Calculation based on Manual Annotation and MBF Roof Drawing Tool



The mean relative error (MRE) was 7.502%. The equation for calculating the MRE is,

$$MRE = 100\% \cdot \frac{1}{n} \sum \left| \frac{x_{true,i} - x_{pred,i}}{x_{true,i}} \right|$$

where:

- *MRE* is the mean relative error;
- $x_{true,i}$ represents the manually annotated area for the i-th sample;
- $x_{pred,i}$ represents the rooftop area annotated with the MBF roof drawing tool for the i-th sample;
- *n* is the number of samples;
- ∑ indicates the summation;
- and || is the absolute value.

Step-by-step instructions for using the MBF tool:

1. Open the interface and enter the park serial number (see Appendix A) in the bottom-left corner. Click “Go to Location” (see Figure C-3).

2. Once redirected to the park’s location, select the interactive polygon drawing tool from the upper-left corner and trace the park’s boundaries (see Figure C-4).

3. Click “Calculate” button in the center once the tracing is complete (see Figure C-5).

4. The map will display all rooftop boundary data within the outlined area. The bottom-right corner will show the park’s basic information, including the geometric center of the outlined area, the Chinese name of the industrial park, the extent of the outlined polygon area, and the total roof area within the park (see Figure C-6).

5. To analyze another park, click “Clear_building” to reset the area statistics and “Clear_polygon” to remove the boundary information of the previous park (see Figure C-7). Repeat steps 1–4 for the next industrial park.

FIGURE C-3 | Enter park serial number in the tool page

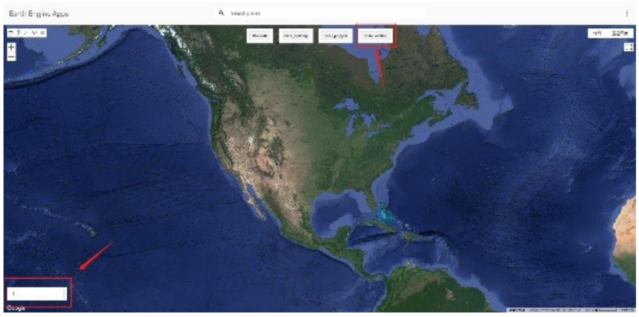


FIGURE C-4 | Outline the park’s boundaries with interactive polygon drawing tool

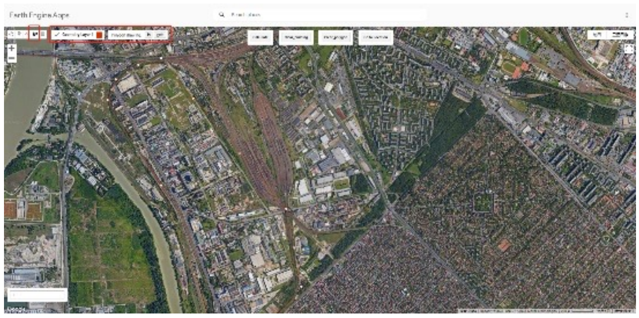
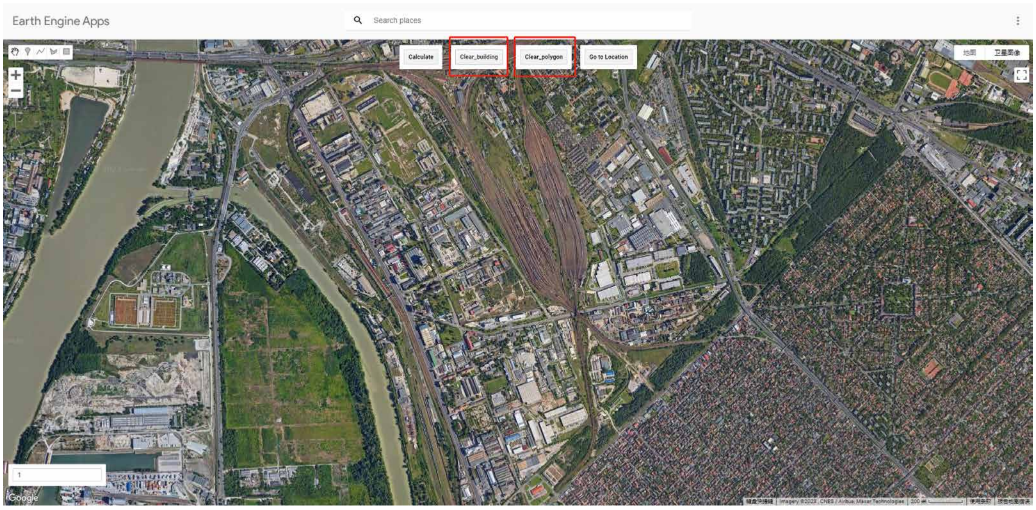


