



dena-REPORT

Industrial Demand Side Flexibility in China

German Experiences – Status Quo and Potential in China –
Policy and Market Recommendations.

Imprint

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Foreword

China has had a challenging history of electricity shortage and forced electricity curtailment. To date, in some parts of China, industrial electricity consumers would still be asked to reschedule their production in peak-demand seasons. On the other hand, China also faces challenges in integrating the production of renewable energy into the power system. A flexible power demand that can adapt to some extent to fluctuation is one of the key components in a complex energy system based on renewables. Industrial demand side flexibility, therefore, may potentially create a profitable industry and contribute to overall efficiency improvements, cost reduction, and pollution mitigation of China's electricity sector. China is quickly installing advanced metering infrastructure (AMI), which could provide tremendous opportunities in developing and utilizing demand side flexibility resources.

Today, China lags behind other countries in utilizing load flexibilities. The power demand side is still steered by one-way regulation by administrative means, such as orderly power consumption. Institutional barriers, including the lack of competitive electricity markets and the absence of mature business models, are preventing the monetization of flexible loads. In order to fully recognise the potential of smart grid measures, China needs to push forward the reforms to establish an open access power market with clear price signals, so the demand side flexibility resources can compete with power generators on equal terms.

This report provides an introduction to industrial demand side flexibility in China. It highlights the importance of this topic by sharing key experiences including results of large-scale smart energy showcase projects in Germany. In a case study for the aluminium branch, the report also indicates the potential for China's energy system and its industry. The report demonstrates a joint collaboration between the Deutsche Energie-Agentur (dena) – the German Energy Agency – and CNREC which is supported by the German Federal Ministry for Economic Affairs and Energy (BMWi) and Children's Investment Fund Foundation. The close cooperation between international experts enhances the quality of the work and provides invaluable implications for China's energy transition.

Wang Zhongying

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Executive Summary

In order to better integrate variable renewable energies (RE) and to ensure the stability of the power system, more flexibility within the power system is needed. One option for providing more flexibility in the electric power system is to use the flexibility potential of electricity consumers, especially of large-scale consumers such as industrial companies called **industrial demand side flexibility (DSF)**.

The example of Germany shows that smart integration of industrial loads not only enhances grid and system stability in a decentralized energy system based on RE. Industrial companies can also benefit economically from marketing their flexible loads, primarily on the **spot market** and the **balancing power market**. There are several ongoing large-scale smart energy showcase projects in Germany that test advanced market-based approaches to utilize industrial load flexibilities and other flexibility options in real-world conditions.

China's approach to integrate the industrial DSF potential is currently based on a highly regulated, static framework that includes so-called **orderly power consumption** and **peak-valley differences** in electricity prices. A number of pilot projects in different provinces were conducted in recent years which provided experiences with a more dynamic integration of industrial load flexibilities based on market mechanisms, e. g. via bidding mechanisms. The example of the Chinese aluminium branch highlights that the flexibility potential of China's industrial sector is huge and could contribute much more to the stability of the electricity system than it does today. An important prerequisite for that is a market-oriented system that reflects the requirements of the energy system while also providing the price signals regarding the value of flexibility for the companies.

In order to foster the use of industrial DSF, the report suggests to

- (1) develop the peak-valley pricing model further: create a more dynamic approach to identify and communicate peaks and valleys and create a compensation model that reflects the system value at the given peak or valley point of time,
- (2) scale-up the experiences with bidding mechanisms from pilot projects and implement,
- (3) strengthen the business model for load aggregators.

For the medium term the recommendation is to focus on

- (1) the implementation of wholesale spot markets that can provide price signals for the utilization of short-term DSF and
- (2) the establishment of ancillary services markets where industrial DSF could also act as a provider.
- (3) In addition, more efforts for stakeholder involvement and information is commended to achieve an effective implementation of the identified measures.

1 Industrial demand side flexibility: win-win for the grid and the industry

1.1 Smart integration of loads as a key factor for grid and system stability in a decentralized energy system based on renewable energies

With the Paris agreement, for the first time virtually all countries worldwide acknowledged that the threat of global warming is real and commonly agreed on “holding the increase in the global average temperature to well below 2 degree above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 degree above pre-industrial levels.”

In order to reach the agreed targets, radical changes to the energy and electricity supply systems are required worldwide. Many countries have initiated a transition towards a more sustainable energy system based on renewable energies (RE). Worldwide, in 2016 almost one quarter (24.5 percent) of electricity generation came from RE sources (1990: 19.9 percent). In China, the share of RE in electricity generation was slightly higher, reaching 25.5 percent (1990: 20.4 percent). For the EU and Germany alike, the share amounted to about 31 percent (1990: 12.8 percent for the EU and 4.6 percent for Germany).¹

However, in order to better integrate RE – particularly wind and solar with a high variability due to fluctuating weather conditions – and to ensure the stability of the power system, more flexibility within the power system is needed, e. g., for providing balancing power for frequency control and supporting the management of grid congestions in transmission grids.

