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WORKING PAPER

DISTRIBUTED ENERGY IN CHINA: REVIEW AND PERSPECTIVE 2020–2025

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EXECUTIVE SUMMARY

Highlights

- Distributed energy is one of the cornerstones of China's energy transition. Yet distributed energy is still drastically underdeveloped relative to its potential in China.
- In China, over the past 15 years, policies for distributed energy have greatly evolved and expanded. During the period 2020–25, current policy supports will be phased out, and distributed energy will gravitate toward market-oriented and competitive models. New policies will indirectly support distributed energy, remove barriers, and provide a favorable environment for distributed energy to continue to grow.
- A variety of market drivers have emerged in recent years, beyond cost-subsidy policies. Very specific distributed energy "use cases" are benefiting from these market drivers.
- Use cases for distributed energy will continue to grow for integrated microgrids, energy storage, electric vehicle charging infrastructure, and larger volumes of small-scale projects for industrial and commercial end users.
- In supporting the acceleration and scale-up of distributed energy, a variety of recommended actions are available to government agencies, industry, project developers and financiers, foundations and other public funders, and research institutions.

CONTENTS

Executive Summary 1
Introduction 3
Policy History and Outlook 7
Market Drivers and Use Cases—History and Outlook 8
Market Barriers—History and Outlook 9
Distributed Energy—History and Outlook 11
Economics of Distributed versus Centralized Energy Solutions—History and Outlook 13
Recommendations 14
Conclusion—China Distributed Energy Outlook 16
Endnotes 18
References 18

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Context

Distributed energy (DE) differs from centralized energy in several respects. It has the advantages of high energy efficiency because it utilizes local renewable resources, and it is located closer to end users, thus avoiding high transmission costs. It is an effective supplement to centralized energy systems.

Distributed energy is one of the essential characteristics of China's energy transition. Yet, there are still many potential scenarios for DE development in China. Despite large and growing markets for some distributed energy applications, only a small fraction of the existing economic potential has been realized. Existing policies, technology applications, business models, financing sources, and stakeholder involvement have scarcely begun to address the true potential or capture the true long-term value of distributed energy.

About This Working Paper

This paper surveys the future of distributed energy in China for the coming period 2020–25, based on the past and current market and policy situation, potential, challenges, and evolving and emerging use cases (i.e., technology applications and business models) for distributed energy. The study provides investors, strategy advisers, policymakers, and foundations with a concise background and perspective relevant to decisions and strategies for promoting distributed energy in China in the coming years.

Approach and Objectives of the Paper

Use cases for distributed energy are an effective way to portray its real potential in China to contribute to the country's climate and clean energy goals. A use case is a particular technology application and configuration that is profitable within the context of a specific business model and enabling environment (including policies and institutional arrangements). Questions we are trying to answer are, Where do we stand with regard to achieving long-term distributed energy potential in China, considering which use cases have already demonstrated scale-up potential and which others remain untested and unproven but show promise? How can we foster greater scale-up of both proven and potential use cases?

Key Findings

- China will develop many new innovations in clean energy, and, among them, distributed energy is expected to take center stage in the coming decade.
- Existing forms of policy support are ending, while new market-based policies are emerging that will indirectly support distributed energy, remove barriers, and provide a favorable environment for distributed energy to continue to grow.
- In parallel with policy evolution, there is an emerging new generation of use cases for distributed energy in China.
- Most of the barriers discussed in this paper will remain during the period 2020–25.
- Costs will continue to decline over the next five years.
- To support acceleration and scale-up of distributed energy, a variety of recommended actions are available to government agencies, industry, project developers and financiers, foundations and other public funders, and research institutions.

Recommendations

Based on this analysis, along with the collective knowledge and work of the authors, we make the following recommendations to promote and accelerate the growth of distributed energy in China.

For government agencies:

- Develop market-based mechanisms and rules that allow local energy trading and chart a pathway to enable distributed energy to participants in future wholesale markets and direct sales to other customers, including both generation and demand-response.
- Promote a simplified grid-connection process for distributed photovoltaic systems to all distributed renewable energy projects.
- Consider developing local markets for distributed heating and cooling, possibly including local feed-in tariffs or other support policies for renewable energy-based heating.
- Explore more distributed solar applications that combine with new types of infrastructure, and make such applications practical for commercial projects such as parking structures, roads and highways, green spaces, fencing, and ground-level building peripheries.

- Establish a national guarantee fund for innovative distributed energy projects that pilot new business models and technology configurations, with detailed investigation and public dissemination of results and metrics.

For industry, project developers, and financiers:

- Innovate new business and finance models so results can be learned and shared within the industry.
- Provide higher-quality supervision for new projects.
- Identify and market third-party energy service company (ESCO) services to new types of potential customers.
- Innovate standardized and accepted forms of project finance, with project assets used as collateral.
- Develop new forms of third-party risk-sharing.

For foundations and other public funders:

- Fund the development and piloting of new business and finance models that are not yet widely adopted but show great potential for scale-up.
- Fund local market assessment studies that allow a locality to measure market maturation for distributed energy at the local level, including business outlooks and potential sites and development opportunities.
- Provide capacity building for enterprises and financiers to understand opportunities, risks, and business models, and for financiers to develop new lending platforms and programs for distributed energy.
- Identify, consult with, educate, and facilitate the activities of a wide range of relevant stakeholders.
- Develop unique and effective tools for decision-making and dissemination of experience, such that pilot projects and models are more likely to be replicated.
- Create coalitions of organizations including industry, professional associations, research institutes, and planners, who agree to work together to implement the activities listed above.

For research institutions:

- Develop ways to measure progress and track scale-up and acceleration. Various local- or national-level indicators beyond simple capacity (megawatts [MW]) are possible and could be used to explicitly measure and define outcomes for distributed energy. They include strategic-level indicators, policy indicators, and proof-of-concept and pilot project metrics of success and viability.
- Develop a variety of research agendas that are needed for distributed energy at the present time.

INTRODUCTION

Distributed energy (DE) is one of the cornerstones of China's energy transition. Yet distributed energy is still drastically underdeveloped relative to its potential in China. Despite large and growing markets for some distributed energy applications, only a small fraction of the existing economic potential has been realized, and existing policies, technology applications, business models, financing sources, and stakeholder involvement have barely begun to address the true potential and capture the long-term value of distributed energy.

Distributed energy differs from centralized energy in several respects. It has the advantages of high energy efficiency, safety and reliability, low overall cost, low loss, and flexible operation. It is an effective supplement to centralized energy systems (IEA 2017). Distributed energy in China[1] can be categorized in terms of two carbon emission types: natural gas-fired combined cooling, heating, and power (CCHP), which is nonrenewable and produces carbon emissions, and distributed renewable energy technologies such as solar, wind, biomass, hydro energy, and geothermal energy, which can be carbon-neutral. Renewables can fuel distributed energy development and application, supplying power, heat, synthetic gas, motive power, and other end-use energy needs. This working paper focuses only on distributed renewable energy.

