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Impact of China wholesale power price reform on economics of distributed PV and storage

Sino-German Energy Transition Project

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Imprint

This report Impact of China wholesale power price reform on economics of distributed PV and storage is a research analysis paper published by GIZ in the framework of the Sino-German Energy Transition Project. The project supports the exchange between Chinese government think tanks and German research institutions to strengthen the Sino-German scientific exchange on the energy transition and share German energy transition experiences with a Chinese audience. The project aims to promote a low-carbon-oriented energy policy and help to build a more effective, low-carbon energy system in China through international cooperation and mutual benefit policy research and modeling. The project is supported by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) in the framework of the Sino-German Energy Partnership, the central platform for energy policy dialogue between Germany and China on national level. From the Chinese side, the National Energy Administration (NEA) supports the overall steering. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH leads the project implementation in cooperation with the German Energy Agency (dena) and Agora Energiewende.

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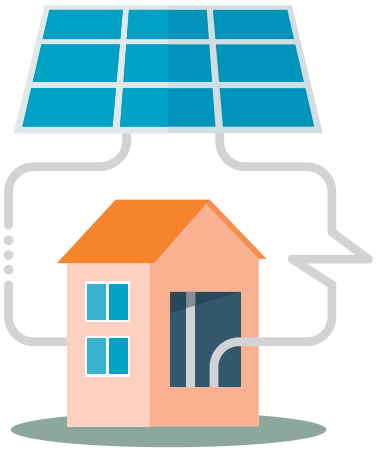


Summary

This short report is an update of the July 2021 study, Economics of Urban Distributed PV in China, published by the Sino-German Energy Transition Project, implemented by GIZ China.[1] The previous report examined model of distributed solar and storage, based on self-consumption to take advantage of offsetting retail price costs given time-of-use (TOU) prices for selected cities across China for the year 2020. The result showed that for stand-alone PV, both commercial and industrial (C&I) internal rate of return (IRR) and residential IRR yields over 15% in over half of the selected cities. Pairing storage for both surplus solar and storing night-time electricity for later use (the two-charge scenario, or scenario 3) would help commercial and industrial users to achieve even higher IRRs in all cities. The 2021 report also noted that reforms to retail power price are one of the most important factors for the further improvement of the economics of distributed solar.

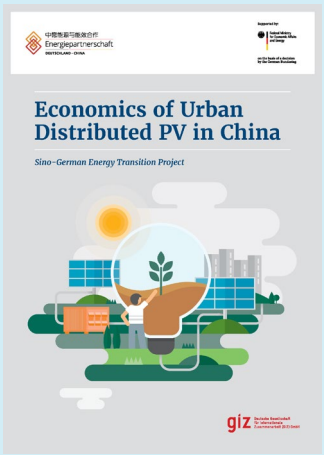
During 2021 China's National Development and Reform Commission (NDRC) announced several important policies on power prices and power markets. Several of these steps towards the market prices for electricity should further improve the economics of distributed solar, in our view.[2] In January 2021, newly published time-of-use (TOU) power tariffs for 2021 and 2022 took effect for most retail electricity customers.[3] On 26 July 2021, the NDRC issued a policy encouraging provinces and localities to widen the peak-to-trough TOU electricity tariff ratio to 4:1 by the end of 2021, implying a possible change in TOU tariff levels for 2022.[4] Before its implementation, an NDRC policy in October announced that C&I users would switch from regulated retail price schedules to market-based contracts from 2022.[5] However, during a transition period, C&I users not already on bilateral power contracts are subject to default power prices (which largely match prior retail rate schedules) issued by grid companies from December 2021.[6]

This report analyses the impact of the C&I power price change in 2021 and 2022 on the IRR of solar plus storage in several major cities in China. Compared to 2020 tariffs, the average IRR would decline by 4.5% in 2021 due to decreased TOU tariffs. However, IRRs would increase by an average of around 13.3% in 2022 due to expected higher market prices. Though the retail power price has fluctuated in the three years from 2020 to 2022, it is clear that the most advantageous IRR is from PV paired with storage charged twice per day under time-of-use rates (scenario 3), as compared with stand-alone PV (scenario 1) or storage with one charge per day (scenario 2). In general, the average IRR premium provided by storage in scenario 3 versus stand-alone PV should increase steadily from 0.7 percentage point in 2020 to 1.1 percentage points in 2022.