FIGURE C-5 | Click “Calculate” button when finished tracing

FIGURE C-6 | Display basic information of the park after calculation

FIGURE C-5 | Calculation for the next park



APPENDIX D

Overview of solar radiation assessment

Solar radiation (or resource potential) is a crucial initial factor in assessing the power generation of PV systems. It closely relates to geographic location and local climate conditions and is often expressed as instantaneous power per unit area (kilowatts per square meter). In PV system design, radiation data is usually represented as energy received per unit area per year (kWh/m^2). There are three ways to represent solar radiation, as shown in Table D-1.

Previous studies use these parameters to estimate solar radiation in specific regions. GHI is widely used in many studies, including solar potential estimations for EU countries (Šúri et al. 2007), Norway (Yordanov et al., 2015), South Africa (Gericke and Luwes 2019), California (Yang et al. 2014), and Texas (Xia et al. 2018). Some studies use both GHI and DNI for a more comprehensie assessment of solar radiation potential. For example, research on India's centralized solar PV potential used both GHI and DNI (Mahtta et al., 2014). This report applies more commonly used GHI for solar radiation estimation.

There are two primary methods for obtaining solar radiation data: **query record method** and **model calculation method**.

In regions with well-developed infrastructure, solar radiation data can be recorded over 20 years or more. In such cases, the query record method can be used to directly obtain the data. This method provides a true and accurate reflection of the region's solar radiation intensity. But it requires a significant amount of historical data and has limited geographic coverage, making it not suitable for large-scale or global estimates.

In regions with limited historical data, solar radiation is often calculated using radiation models and temperature models. For example, the US National Solar Radiation Database uses the Fast All-sky Radiation Model for Solar Applications to calculate GHI. ArcGIS by the Environmental Systems Research Institute is another widely adopted tool for solar radiation analysis in specific areas. This model accounts for atmospheric effects, site latitude and altitude, slope, compass direction, daily and seasonal solar angle variations, and shadow effects from surroundings. It also allows for adjustments for atmospheric transmissivity.

The Global Solar Atlas, recommended by the World Bank, is an online platform for assessing PV power potential. Powered by the Solargis solar database, it provides a spatial resolution of up to 250 meters and is applicable to regions between 60°N and 55°S latitude. This report uses the platform to obtain solar radiation data for COIPs, as its geographic coverage includes all locations in our overseas industrial parks database.

TABLE D-1 | Three ways to represent solar radiation

NAME	DEFINITION	REFERENCE SURFACE
Global horizontal irradiance (GHI)	The total amount of shortwave radiation received from above by a horizontal surface on the ground	Horizontal surface on the ground
Direct normal irradiance (DNI)	The amount of solar radiation received per unit area by a surface that is perpendicular (or normal) to the current rays	Surface perpendicular to the rays
Diffuse horizontal irradiance (DHI)	The amount of solar radiation received per unit area by a surface after being scattered and diffused by the atmosphere	Horizontal surface on the ground

APPENDIX E

Overview of wind energy potential assessment

Wind energy resource potential assessment is a key step in wind energy development planning, with results that are vital for organizations to make wind power strategies and to evaluate economic benefits of wind farms. The two main parameters in this assessment are wind speed and wind direction.

Wind speed, or air velocity, refers to the rate of air movement relative to a fixed location on Earth, measured in meters per second (m/s). It is mainly influenced by meteorological and topographical factors. Generally, higher wind speeds correspond to higher wind scale and greater wind power potential.

Wind direction indicates the direction from which the wind blows, expressed in terms of orientation. Wind direction frequency represents how often wind comes from a particular direction, calculated as the percentage of time wind blows from that direction over a year/month relative to the total wind occurrences from all directions.

Since wind direction is usually expressed in terms of orientation and is hard to quantify, it is not included in most studies on wind energy potential. Instead, only wind speed data is used. Additionally, given that this report examines over 100 COIPs, obtaining wind direction data for each park would be challenging. Therefore, our report uses only wind speed data to quantify wind energy potential.