Although distributed energy does not have an agreed-upon global standard definition, the characteristics of distributed energy are uniformly understood across countries. The main characteristics of DE encompass three aspects. First, the scale of distributed power generation projects is small, usually less than one megawatt (MW). Second, the distributed power generation source is connected to the distribution network (low-voltage grid or local heating network), close to the end-use energy load (demand), and the power generated is mainly or partly for local consumption. Third, a distributed energy project can include and integrate a range of supply- and demand-side technologies such as energy storage, energy management and demand response, and smart controls—not just power generation and heating supply-side technologies.

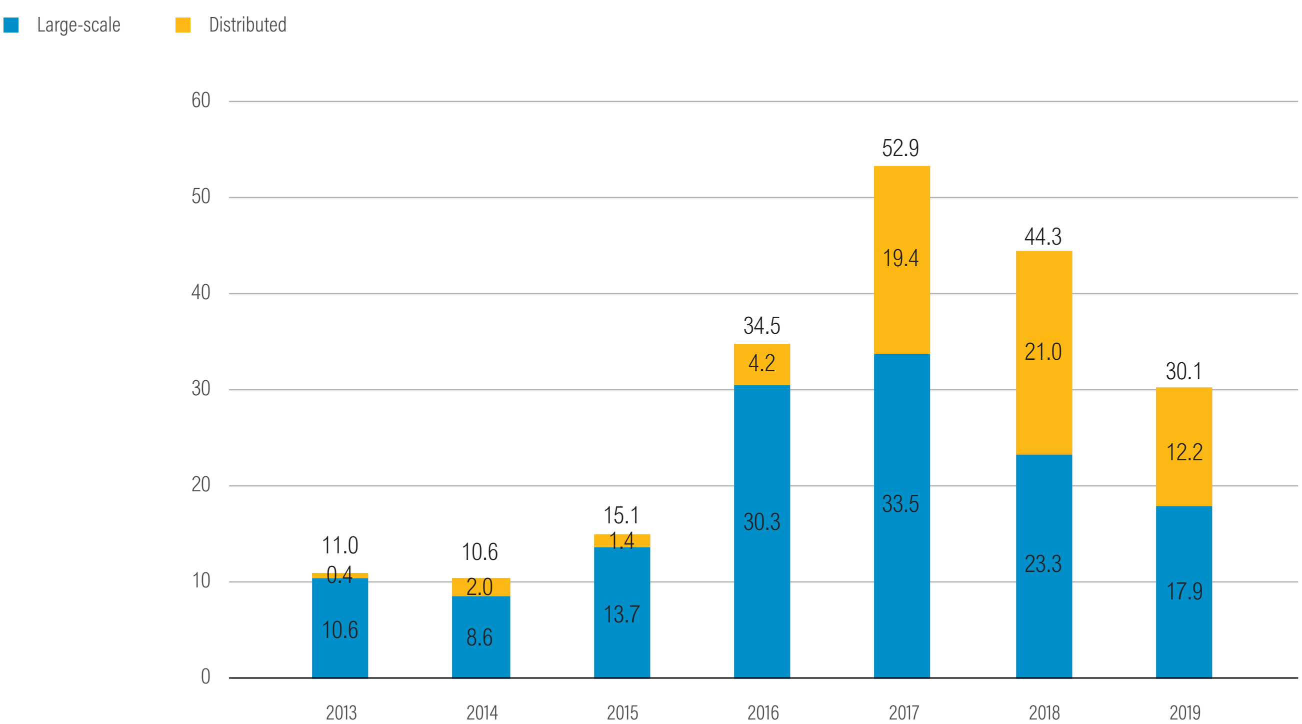
Distributed energy, as a local energy supply system, avoids the negative impacts of long-distance energy transmission (such as line loss and environmental impacts from power lines). Distributed energy offers users a reliable, economical, and stable power supply, and can meet multipurpose energy demands. Historically, distributed solar photovoltaic (PV) systems and small hydropower generation units have solved the problem of energy supply in remote and unelectrified rural areas.

At present, the most mature technology application is PV power generation. In the true sense of multi-energy complementarity, there are still very few applications that can provide a range of energy products (i.e., electricity, cooling, heating, steam, etc.) and integrated and optimized energy services. Therefore, the main policy and application focus of this paper is on the distributed application of solar PV.

China has been the world's largest PV market since 2013. New installed PV capacity in China keeps increasing (Figure 1) in response to the rapid fall in PV model prices and capital expenditure in terms of PV project capacity (Figure 2), as well as due to incentive policies in the form of feed-in tariffs (FITs) and subsidies (Table 1). Before 2016, large-scale PV power stations dominated the PV market in China.

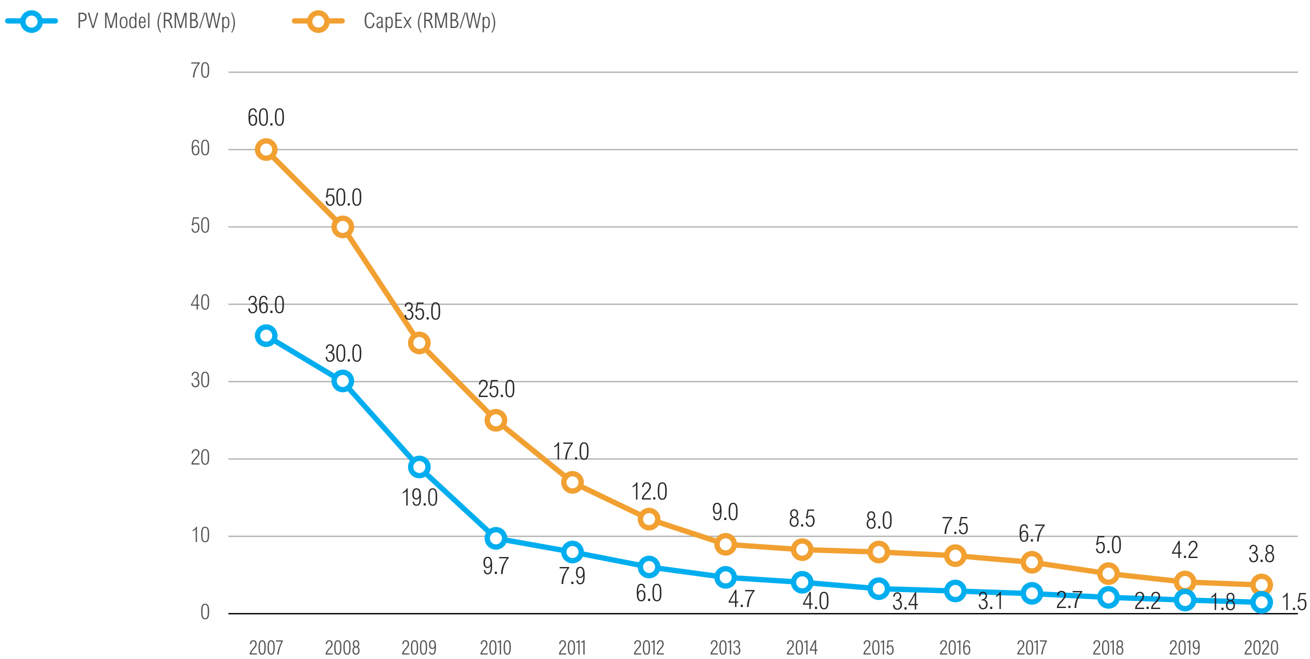
Distributed PV energy began to develop very quickly in 2016, driven by incentive subsidy policy, rapidly falling costs, and simplified management procedures. The subsidy for distributed PV remained the same as in 2013, while the FIT for large-scale PV projects was reduced by between 0.15 and 0.25 RMB/kilowatt hours (kWh). The distributed investment in China reached a peak in 2017, with over US$45 billion in annual investment flowing to mostly industrial and commercial megawatt-scale solar PV applications. That year, 19.4 gigawatts (GW) of

Figure 1 | **China's Annual Installed Solar Photovoltaic Capacity, 2013–2019 *(Gigawatts)***



Source: Energy Resources Institute, NDRC, with data from NEA 2020.