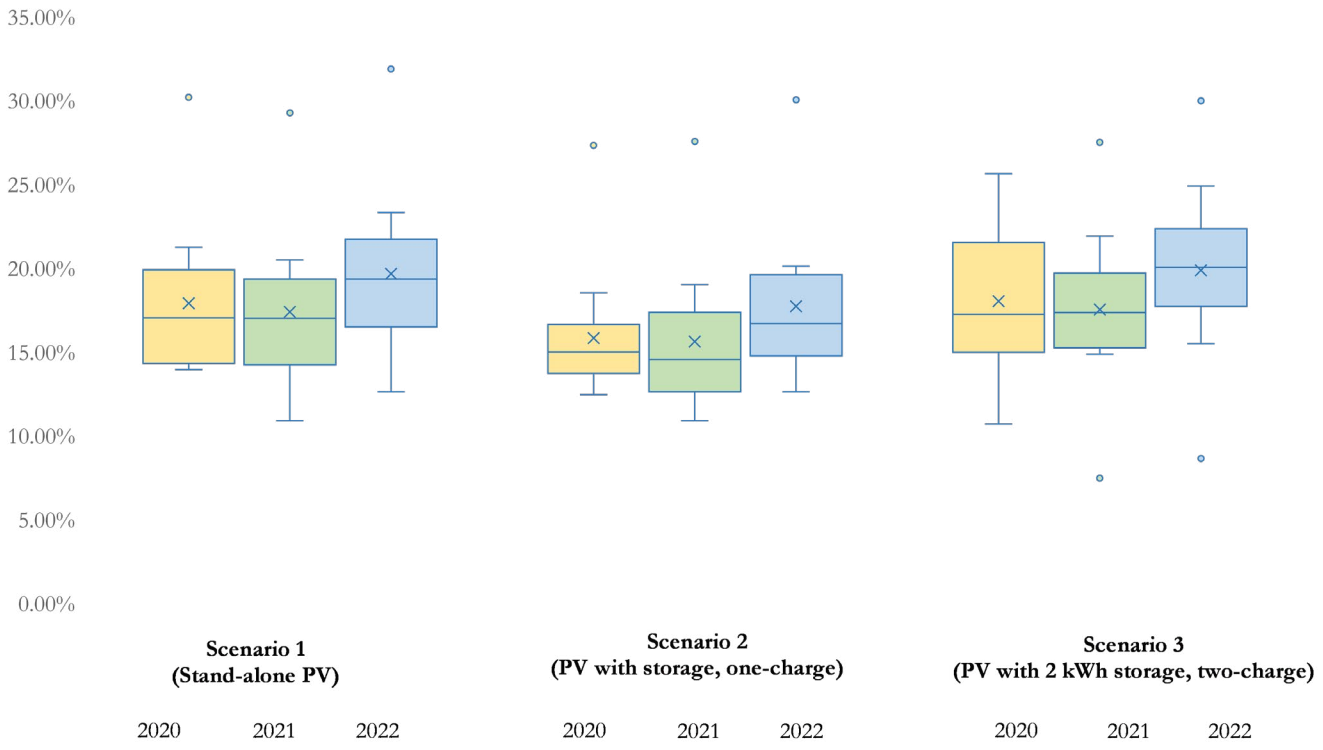
For more information about

Economics of Urban Distributed PV in China

read the full report



Internal rate of return (IRR) for commercial and industrial (C&I) distributed PV in 2020, 2021, and 2022