There are four main methods to obtain wind speed data (Table E-1). For small areas with well-established monitoring facilities, data can be collected through on-site measurement (Bañuelos-

TABLE E-1 | Methods for wind speed data collection

NAME	DESCRIPTION	FEATURES
On-site measurement (Bañuelos-Ruedas et al. 2010)	On-site measurement involves collecting wind speed and other resource-side data at monitoring stations.	Advantage: ▪ Delivers accurate real-time measurements for the study. ▪ Disadvantages: ▪ Requires significant resources and time. ▪ Limited to specific measurement heights; other heights require wind shear calculations.
Experimental data verification (Ongaki et al. 2021)	After obtaining long-term data from meteorological departments, experimental data is used to verify the accuracy of wind speed profiles and determine short-term characteristics.	Advantage: ▪ Uses experimental data to verify whether long-term meteorological records accurately reflect local wind speed profiles. ▪ Disadvantage: ▪ Experimental data collection may be subject to interference, which could result in inaccurate data.
Meteorological stations and satellite data combination (Wei et al. 2019)	A relatively complete wind speed dataset is created by combining meteorological station observations with satellite vector wind data, after validating the usability of satellite wind data and calibrating any discrepancies.	Advantages: ▪ Satellite data compensate for the high costs and often missing and invalid meteorological data. ▪ Meteorological data can also help verify the usability of satellite data. ▪ High spatiotemporal resolution satellite data significantly improve the accuracy of wind speed data. ▪ Disadvantages: ▪ Only applicable to small-scale studies. ▪ Requires high-quality satellite data.
Wind energy database retrieval (Bandoc et al. 2018; Feng et al. 2020; Mentis et al. 2015; Siyal et al. 2015).	This method retrieves wind speed data directly from established databases for target regions.	Horizontal surface on the ground

Ruedas et al. 2010). While this method provides accurate, real-time wind speed data, it has limitations due to high costs in terms of labor, resources, and time. Additionally, data for nonstandard heights cannot be directly obtained and must be calculated using wind shear indices. For larger areas, wind speed data can be obtained through the other methods, which are experimental data verification (Ongaki et al. 2021), meteorological stations and satellite data combination (Wei et al. 2019), and wind energy database retrieval (Bandoc et al. 2018; Feng et al. 2020; Mentis et al. 2015; Siyal et al. 2015).

Given the wide presence of COIPs, this report requires extensive wind speed data. After comparing the four methods above, we chose to use the method of wind energy database retrieval. Specifically, we use the Global Wind Atlas to get wind speed data for two main reasons. First, the platform features a spatial resolution up to 250 meters and takes into account local terrain and roughness effects on wind energy. This enables better representation of typical and extreme climate conditions and improves the accuracy of wind speed simulations. Second, the platform's wind speed covers global land areas, including all COIPs in this report, which meets our requirements on level of details.

Wind power density

Wind power density (WPD) refers to the annual average available power per square meter of turbine sweep area. It relates to air density and wind speed, expressed as,

$$WPD_t = ½ \rho U^3$$

where:

- WPDt is the wind power density per sweep area during time period of t (W/m²);
- ρ is air density (kg/m³); and
- U is wind speed at each grid point (m/s).

Wind speed is a highly variable parameter that requires observation over time to understand its average conditions. Therefore, calculations of the average WPD for a given area need to integrate the time in the above formula. The equation is as follows:

$$WRD = \frac{1}{2} \bullet \overline{\rho \bullet U^3} = \frac{1}{2} \bullet \rho \int_0^\infty U^3 f(U) dU$$

In this report, we use the following formula to simplify the wind power density calculation (Mentis et al. 2015):

$$WPD \approx 0.955\ \overline{\rho U^3}$$

where:

- ρ is the air density (fixed value), generally taken as 1.225 kg/m³; and
- $\overline{U}$ is the annual average wind speed at the hub height of the wind turbine (m/s).

TERMINOLOGY

Technical potential Technical potential is the achievable energy generation of a technology under optimum conditions, considering system performance, topographic, environment, and land-use constraints (National Renewable Energy Laboratory 2025).

Investment potential Investment potential is the anticipated economic returns and growth potential of a project or technology. It examines both current conditions (market demand and resource availability) and future prospects (market trends, technological advances, and policy support) to assess investment viability. Research and analysis will help investors identify and measure the key factors that will shape investment outcomes (ForrestBrown 2025).

Power generation Power generation is the amount of electricity a generating unit can produce within a specific period of time (EIA, n.d.). This report focuses on the actual electricity generated and utilized by renewable energy technologies, influenced by factors such as natural resources availability, technical efficiency, environmental conditions, and equipment performance.