Figure 2 | **Photovoltaic Model and Photovoltaic Power Generation Cost, 2007–2020 *(RMB/Wp)***



Note: Wp = Watt peak; CapEx = Capital expenditure.
Source: Energy Resources Institute, NDRC 2020.

Table 1 | **China's Feed-in Tariff and Subsidy for Photovoltaic Projects, 2013–2020 *(RMB/kWh, including tax)***

Types	Year	2013–2015	2016	2017	2018 Before May 31	2018 After June 1	2019	2020
FIT for large-scale PV	I Zone	0.90	0.80	0.65	0.55	0.5	0.40	0.35
	II Zone	0.95	0.88	0.75	0.65	0.6	0.45	0.40
	III Zone	1.00	0.98	0.85	0.75	0.7	0.55	0.49
Subsidy for distributed PV	Industrial and commercial (wholesale)	0.42	0.42	0.42	Same as large-scale PV			
	Industrial and commercial (self-consumption and sale to grid)				0.37	0.32	0.10	0.05
	Household						0.18	0.08

Note: FIT = Feed-in tariff; PV = Photovoltaic.
Source: Energy Resources Institute, NDRC 2020.

distributed solar PV capacity was added, along with more modest amounts of distributed wind power, local heating from solar and biomass, and other distributed energy investment (NEA 2018c). This US$45 billion in 2017 was a fourfold increase from the 2016 investment level of about US$10 billion.

The market shifted in 2018 in response to major adjustments in policy support, but added capacity of distributed PV in 2018 still reached 21.0 GW, higher than the 19.4 GW added in 2017. By the end of 2018, distributed solar PV in China amounted to 50.6 GW, representing about 30 percent of total solar PV capacity of all forms (NEA 2019b). In addition, by the end of 2018, about 400 MW of distributed (on-site) wind power existed, with plans for an additional 9 GW of distributed wind power in 10 provinces by 2020. Distributed natural gas projects accounted for about 5 to 10 GW of power generation and/or cogeneration.

Policy adjustments in June 2018 initially created much market uncertainty. FITs and subsidies were greatly reduced and capacity caps and budget controls became stricter—not only for centralized (utility-scale) solar PV as before but also for distributed PV projects, which were capped at no more than 10 GW for the first time. In 2019, capacity caps and subsidy budget control became stricter still. The total budget for PV projects was RMB 3 billion, including RMB 0.75 billion for household distributed PV (about 3.5 GW) and RMB 2.25 billion for large-scale PV projects and wholesale distributed PV projects.

By mid-2019, following the policy adjustments of 2018 and mixed market response, the outlines of a multiyear future outlook had become sharper. They provide an opportunity to assess strategies for and challenges to supporting the acceleration and scale-up of distributed energy markets in the coming years.

This paper assesses the future of distributed energy in China for the period 2020–25, based on the past and current market and policy situations, potentials, challenges, barriers, and evolving and emerging use cases (i.e., technology applications and business models) for distributed energy. Our review provides investors, strategy advisers including researchers and industry associations, and foundations with a concise background and perspective relevant to strategies and decision-making that promotes distributed energy in China in the coming years.

Distributed energy can involve many different implementation levels, technologies, policy situations, business and finance models, and sets of stakeholders. A broad characterization of distributed energy at four different implementation levels would include the following:

- Individual building level. An integrated (or “hybrid”) building-level installation that combines renewable energy with energy efficiency and demand management and storage to reduce operating costs and grid charges. Implemented either by the building owner or a third-party energy service company (ESCO), and moves toward a “zero net-energy (ZNE) building” concept.
- Microgrid level. A microgrid for an industrial or urban zone that includes both heating and electricity distribution, run by a third-party operator (“micro-utility”). A microgrid-level distributed energy system can supply energy without backup from the grid.
- Zone or district level. A zone-level plan within an urban district or town, implemented by the local government, that targets groups of distributed renewable energy installations to achieve specific goals within the zone. A district management agency or third-party operator is engaged to develop and run the installation, and to sell, buy, and consume the energy produced. The zone- or district-level distributed energy system normally needs backup from the grid.
- Village level (community level). A distributed energy system for both electricity and heating for an entire village or community run by an energy cooperative.

Exact definitions of distributed energy vary, both among institutions and across countries and stakeholders (Jiang et al. 2018). This paper does not concern itself with a precise definition, but rather treats distributed energy in juxtaposition to other clean energy resources that are much larger in scale and/or not associated with any energy end users. Until 2017, the Chinese government treated distributed PV systems as either small-scale (less than 6 MW) regardless of whether associated with an end user, or larger scale (above 6 MW), if associated with an end user that itself consumed at least half of the generated energy (The State Grid 2017). After 2017, the definition of distributed PV system changed to “household-,” “small-,” and “large-” scale distributed generation, with each scale treated differently in terms of policy support (NEA 2013, 2018a).

POLICY HISTORY AND OUTLOOK

Over the past 15 years, policies for distributed energy in China have greatly evolved and expanded. Policies can be characterized in three distinct "policy stages" during this time.

During the first stage, 2005–12, most policy focused on distributed energy for (off-grid) rural electrification. Before 2012, distributed energy in China had been used primarily for rural applications such as household solar systems, biogas digesters, wind-powered water pumps, and village-scale mini-hydro plants. Most project investment came from central government, especially for off-grid systems that benefited nonelectrified counties, towns, villages, and households. China led the world in these applications for decades as it approached near-universal electrification of rural areas by the mid-2000s. But there was virtually no grid-tied (urban) use of solar power.

During the second stage, 2013–16, new policies for grid-connected solar PV and distributed wind were enacted and expanded at the national level, and additional policies were enacted at provincial and municipal levels. During this period, markets grew rapidly in response. Solar PV support policies included two basic types: feed-in tariffs for utility-scale systems that exported all power produced, and production subsidies (per kWh) for distributed solar systems' entire generation (i.e., including self-consumption and power sold to the grid). This meant that systems with high self-consumption (end-use on-site) projects benefited more. However, distributed solar systems were at an economic disadvantage relative to utility-scale systems if the distributed system exported a high share of its power generation to the grid. That is because power self-consumed by end-user load received the subsidy plus the avoided retail price, while power exported to the grid received only the subsidy plus the wholesale grid price (based on wholesale coal tariffs). Because of better returns, high shares of self-consumption PV projects were more attractive to investors. Thus, distributed energy projects with high shares of self-consumption have historically been favored in order to paint the most favorable economic picture. Nevertheless, both types of solar PV support policies proved very popular and profitable in the ensuing years and drove huge increases in capacity additions seen after 2013.