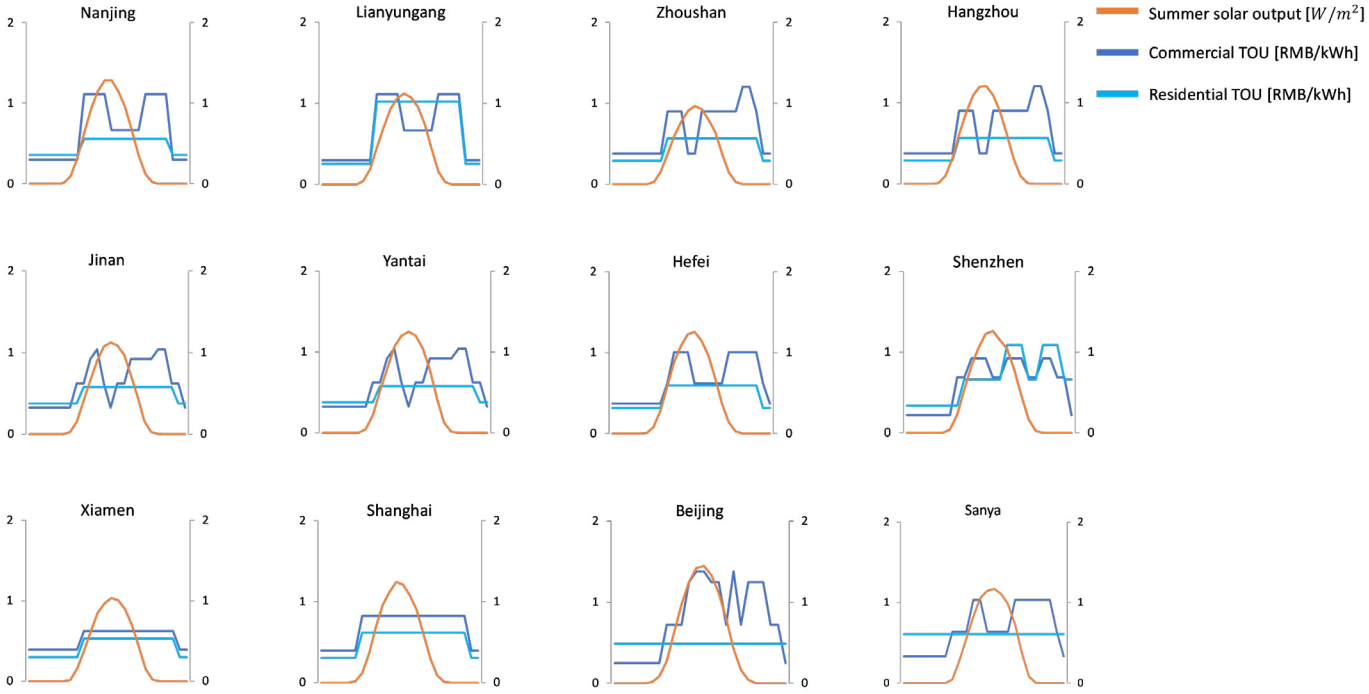
Note: Scenario 1 represents stand-alone PV; scenario 2 represents PV paired with sized storage, charging once daily at midday for surplus solar and discharging during peak hours in the afternoon; scenario 3 represents PV paired with 2-hour storage charging twice daily, whose second charging is self-consumed. The range of values represents the returns across 12 Chinese cities studied.

Source: Liu Yuzhao, Anders Hove, Liu Qingyang, and Zheng Qi, GIZ, 2021

Power prices in 2021

Power price is one of main factors in the economics of distributed solar. We extract the power price of 2021 from the websites of State Grid Corporate of China[7] and China Southern Power Grid[8], which are integrated platforms to look up electricity tariffs in China. In most cities, the price is effective from January 2021 to November 2021. The figure below summarises the commercial and residential price levels and solar outputs in summer in the 12 selected cities.

Time-of-use (TOU) prices and average annual solar output in 12 cities



Source: PVWatts, SGCC website, CSG website, and GIZ analysis, 2021

Due to the fact that each province recalibrated its T&D price at the end of 2019, the 2021 retail price in most cities decreased on average 2.8% compared to 2020. (Though the 2021 analysis included Shantou, the city apparently dropped its published TOU tariff schedule for C&I.)

Commercial and industrial power market

In the 2020 study, we pointed out that power price reform represents a critical change that should improve the economics of distributed solar and storage. In the last quarter of 2021, China adopted several reforms that will affect commercial and industry (C&I) users. Prior to these reforms, 56% of C&I power consumption was via regulated retail prices set by local power bureaus, rather than via bilateral monthly or annual power contracts that dominate China's growing wholesale power market. After December 2021, for those C&I consumers not yet on bilateral power contracts, the grid company assumes responsibility for publishing a default tariff—often similar to or identical to previous published regulated retail power prices.[9] However, this is only a transition to full marketisation. Some provinces, such Shandong and Zhejiang, already explicitly announced that all C&I users should enter the power market by 2023.[10]