Installed capacity Installed capacity specifies the maximum amount of electricity a generating unit can produce (SMARD 2025). This indicator represents the power capacity a system can provide under optimal operations.

Levelized cost of energy (LCOE) LCOE represents the average total cost per unit of electricity over the entire life cycle of a power generation project. This metric includes all related expenditures covering equipment, construction, operation, maintenance, and fuel costs, which are then divided by the total power generation of the project (ChinaPower.com.cn 2023).

China's overseas industrial parks (COIPs) COIPs are categorized into six main types: multifunctional integrated parks, processing and manufacturing parks, resource utilization parks, technology research and development (R&D) parks, agro-industrial parks (or agricultural development parks/agricultural parks), and trade and logistics parks (Song et al. 2022).

Geographic Information System (GIS) GIS is a tool for capturing, storing, analyzing, and managing geospatial data. Developed by organizations like the Environment Systems Research Institute, it integrates information from various sources and provides users with advanced spatial analysis and decision-making support through maps and other visualizations (Esri n.d.).

Global Solar Atlas This is an online platform provided by the World Bank and the International Finance Corporation (collectively known as the World Bank Group). It offers users assessment of photovoltaic power potential and related information on a global scale (WBG 2024).

Global Wind Atlas This is an online platform jointly developed by the World Bank Group and the Department of Wind Energy at the Technical University of Denmark. It provides users with high-resolution global wind energy data (DTU and WBG n.d.).

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
DHI	diffuse horizontal irradiance
DNI	direct normal irradiance
GHI	global horizontal irradiance
GIS	Geographic Information System
IRENA	International Renewable Energy Agency
LCOE	levelized cost of energy
MBF	Microsoft Building Footprints
PR	performance ratio
VSIP	Vietnam Singapore Industrial Park
WRI	World Resources Institute

ENDNOTES

1. For regional division, please refer to Li et al. 2019.

2. This refers to the industrial parks that are invested and built by overseas Chinese-controlled entities with independent legal person status, which were established by qualified Chinese companies with independent legal person status registered in mainland China (excluding Hong Kong, Macau, and Taiwan). These industrial parks feature complete infrastructure, clear leading industries, and comprehensive public services and demonstrate economic clustering effects (MOFCOM 2015).

3. Arranging a gird of turbines in multiple rows can use a single-row grid as a reference. For multiple rows, the number of turbines (N) can be calculated with the following equation: $N = 4 + 2(N_0 - 1) + (R - 1)(N_0 + 1) = 1 + (R + 1) N_0 + R$, where N_0 is the number of grids per row and R is the number of rows. Assuming N_0 is fixed, in the minimum turbine spacing scenario: $N_0 = S0/(8D \times 3D \times R)$; in the maximum turbine spacing scenario: $N_0 = S0/(12D \times 5D \times R)$. Since the number of grids per row must be greater than one and an integer, for each park, the in minimum turbine spacing scenario, $R \leq S0/24D^2$; in the maximum turbine spacing scenario, $R \leq S0/60D^2$. According to the general formula for wind generation, the ratio of power generation between single-row and multiple-row grid arrangements (E1/E2) equals the ratio of turbine numbers in these two arrangements (N1/N2), where R takes the maximum integer that satisfies the conditions. Calculation shows that the power generation ratio between these two layout methods is approximately 1:1 for all industrial parks. Therefore, this study uses single-row grid arrangement results to represent multiple-row grid results.

4. Some industrial parks lack planned area data. Among all Tier 1 to Tier 3 parks, 7 parks have no planned area data, and another 10 parks only include farmland area with almost no industrial/commercial land. The PV power generation potential for these 17 industrial parks is recorded as zero in the resource potential scenario.

5. Some industrial parks lack roof area data. Among all Tier 1 to Tier 3 parks, 40 parks do not show satellite imagery data in the map, and satellite images for 12 parks show no building at their locations. The PV power generation potential for these 52 industrial parks is recorded as zero in the satellite imagery scenario.

6. Among all the agricultural parks, only 38 from Tier 1 to Tier 3 are considered. It is assumed that both crop-growing and livestock land can be used for PV panel installation. Agro-industrial parks focused on forestry (10 in total) are not suitable for traditional agrivoltaic systems, so their PV potential is not included. Three agro-industrial parks are primarily for industrial purposes, so the solar potential on farmland is considered as zero. For industrial areas in those three parks, solar potential is calculated using the method for industrial and commercial parks. Additionally, one agricultural park lacks specific information on planting area; since its total area is only 0.3 km2 and makes up a very small portion, it can be disregarded.

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ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

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