2014 saw two other important policy measures for distributed energy, the "Distributed Power Grid Connection Management Rule" issued by the National Energy Administration (NEA) and the State Grid, and a series of regulations to simplify administration procedures and management for connecting to the grid, by the NEA. However, both these measures took several years to be fully implemented across the country, as local governments developed implementing procedures. Thus, their impact was only felt after 2016.

The third stage, from 2017 to 2018, saw policies for solar PV focus on curtailment issues; for example, placing limitations on capacity, and even phasing out FITs by auction price over time. Both the feed-in tariffs and production subsidies created such large market volumes that the cross-subsidies from energy consumers (via higher power prices) to pay for these policies became very large, and market conditions became too volatile, according to the Chinese government. Consequently, both policies were cut back and revised in 2018. Feed-in tariffs were scaled back and plans were made to replace them entirely with an auction-based mechanism under an annual PV capacity cap by 2020. The power generation subsidies were also reduced and subjected to an annual national capacity quota of 10.0 GW (capacity eligible for distributed PV) in 2018 and 3.5 GW in 2019 that had never existed before. Plans called for generation subsidies to be phased out entirely by 2022. In addition, policy orientation began to shift from gross-added capacity toward greater actual energy output and emissions reductions.

A new policy for distributed wind addressed project development, construction, and management measures, but did not affect pricing.

Another positive policy concerned urban heat supply, and encouraged a two-part heating tariff for capacity and energy: basic heating prices for capacity mainly reflect fixed costs; metering heating prices for energy mainly reflect variable costs, which created more incentives for third-party projects and also for energy efficiency in heating. Some local policies for local heating permit requirements and concessions now allowed third parties to bid for permits (concessions) to serve a particular community. (Previously, only local utilities or the local heating authority had the right to develop projects.)

Other policy changes in 2018 meant that wholesale distributed PV projects could not use the production subsidy policy and had the same FIT price as large-scale PV projects, to encourage self-consumption. This change in definition is beginning to be felt in the market, but it is still too early to predict its effects. Even as national subsidies are reduced, capped, and/or eliminated in the coming years, some cities and provinces will continue to take an active or leading role in supporting distributed energy with local policies and planning strategies (Zhang et al. 2019).

Policy Outlook, 2020–2025. The existing forms of policy support are ending, including both the feed-in-tariff policy and production subsidies. As this happens, distributed energy is gravitating toward market-oriented and competitive models. At the same time, new policies are emerging that will indirectly support distributed energy, remove barriers, and provide a favorable environment for distributed energy to continue to grow. For example, new policies encourage that additional energy demand in cities be met, in full or mostly, by distributed energy generation. The small residential subsidy may still prove effective because the residential retail tariff is low. A possible new policy and market mechanism will allow "peer-to-peer" sales and exchanges of distributed power on a local distributed system, with distribution wheeling fees to be paid to the grid utility. And Chinese cities are faced with reducing and stabilizing carbon emissions by 2030 and will be enacting a wide range of urban planning strategies and investments to meet those goals, including distributed energy.

MARKET DRIVERS AND USE CASES—HISTORY AND OUTLOOK

During the two policy stages 2005–12 and 2012–16, a variety of market drivers emerged beyond the cost-subsidy policies outlined in Section 2. Over the period 2010 to 2017, these included:

- More and better information and experience on green finance by banks, starting with wind power in the late 2000s and continuing with solar PV in the 2010s
- Increased pressure on management committees of industrial parks to transition to low-carbon development, which led to many industrial parks requiring or encouraging investment in distributed energy
- Improved business environment for third-party ESCOs
- China's national strategy for industrial development based on clean technologies, and the creation of a domestic market for grid-tied solar PV, which scarcely existed before 2012

Distributed solar PV continued to account for a relatively low share of total solar PV during the years 2013–16 because market drivers favored utility-scale solar PV, as listed below:

- Attitudes and bias in favor of large-scale systems
- Continuing economies of scale for larger systems
- No central targets or goals for distributed energy prior to the 13th Five-Year Plan (FYP) 2016–20
- No clear sense that distributed energy was a serious contender or could be a serious contributor

This situation changed in 2017 when distributed energy attained a 40 percent share of the total solar PV market, as profitability increased for large enterprises that were able to overcome barriers thanks to balance-sheet finance, high self-consumption percentages, and large enterprises like Southern Grid establishing third-party ESCOs. Large enterprises began to add distributed energy in "clusters" to all their existing buildings, rather than doing one-off building projects. The emergence during 2017–18 of local government targets and planning for emissions reductions and an emissions peak by 2030, in line with the 2015 Paris climate accord, led to greater local interest in promoting distributed energy. And the rise of a favorable business environment encouraged large companies to form ESCOs to install distributed energy and sell the power to local end users, and increased their willingness to carry the risk of future power sales and power purchase agreement (PPA) renewals.

Curtailment of power generation in China's northwestern and western provinces could also be considered a market driver. In some provinces in the northwest and west, centralized wind and solar power plants are routinely subject to high levels of power generation curtailment because provincial grids cannot absorb all generated power, and transmission capacity to neighboring provinces remains limited. In 2018, many provinces did not approve any new utility-scale power plants because there was too much curtailment. As a result, only distributed energy was installed. Distributed solar PV is not subject to curtailment. The curtailment of utility-scale generators is actually an advantage for distributed energy.

The existing use cases for distributed solar PV that developed from 2013 to 2018 fall into three main categories, which emerged due to the market drivers and barriers discussed in the sections below.

1. Large industrial rooftop installations that are self-built, self-financed (balance sheet), and commonly done for a whole series or cluster of buildings owned by one enterprise. Most or all of the power produced is consumed by the enterprise itself with little or none exported to the grid (residual only).
2. Large industrial rooftop installations, same as above, except that the solar PV is owned, financed, and installed by a third-party ESCO, which sells the power to the industrial enterprise, typically discounted below the prevailing retail prices charged by the utility, for example 90 percent of retail rates.
3. Large industrial rooftop or land installations that are leased by a third party solely for the purpose of selling power to the grid under the utility-scale feed-in-tariff regime, with no self-consumption.