How will this reform influence the economics of distributed solar 2022? There are four typical ways a C&I user can purchase power from December 2021:

- From the market through a spot market, which is only available in a few cities
- From the market through mid-to-long-term power contracts with power plants
- From the market through power supply contracts with retailer
- From a grid company by taking the default offer price

Despite these options, the majority of smaller C&I will continue to pay the default power price. Firstly, the spot market only represents a tiny share of China's power supply. Secondly, most power contracts are comparable to the default offer price because their mandatory time-of-use structure is regulated under the same scheme as the catalogue tariff and default offer price. Finally, the power price in most power contract is similar to the default offer price because the market price in 2022 is likely to approach the upper-bound set by the government given the high coal power price in recent months.

In China, all power prices, including catalogue prices, default offer prices, or market-based prices, consist of three elements:

- Wholesale power price (including wholesale clearing price, ancillary service costs, apportionment of cost variance and so on—the market clearing price constitutes the majority of costs);
- Transmission and distribution (T&D) price;
- Government taxes and surcharges.

For the catalogue price, the wholesale price part equals to the benchmark on-grid coal power price, whereas for default price and market-based prices, the wholesale price essentially reflects the market clearing price. In this report, the two are assumed to be the same. As noted, the wholesale clearing price will approach the upper-bound of the market price, which the new policy from October 2021 sets at 120% of the prior benchmark coal power price.[11] This assumption is the basis for the 2022 wholesale price used in the analysis of distributed PV and storage.

After summing up three price components, in this example, the retail price (that is, the off-peak price), taken by C&I users is 14.1% higher in 2022 versus 2021. Taking into account the time-of-use price ratios in each region, we can then estimate the peak, trough, and critical-peak prices.

Example of power price prediction for 2022

	Wholesale price	T&D price	Tariff additions	Total (retail price)
Example price 2021	0.5	0.2	0.01	**0.71**
Predicted price 2022	0.6	0.2	0.01	**0.81**
Increment	20%	Unchanged	Unchanged	**14.1%**

After repeating this calculation for all 12 selected cities, the estimated increases in the retail price are between 3.6% and 14.2%. The average increment across these cities is 12.0%.

The economics of distributed solar and storage in China in 2022

This study provides a detailed review of how the economics of distributed solar and storage develops in 2021 and 2022 based on similar assumptions to the analysis of 2020 distributed PV and storage economics. This report employs the official TOU power price for analysis of PV and storage economics in 2021 and predicted retail prices for PV and storage economics in 2022.

As with the prior analysis of 2020, the three scenarios are:

- Scenario 1: 10-kW stand-alone PV. Surplus solar is curtailed.
- Scenario 2: 10-kW PV plus storage, one charge per day to absorb surplus solar at noon, if any. The energy is discharged during the peak-hour in the afternoon. The battery capacity is between 4 kWh and 10 kWh, sized such that it can charge full in 90% of the days analysed.
- Scenario 3: 10-kW PV plus storage, two charges per day. One daytime charge to absorb surplus solar and a second charge at overnight TOU rates for later consumption at peak prices. The battery capacity is 20 kWh.