Use Cases Outlook 2020–2025. The government has been piloting a number of new use cases by awarding specific projects to commercial developers to pilot both technology integration and market mechanisms. Programs have included "new energy minigrid" pilots (NEA 2017), "energy internet plus smart energy" pilots (State Council Information Office of the People's Republic of China 2016), and "distributed energy market pilots" (NEA 2019a). These and other efforts to pilot use cases will begin to create a new generation of use cases for distributed energy in China, beyond those established in recent years. In the future, as the market drivers and barriers undergo changes—particularly local government policies and planning, the rise of a favorable business environment for distributed energy, and favorable economics (see also Section 6 below)—a variety of new potential use cases will emerge:

- Local electricity trading ("peer to peer") between local consumers on the same distribution grid. National rules are possibly forthcoming in 2020, based on emerging pilot experience. A series of pilot projects funded by the government was being considered in 2018 and 2019 but had not been implemented at the time of writing.
- Microgrids and local power and heat-supply systems for industrial parks and other district-scale or clustered buildings, including new microgrid management and tariff schemes that lower risks and costs for all connected consumers.
- Residential and commercial solar PV rooftops with battery storage that allow for self-consumption.
- Tighter integration of distributed energy with zero net-energy (ZNE) buildings and architectural design, including power, heating, and cooling. Building integrated PV (BIPV) products will attract more attention and market opportunity.
- District and local heating systems, including cogeneration and locally powered heat pumps, typically from biomass or solar, either as monopoly concessions awarded by county or municipal governments, or as part of microgrids or local power systems.
- Linear solar PV power plants (long thin strips of solar arrays) along streets and highways.
- A variety of nonrooftop distributed solar PV applications for parking lots, electric vehicle (EV) charging stations, landscaped areas around buildings, and other available spaces.
- "Greenfield" power projects with distributed energy built on unused and unproductive land (also called "barren hills" projects).
- Agricultural greenhouses.

In addition, a variety of new financing mechanisms will accompany existing and new use cases. In the past, the primary financing vehicles have been balance-sheet finance by large enterprises, either the end user or a third-party ESCO. For example, in the future we may see crowdfunding of projects. Residential and commercial leasing of smaller solar PV systems, similar to leasing models in the United States, is already being applied in China,[2] as is fixed-income equity investment such as Yield Co.[3] The company GCL New Energy is already doing this in China.[4]

MARKET BARRIERS—HISTORY AND OUTLOOK

Market barriers to distributed energy over the past decade have also evolved and will continue to evolve and change in the future. Some of the most tangible barriers, both those that have been removed or that still remain, are described below:

Interconnection rules. Interconnection rules were largely absent prior to 2014, which led to several rounds of case-by-case negotiations and separate agreements for project implementation. With the enactment of landmark 2014 regulations on connecting distributed energy to the grid (The State Grid 2017), a major barrier was removed by the standardized interconnection arrangements and simplified procedures. Projects were exempted from the need for environmental reviews and government approval based on those reviews, and standard interconnection completion time lines were specified. The market growth during 2015–17 was definitely supported by these 2014 regulations.

Rooftop leasing or ownership. The lifetime of a rooftop solar PV system is 20 years or longer, requiring certainty about rooftop ownership and permission on such timescales. However, the nature of business in China has meant that such timescales are much longer than the average business agreement, and the expected lifetime and/or ownership of infrastructure. A typical rooftop leasing contract is only 5 to 10 years. This creates significant third-party risks for infrastructure leasing and contractual agreements. This significant barrier is likely to persist for the foreseeable future.

Costs versus subsidies. Policymakers have reduced subsidies because costs have been declining year-by-year. But at the same time policy uncertainty has increased with the prospect of feed-in tariffs and production subsidies being further reduced or canceled outright. In addition, controls and caps on annual subsidies began to be applied to distributed solar PV in 2019 (NEA 2019c). As the basic economics of distributed energy have improved, subsidies have been reduced but not in an even or equal measure. The principle of subsidies is to cover operators' costs and allow a reasonable profit. One key indicator of this balance is the volume of projects added in 2018 and 2019 that were not on the central government's approved project list and that will therefore not be subsidized (i.e., not covered by the subsidy quota).

Economic imperative for high self-consumption. Chinese power grid companies purchase power from distributed energy generators at wholesale rates, rather than at retail rates, and the "net metering" policies common in other countries have not been issued. This, coupled with the production subsidies that started in 2013, has meant that a customer benefits most by consuming most or all of the power that it generates on-site (self-consumption). Self-consumption is valued at the avoided retail price and also receives the production subsidy, whereas power exported to the grid is compensated at the much lower wholesale price. Thus, solar PV has flourished only in those enterprises that can consume high shares of the power they generate, typically above 80 percent. Even the case of an enterprise that closes on the weekend, and thus must export power to the grid then, may make investments only marginally profitable.

Residential power prices and lack of mortgage-based credit. Residential power prices are lower than those charged for industrial and commercial power. This means that the benefit of avoided retail purchases of distributed energy to a residential household is reduced. This barrier will continue to hinder the scale-up of residential distributed solar for a long time to come. Furthermore, it is very difficult for a residential homeowner to finance distributed energy through mortgage finance, as is common in other countries.

Third-party risks. If a business model relies on the financial solvency of a third party; for example, if an ESCO or other performance contractor is involved, there are significant third-party risks because the average lifespan of an enterprise in China is much less than the 20-year life span of a solar PV system. Any leasing contract will likely be at most 10 years, and the average life span of many types of Chinese companies today is less than 10 years.

Financier "wait and see" policies limiting project finance. Banks and other financiers have been slow to provide financing for solar PV projects, preferring to adopt a "wait and see" attitude and policy. This has meant that most projects get financed from the balance sheets of large and liquid companies, rather than through project finance (IRENA 2014).

Headwinds facing ESCOs. Small ESCOs have been "locked out" of the market for distributed energy and cannot easily get financing. This has left the ESCO field to larger enterprises that can finance from their balance sheet.

Lack of integrated policy approaches. Governments at all levels have taken largely ad hoc approaches to promoting distributed energy, rather than more integrated approaches that might combine, for example, transport, housing, and industrial policy with distributed energy policy. The one exception has been integrated approaches within industrial parks, where a park management committee can implement such integrated approaches.

Market Barriers Outlook 2020–2025. Some barriers will remain. Since 2016, the curtailment issue has generally been addressed and improved. However, in certain provinces, curtailment of utility-scale renewable energy will remain a challenge, leading to increased investment in distributed energy not subject to curtailment, relative to utility-scale energy. The continued presence of most of the barriers described above may be mitigated, however, by the fact that at least some will be changing or diminishing in coming years. In particular, we anticipate four main areas of change: power sector reforms; local government motivation, planning, and understanding; energy storage and other new enabling technologies; and electric vehicle charging. These are elaborated on below:

Power sector reforms (national level). Many experts expect the introduction of a number of new policies that will reduce or remove historical barriers (Hui Yu 2018). These potential new policies include the following:

- Distribution of wheeling charges to allow peer-to-peer sales, and other types of breakthroughs or policies issued by government in consultation with stakeholders, on the basis of existing pilot experience.
- New Renewable Portfolio Standard (RPS) (in China, named the Renewable Energy Obligation Mechanism) policies that should apply mainly to grid utilities, dealers (retailers), or direct power purchasing entities (bilateral contracts to purchase any form of power). Such new policies could encourage utilities to purchase more renewable energy themselves, including renewable distributed energy, and to allow more distributed energy purchasing and procurement to meet RPS requirements.
- New distributed energy targets or goals at national, provincial, and local levels for the 14th FYP 2021–2025.
- Continued subsidy policies beyond 2022 (at least through 2025) by provincial, city, and/or county governments.
- Time-of-use (peak hour) pricing.

Local government motivation, planning, and understanding. Local governments are increasingly proactive in low-carbon planning and investment; this will create a positive influence in the coming years in terms of local microgrids, local power systems within urban settings, local encouragement of peer-to-peer power purchasing models, greater integration of heat supply into low-carbon distributed energy solutions for buildings, and greater integration with low-carbon transport and electric vehicle charging.

Energy storage and other new enabling technologies. A variety of new applications, configurations, and ways of capturing value are emerging in China, including the following:

- Storage integrated with demand-management systems and with distributed generation from solar PV and wind. Such storage could encourage local power selling (peer-to-peer power exchange) because supply could be more reliable and constant, allowing new "firm" power contracts between buyers and sellers.
- Large-scale storage integrated with solar PV implemented by an ESCO or customer, for example, integrated with plants of up to 50 MW scale.
- Deferred investments in distribution and transmission grids by the State Grid enabled by greater use of storage.

As these new technologies and configurations take hold, including learning from international experience and identifying new business opportunities, many enterprises may overcome their reluctance and turn to new business models for integrated distributed energy configurations, including energy storage.

Electric vehicle charging. A variety of pilots for vehicle fleets charged from centralized charging portals are under way throughout China, and mechanisms are being proposed to guide EV charging during certain periods. This, plus special EV charging tariffs, regulation, and load management, mean that distributed energy is likely to play an expanding and central role in providing significant shares of the power for EV charging, taking advantage of rates and load management opportunities.

DISTRIBUTED ENERGY HISTORY AND OUTLOOK

Historically, distributed energy in China was mostly oriented to rural off-grid electricity for areas not yet served by power grids, for local heating and motive power using biomass and biogas, local power production from small hydro, and building-scale solar hot water heating. China has led the world in solar hot water heating since the 1990s, with virtually unsubsidized markets thriving and low-cost products available throughout the country. With the exception of solar hot water, most distributed energy markets were bolstered or subsidized by the Chinese government and/or foreign aid programs.

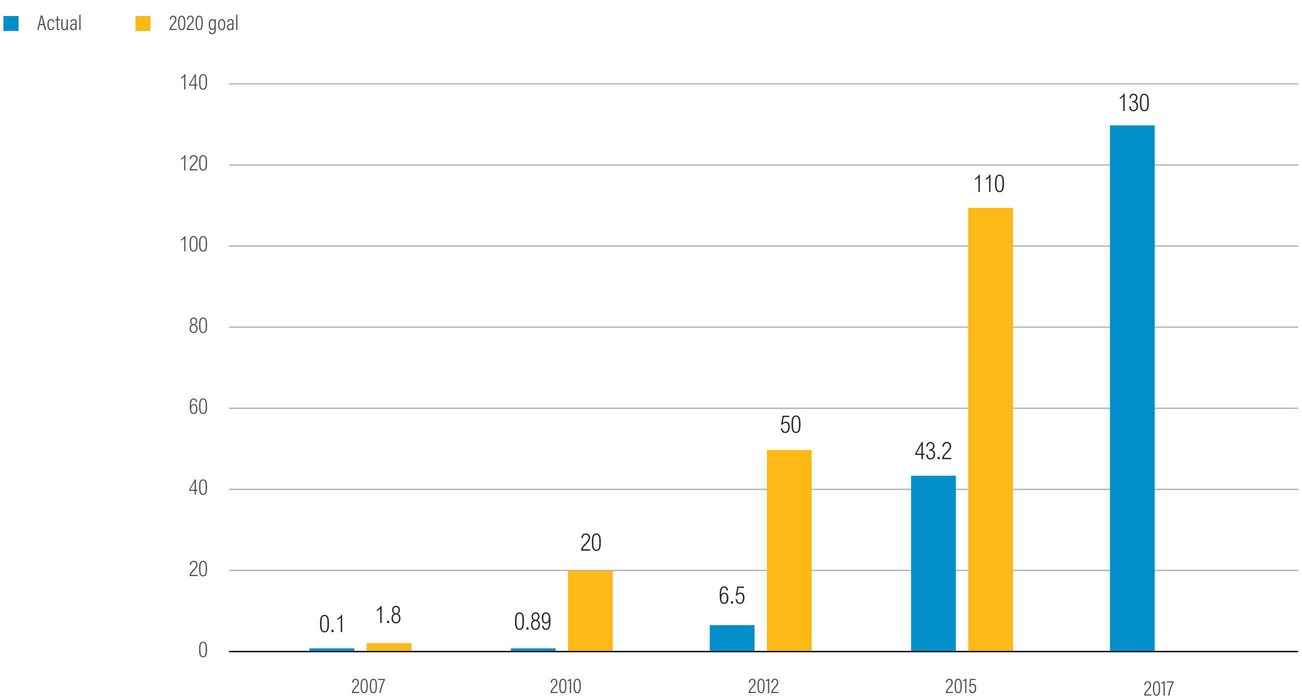
The policies enacted in 2012–14 were a real turning point for both centralized and distributed solar PV in China. It is fair to say that the impact of these policies, together with global technology cost reductions, caught everyone by surprise. No one expected the sudden and explosive domestic growth that took place from 2013 to 2016 and the boom years of 2017 and 2018. To illustrate how sudden and unexpected this market growth was, the official government target for solar PV established in 2007 envisioned less than 2 GW solar PV existing nationally by 2020 (NEA 2007). This 2020 target was later revised several times, to 20 GW in 2010 and to 50 GW in 2012 (NDRC 2012). China's current target of 110 GW total solar PV by the end of 2020, including 60 GW of distributed solar PV, was set in 2015 as part of the 13th Five-Year Plan (NDRC 2016). That 110 GW target was exceeded just two years later, in 2017, when total solar PV in China grew to 130 GW, including 30 GW of distributed solar PV (NEA 2018b) (Figure 3).

A 2005 national renewable energy law provided feed-in tariff subsidies for biomass power generation (for large-scale plants of 10–25 MW, including combined heat and power [CHP] plants, though the heat was not subsidized), but plants at these large scales were very slow to develop and very few were built. A boom in small hydro development began in the 1990s because the economics were favorable. Small hydro also led to these technologies being employed for distributed power generation and heating from biomass. The number of geothermal heat pumps has also been growing since the 1990s.

The growth of distributed energy slowed considerably in 2018 as reduced subsidies and capacity caps created short-term uncertainty in the markets. However, the outlines of a growing number of new use cases could be seen, as noted in Section 3.

One rapidly expanding use case is for distributed solar in industrial parks; for example, the Sanshui Industrial Park in Guangdong. Total rooftop solar PV capacity installed by all enterprises in the park has now exceeded 130 MW. The industrial park has more than 400 companies and encourages business

Figure 3 | **Official Government Targets and Actual Solar Photovoltaic Installed Capacity, 2007-2017 *(Gigawatts)***



Source: WRI authors, with data from NEA (2007, 2018b) and NDRC (2012, 2016).

owners to invest in distributed solar, either themselves or using third-party developers under a variety of contracting models. This encouragement can take the form, for example, of the industrial park's management committee obtaining promises from new tenants. Management committees have also set up local ESCOs or invited local ESCOs to participate in the industrial park's development plan for distributed energy. Finally, local government agencies promote distributed solar PV for the industrial park during new building permitting and provide financial incentives.