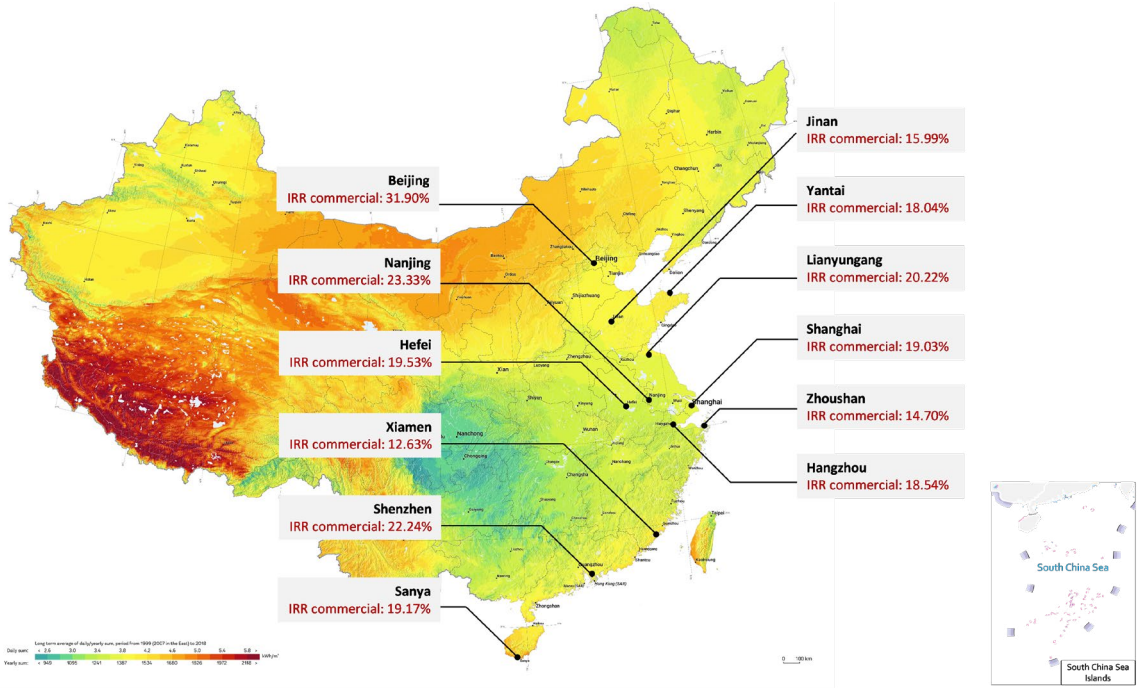
Summary of scenarios

Scenarios	PV capacity	Battery capacity	Function of battery
Scenario 1: Stand-alone PV	10 kW	No battery	No battery
Scenario 2: one-charge	10 kW	4-10 kWh (Choose to charge full in 90% of days)	For surplus solar
Scenario 3: two-charge	10 kW	20 kWh (2-hour battery)	For surplus solar and energy arbitrage

In all scenarios, we assume a self-consumption of electricity from either PV or storage. For other assumptions in our quantitative model, please refer to the Appendix.

scenario 1

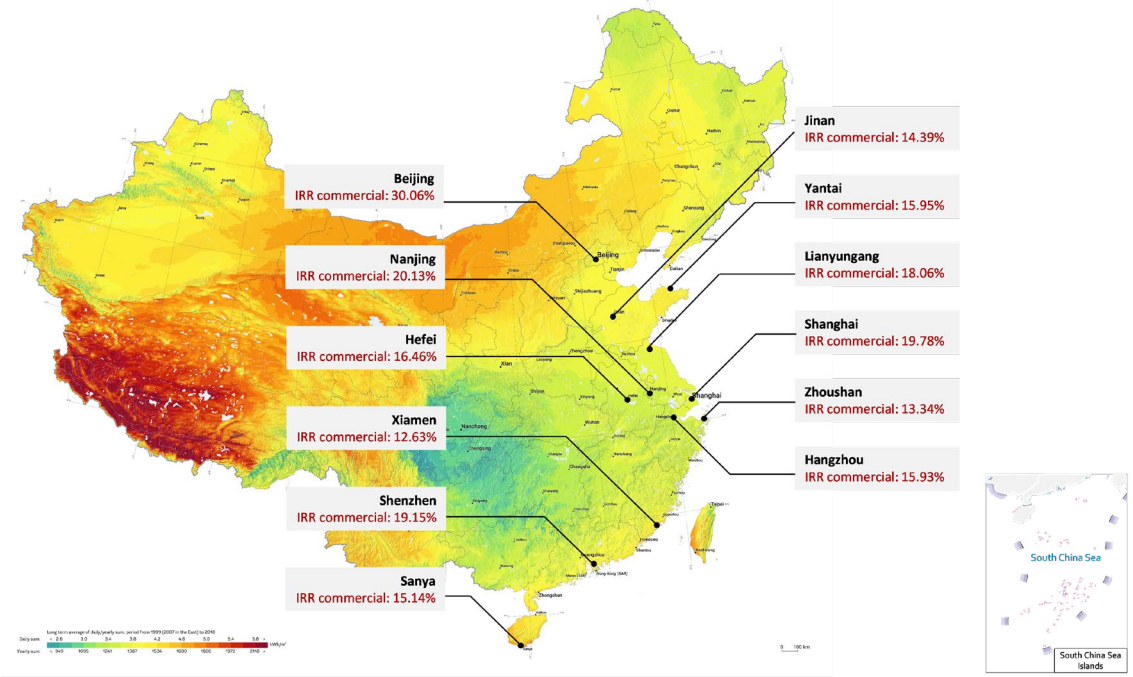
IRR of stand-alone distributed solar PV systems in selected Chinese cities in 2022



Source: Source: Liu Yuzhao, Anders Hove, Liu Qingyang, and Zheng Qi, GIZ, 2021

scenario 2

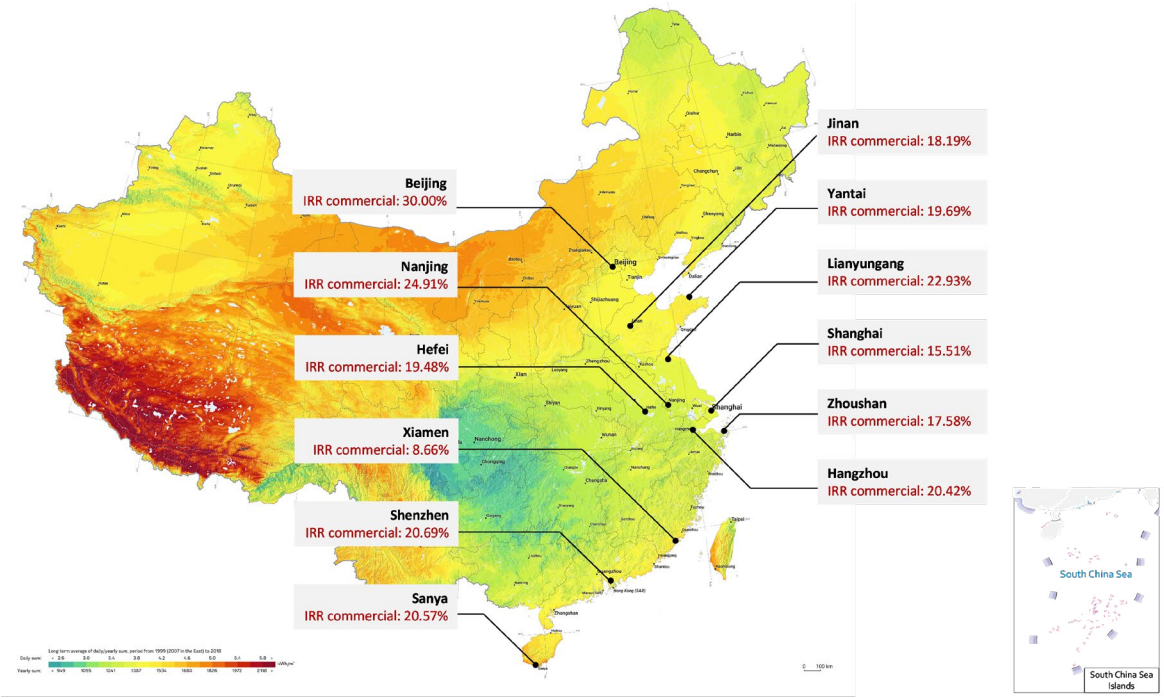
IRR of distributed solar PV and storage in selected Chinese cities in 2022, one-charge



Source: Liu Yuzhao, Anders Hove, Liu Qingyang, and Zheng Qi, GIZ, 2021

scenario 3

IRR of distributed solar PV and storage in selected Chinese cities in 2022, two-charge



Source: Liu Yuzhao, Anders Hove, Liu Qingyang, and Zheng Qi, GIZ, 2021

In general, the IRRs of stand-alone PV (scenario 1) for C&I users are in the range of 10.9% to 29.3% in 2021 and 12.6% to 31.9% in 2022. For PV with battery for surplus solar (scenario 2), IRRs range from 10.9% to 27.6% in 2021 and 12.6% to 30.1% in 2022. For PV with battery for both surplus solar and energy arbitrage (scenario 3), IRRs range from 7.5% to 27.5% in 2021 and 8.7% to 30.0% in 2022. More cities offer IRRs over 20% in 2022 than in 2021 for all scenarios. In scenario 3, there are six cities in 2022: Beijing, Nanjing, Lianyungang, Hangzhou, Shenzhen, and Sanya. In scenario 1, Beijing, Nanjing, Lianyungang, and Shenzhen also feature IRRs over 20% in 2022.