There is also significant growth potential for investment in heating infrastructure based on distributed renewable energy, such as biomass-fueled cogeneration plants. Some county and municipal governments have awarded or considered awarding concessions to heating system providers, or offering feed-in tariffs for locally produced heat from renewable energy and natural gas.

The China Renewable Energy Outlook 2018 by the China National Renewable Energy Center projects an annual solar PV market of up to 80 GW by 2025 (CNREC 2018). While there are no specific breakdowns of that projection into distributed solar versus utility-scale centralized solar, it is likely that at least half of the market will remain distributed in the years ahead, so the market for distributed solar PV could rise to at least 30 to 40 GW annually by 2025. The CNREC projection includes new strong climate mitigation policies associated with a two-degree scenario. In the absence of such policies, the annual distributed solar PV market is estimated to range between 15 GW and 30 GW by 2025.

Distributed Energy Outlook 2020–2025: The overall distributed energy outlook depends on the market drivers and barriers discussed in Sections 3 and 4 above, as well as financing trends and innovations, and how rapidly new technology-integration paradigms will take off. Estimates of the total distributed solar PV market vary. It is expected that the market will maintain its 2018 annual level of 10 GW as long as production subsidies exist, but sometime during the period 2020 to 2025, subsidies will decline or be eliminated. Other use cases for distributed energy will continue to grow for integrated microgrids, energy storage, electric vehicle charging infrastructure, and larger volumes of small-scale projects for industrial and commercial end users. Changing attitudes by financiers, project developers, and local governments will be a big contributor to market growth. Use cases for heating provided by distributed energy technologies—for example, biomass CHP plants—may experience an upswing as county- and municipal-level programs structure heating concessions and bid for municipal and county heating infrastructure.

ECONOMICS OF DISTRIBUTED VERSUS CENTRALIZED ENERGY SOLUTIONS—HISTORY AND OUTLOOK

The fact that distributed energy has lagged behind centralized utility-scale solar PV installations is often attributed to what many consider to be more favorable economics of utility-scale and centralized installations. However, other factors play a part, and understanding them is key to understanding that distributed energy is not likely to lag as far behind in the future, and may even begin to lead utility-scale.

First, the economics and subsidies picture has changed. Distributed solar PV power purchase prices, including subsidies, are not declining as fast as power purchase prices for large-scale solar PV, and this creates a growing advantage for distributed solar PV over large-scale solar PV.

Second, interconnection rules issued in 2014, which establish a simpler process and time line for connecting distributed PV projects to the grid, took some time to be understood and implemented by local governments. The impact of the new rules is likely to grow in coming years.

Third, it took time to establish the entire component chain, market infrastructure, and business capacity and skills for finance, design, construction, operation, and maintenance of distributed installations. And it took time to scale this up, including the formation of new ESCOs and energy performance contracting (EPC) companies to take advantage of the new business models and profitable opportunities.

Before these three changes took place, distributed energy was unquestionably much more expensive than centralized utility-scale solar, and transaction costs were high. Large projects were performing well, and large investors and companies were eager to invest in them. However, the policy reforms of 2012–14 and falling technology prices caused transaction costs to decline. Projects became more standardized, a reliable component supply chain and business capacity and skills developed, and the economics of distributed energy became more favorable.

With the increase in the number and sophistication of third-party ESCOs able to handle large volumes of smaller projects, such ESCOs were able to compete favorably with retail electricity rates for their clients. This meant that the value and profitability of distributed energy competed with retail electricity prices, not wholesale prices. This proposition will accelerate as subsidies decline in the coming years for both centralized (i.e., feed-in tariffs) and distributed power (i.e., self-consumption production subsidies).

Economic Outlook 2020–2025: Over this five-year span, costs will continue to decline, and by 2025 most distributed energy projects will be profitable without subsidies, particularly those that compete with industrial and commercial retail rates. By 2025, a greater number of use cases will become profitable, with an expectation that rapid growth can begin for microgrids, local (district) power and heating systems, peer-to-peer local energy trading, electric vehicle smart-charging, and multitechnology integration with new designs for zero net-energy commercial buildings. By 2025, residential installations will still be unprofitable relative to residential retail rates, although residential-based generation selling into local peer-to-peer energy markets (for both electricity and heating) could emerge, if such sales could occur at prices higher than residential retail rates.

RECOMMENDATIONS

On the basis of our analysis, and the collective knowledge and work of the authors, we make a number of recommendations to promote and accelerate the growth of distributed energy in China.

For government agencies:

- Simplify the grid-connection process for distributed energy resources beyond the original 2014 interconnection rules. This would apply mainly to distributed solar PV projects. Additional aspects of interconnection to consider now include interconnection of storage and electric vehicles, integration with demand-response and demand-management systems, "nonexporting" systems that consume all local power generation (including microgrids), "smart inverters" that can adjust their output and function in response to grid conditions, and special treatment for distributed solar and storage paired together.

- Develop local peer-to-peer trading platforms and other market-based mechanisms and rules that allow local energy trading and are designed to simplify transactions, or aggregator mechanisms to enable distributed energy owners to participate in future wholesale markets.

- Consider developing local markets for distributed heating and cooling, possibly including local feed-in tariffs or other support policies for renewable energy–based heating.

- Explore ways to make available new types of infrastructure locations for distributed solar, and work to make such locations practical for commercial projects, such as parking structures, roads and highways, green spaces, fencing, and ground-level building peripheries.

- Drawing upon the experience of wholesale market participation from other jurisdictions (e.g., California), chart a pathway, including both generation and demand-response, that allows distributed energy to participate in wholesale power trading markets and to direct sales to other customers. Modify the mechanism that determines the price for transmission and distribution and allow the market to set the price, which is more favorable for distributed generation.

- Establish a national guarantee fund for innovative distributed energy projects that pilot new business models and technology configurations, with detailed investigation as well as public dissemination of results and metrics.

For industry, project developers, and financiers:

- Innovate new business and finance models so that results can be learned and shared among industries.

- Provide higher-quality supervision for new projects.

- Identify and market third-party ESCO services to new types of potential customers.
- Innovate standardized and accepted forms of project finance, with project assets used as collateral.
- Develop new forms of third-party risk-sharing.