We also analyse the impact of different load patterns on the IRRs, using four cities for more detailed analysis: Nanjing, Beijing, Hangzhou, Shenzhen. The analysis is based on an enterprise with high and flat electricity load during for operating hours (or weekends/holidays), after which its load falls to 25% of peak for non-operating periods. The analysis considers four stylised load patterns representing a wide range of commercial and industrial use cases:

- Load case A: operational during 0:00-24:00 on all days. Load falls to 25% of full power for the rest of time. This case likely represents fully automatised industries with three shifts every day.
- Load case B: operational during 9:00-18:00 on all days. Load falls to 25% of full power for the rest of time. This case likely represents industries with only one shift every day.
- Load case C: operational during 0:00-24:00 on working days (i.e., all days in the year excluding weekends and Chinese official holidays). Load falls to 25% of full power for the rest of time. This case likely represents 24-hour commercial enterprises, such as special shops.
- Load case D: operational during 9:00-18:00 on working days. Load falls to 25% of full power for the rest of time. This case likely represents most commercial enterprises such as office buildings.

Impact of TOU and load patterns on IRR of PV and storage with 2 charges per day

	Time when operating in full load (25% load otherwise) Year	Year	
		2021	2022
Nanjing	0:00-24:00 on all days	21.91%	**24.91%**
	9:00-18:00 on all days	21.72%	24.69%
	0:00-24:00 on working days	20.85%	23.72%
	9:00-18:00 on working days	20.71%	23.58%
Beijing	Time when operating in full load (25% load otherwise) Year	Year	
		2021	2022
	0:00-24:00 on all days	27.52%	**30.00%**
	9:00-18:00 on all days	27.38%	29.86%
	0:00-24:00 on working days	24.97%	27.25%
	9:00-18:00 on working days	24.88%	27.15%
Hangzhou	Time when operating in full load (25% load otherwise) Year	Year	
		2021	2022
	0:00-24:00 on all days	17.64%	**20.42%**
	9:00-18:00 on all days	17.49%	20.25%
	0:00-24:00 on working days	17.19%	19.92%
	9:00-18:00 on working days	17.08%	19.80%
Shenzhen	Time when operating in full load (25% load otherwise) Year	Year	
		2021	2022
	0:00-24:00 on all days	18.06%	**20.69%**
	9:00-18:00 on all days	18.01%	20.64%
	0:00-24:00 on working days	17.36%	19.92%
	9:00-18:00 on working days	17.33%	19.88%

Source: Anders Hove, Zheng QI, GIZ China, 2021

The calculated IRR differences between typical industrial and commercial loads are more significant. The difference between the first two cases and the last two cases is 1.2 percentage points on average. In comparison, shortening the operational period from 0:00-24:00 to 9:00-18:00 results in a smaller difference, just 0.13 percentage point on average.

Summary of key findings

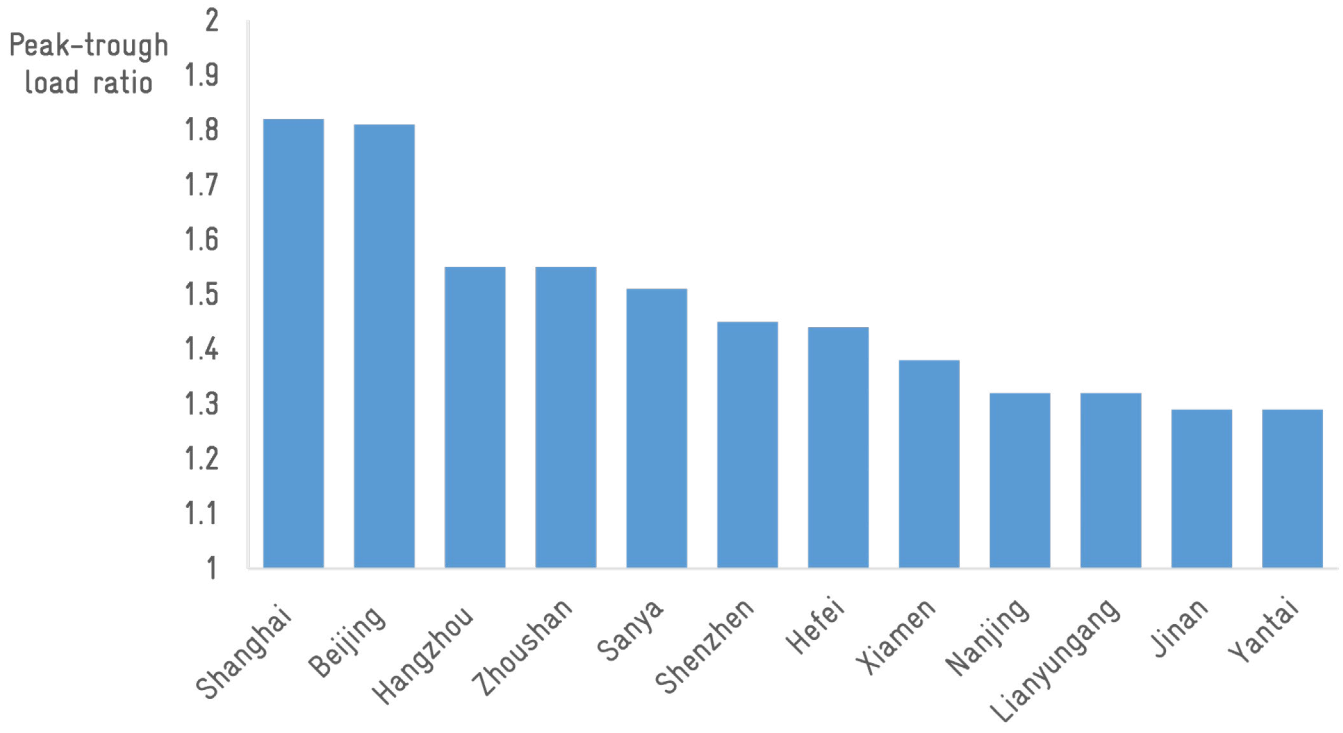
- The average IRR decreased in 2021 but increases significantly in 2022. The average IRR should reach an average of 18.2% in 2022 around 12 selected cities in China. The highest value of 31.9% would be achieved in Beijing.
- The main factor in these changes is the retail power price, which decreased by 2.8% in 2021 and increases by 12% in 2022.
- Because of time-of-use pricing, the advantage of adding storage to the PV system is increasing despite of the decrease of power prices in 2021. Scenario 3 yields the highest investment returns in all cities except Beijing, Shanghai, Hefei, and Shenzhen.
- When comparing the IRRs under different load patterns, full-time operation gets the best results. Shortening the daily load time from 24 hours to 9 hours during the day has a small impact on the IRR. However, turning down the load on weekends and holidays has a larger influence on the IRR.
- Power market reforms in China are likely to accelerate in near future, involving increasingly more market risks to C&I users. This is also a significant opportunity for distributed solar owners to hedge against retail power price fluctuations. For the self-consumption model, where PV and storage represent a small fraction of each enterprise's electricity use, the hedge would only present a discount on a portion of electricity costs—not a full substitute for grid electricity.

Outlook: the most promising regions

As power market reforms proceed, electricity spot markets are likely to become more widespread and eventually function as the main price reference across the market.[12] If distributed solar continues to grow in China as it has elsewhere, electricity net demand could eventually represent a duck curve as takes place now in California, meaning midday electricity prices could collapse or even go negative. Cities where the future duck curve develops will show the largest TOU price variations and thus where the highest investment returns of energy storage may arise.

The current peak-trough load ratio from the demand curve in 12 selected cities can indicate their potential for attractive PV and storage economics in long-term. Currently Shanghai, Beijing, Hangzhou, and Zhoushan have large peak-trough load ratios, and thus the IRRs of distributed solar in these cities are most promising.

The peak-trough load ratio in a typical week, based on provincial load curves



Source: NDRC, 2021[13]

The power market reform in China is gaining momentum, and the economics of distributed energy and storage are improving due to declining technology costs and rising fossil fuel prices. The resulting improvement in the economics of distributed solar will help accelerate the low-carbon energy transition in China as well as increase the potential for customers to play an active role in China's energy revolution.

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