For foundations and other public funders:

- Fund the development and piloting of new business and finance models that have not yet been widely adopted but show great potential for scale-up. This includes learning from, developing, designing, and elaborating those models that appear to be the most practical for distributed energy in China, based upon domestic and international case studies, assessments, and stakeholder insights from failed and successful real world attempts.
- Fund local market assessment studies that allow a locality to measure market maturation for distributed energy at the local level, including business outlooks and potential sites and development opportunities.
- Provide capacity building for enterprises and financiers to understand the opportunities, risks, and business models, and for financiers to develop new lending platforms and programs for distributed energy.
- Identify, consult with, educate, and facilitate the activities of a wide range of relevant stakeholders. Interaction with stakeholders can enable them to share their existing experience, initiate and take part in pilot projects, learn and disseminate experience from pilot projects, set goals or targets, and enact or strengthen necessary policies for distributed energy.
- Develop unique and effective tools for decision-making and dissemination of experience such that pilot projects and models are more likely to be replicated. Some of these tools may be analytical in nature, while others are more oriented to communication and learning.
- Create coalitions of organizations, including industry, professional associations, research institutes, and planners, who agree to work together to implement the activities listed above. Such coalitions could focus in particular on the following:
    - Educating and making the business case to public and private financiers, to break out of the balance-sheet finance used predominantly to date and enable faster mainstreaming of finance
    - Making detailed recommendations to foundations and other funders on strategic use of funds in climate mitigation objectives
    - Creating partnerships to enable technology and business model integration for new use cases, such as industrial park microgrids
    - Making the case for and advising local governments on new platforms and management measures for peer-to-peer trading and local energy markets

For research institutions:

- Develop ways to measure progress and track scale-up and acceleration. A variety of local- or national-level indicators beyond simple capacity (MW) could be used to explicitly measure and define outcomes for distributed energy, including, as follows:
    - Strategic-level indicators. Greenhouse gas (GHG) emissions reductions, capacity (GW) of distributed renewable energy in specific pilot cities with strong policy and business environments, capacity (MW) of operating microgrids in pilot cities, annual flows of investment into distributed renewable energy
    - Policy indicators. Adopted methodologies for grid pricing and interconnection costs, enacted microgrid technical standards, number of cities/townships adopting or incorporating distributed renewable energy promotion in urban planning (note: tracking but not necessarily influencing)
    - Proof-of-concept and pilot project metrics of success and viability. Innovative and viable business strategies identified and piloted, innovative financing mechanisms designed and piloted, ratings of profitability and scale-up potential of pilots
- Different research agendas are needed for distributed energy at the present time to pursue a variety of different goals, such as the following:

- Using learning from China in South-South development contexts
- Understanding and measuring direct and indirect GHG emissions impacts
- Integrating distributed energy concepts with broader local government planning for economic and social development
- Assessing policy impacts in a systematic and analytical way
- Assessing long-term capacity-building needs for local governments and stakeholders in various categories based on the initial experience with pilot projects and policy development
- Exploring linkages with emerging national strategies, future five-year plans, and the ongoing process of power sector reform

CONCLUSION — CHINA DISTRIBUTED ENERGY OUTLOOK

To meet its carbon emissions targets for the year 2030 and beyond, China will need to develop many new innovations in clean energy, and distributed energy is expected to take center stage in the coming decade. Market drivers and barriers, cost trends, and new emerging and potential use cases all point in the direction of accelerated growth, in spite of short-term policy pullbacks during 2017–18 that have generated uncertainty in the industry.

It is clear that existing forms of policy support are ending, including both the feed-in-tariff policy and production subsidies. As this happens, distributed energy is gravitating toward market-oriented and competitive models. At the same time, however, new policies are emerging that will indirectly support distributed energy, remove barriers, and provide a favorable environment for distributed energy to continue to grow.

In parallel with policy evolution, there is an emerging new generation of use cases for distributed energy in China, beyond the established use cases of recent years. This new generation is driven by many new pilot programs and some new risk-taking by enterprises. In the future, the market drivers and barriers discussed in this paper will undergo changes that create new opportunities; for example, local government policies and planning and the rise of a favorable business environment for distributed energy by enterprises needing project finance to make investments.

Most of the barriers discussed in this paper will remain during the period 2020–25. Curtailment of utility-scale renewable energy in certain provinces will continue and likely increase in severity, leading to increased investment in distributed energy not subject to curtailment, relative to utility-scale. The continued presence of most of these barriers may be offset by changes in four specific areas: power sector reforms (including new RPS regulations issued in 2019); local government motivation, planning, and understanding; energy storage and other new enabling technologies; and electric vehicle charging.

The overall outlook for the period 2020–25 depends on the market drivers and barriers discussed in this paper, as well as financing trends and innovations, and how rapidly new technology-integration paradigms will take off. Some markets will clearly continue to grow, including those for integrated microgrids, energy storage, electric vehicle charging infrastructure, and larger volumes of small-scale projects for industrial and commercial end users. Changing attitudes by financiers, project developers, and local governments will be a big contributor to market growth. And markets for heating provided by distributed energy technologies may experience an upswing from county- and municipal-level programs.

Over the next few years, costs will continue to decline (IRENA 2016), and by 2025, most distributed energy projects will be profitable without subsidies, particularly those that compete with industrial and commercial retail rates. By 2025, a greater number of use cases will become profitable, with the expectation that rapid growth can begin for microgrids, local (district) power and heating systems, peer-to-peer local energy trading, electric vehicle smart-charging, and multitechnology integration with new designs for zero-net-energy commercial buildings.

The following key trends and milestones will be worth tracking in the future:

- Willingness of Chinese power utilities to accommodate and support distributed energy with new interconnection rules, new forms of distribution-level wheeling arrangements supporting local energy trading, and new power-purchase arrangements

- Rise of third-party ESCOs and their ability to secure financing
- Local governments' continued interest and drive for supporting distributed energy
- Architects, developers, and architectural component suppliers turning to distributed energy solutions and products in far greater numbers
- Emergence of electric vehicle smart-charging

Recommended and emerging actions will be particularly effective in the period 2020–25 as the next stage of development for distributed energy takes shape and begins to create a solid foundation for China to meet its climate and clean energy goals. They will also be important as China starts to provide even stronger leadership and assistance among developing countries for the transition to clean energy and low-carbon economies.

ENDNOTES

1. The definition of distributed generation projects in China is that (1) they are connected to 110 kilovolts (kV) and a lower voltage grid, and (2) they are less than 50 megawatt (MW) capacity, State Grid implements the simplified grid connection procedure. For photovoltaic (PV) project management and incentive policy, the definition of distributed PV project is that (1) it is connected to 10 kV and a lower voltage grid, and (2) it is less than 6 MW capacity in a single connection point.

2. Risen Energy (Shanghai) Financial Leasing Co. https://www.risenenergy.com/index.php?c=show&id=45.

3. A yield co or yieldco is a company that is formed to own operating assets that produce a predictable cash flow, primarily through long-term contracts. https://en.wikipedia.org/wiki/Yield_co.

4. GCL Yield Holding Company Limited. http://www.gcl-power.com/news_detail/1992-%E5%8D%8F%E9%91%AB%E6%96%B0%E8%83%BD%E6%BA%90CFO%E8%AF%A6%E8%A7%A3%E8%B5%84%E6%9C%AC%E8%BF%90%E4%BD%9C%E6%96%B0%E6%A8%A1%E5%BC%8F+GCL+Yield+Co%E6%8F%AD%E5%BC%80%E7%A5%9E%E7%A7%98%E9%9D%A2%E7%BA%B1.

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ABOUT WRI

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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 that our outcomes will be bold and enduring.

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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.