Besides the possibility to expand the grid or to use energy storages or sector coupling technology as options for providing more flexibility in the electric power system, another option is to match electricity consumption more closely with electric power generation by exploring and using the flexibility potential of electricity consumers, hereafter called demand side flexibility (DSF). This involves active and automated management of electric loads, especially of large consumers such as industrial and commercial companies, in response to an external price signal or a contractually agreed switching signal.

As Figure 1 shows, DSF potential can be distinguished between:

- the theoretical potential, which refers to the long-term flexibilization of a process, including replanning production and, if necessary, acquiring new operating resources;
- the technical potential, which is the presently available capacity of a process that can be flexibilized;
- and the feasible potential as the intersection of accepted and economic DSM potential, which represents the actual extent of flexibility that a company is willing to offer in the market under the precondition that the offering can be marketed economically.

¹ International Energy Agency (2019)

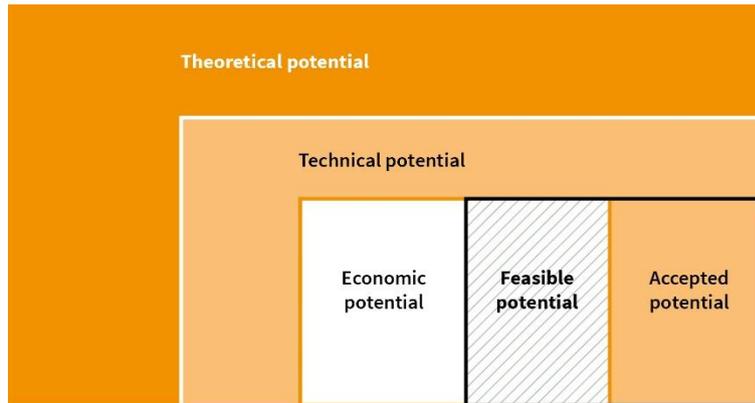


Figure 1 Categories of DSF potentials

Enabling electricity users and particularly energy-intensive industrial companies to react to system needs by maximizing their feasible potential is therefore an essential element of increasing system flexibility. Besides awareness among electricity consumers for this topic, the most crucial aspect for achieving this is the existence of some form of market price or incentive signal for flexibilities which reflects the system needs and is neutral towards the technology or actor who offers the service (so-called “level playing field” for flexibilities).

The example of the German market segments for DSF (see Figure 2) highlights this approach. With the exception of the AbLaV ordinance, these market segments are configured with a focus on power generating units (above all, large-scale power plants) and have been adjusted for more technology-neutrality.

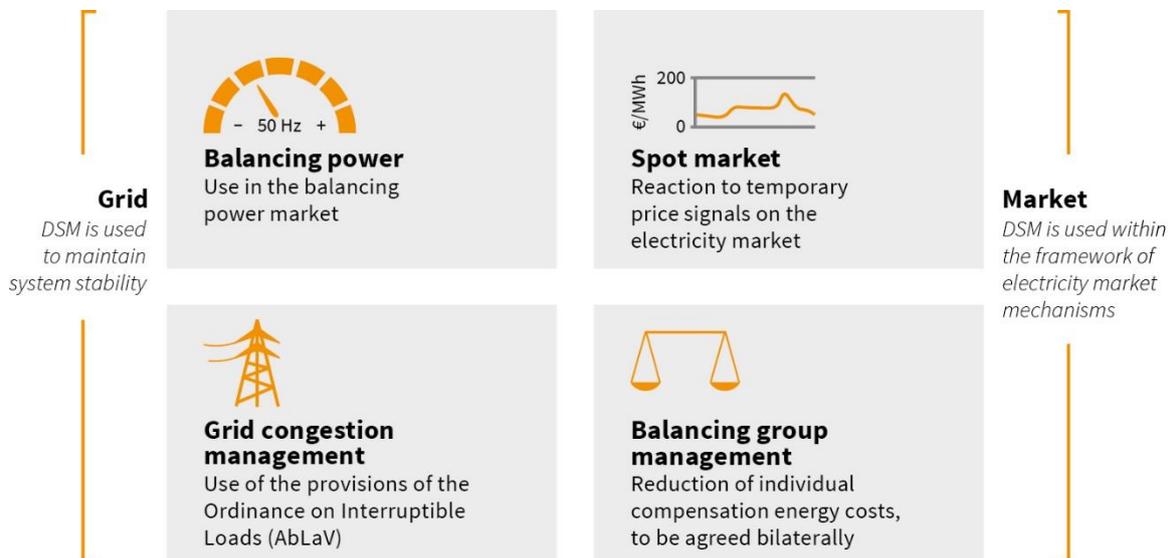


Figure 2 Market segments for DSF in Germany

Generally, all measures contribute to a flexible control of electricity consumption depending on the current power generation, the use of the available grid capacity, or price signals on the power market. The two most

important and most widely used market segments for DSF in Germany are the spot market and the balancing power market:²

- Spot market:** The marketing of DSF on the Intraday spot market (EPEX Spot) involves adjusting the consumption of the electricity load to the electricity price at relatively short notice. In the future, as a result of the expansion of variable RE sources and the parallel decline of conventional power plant capacities, increasing scarcity scenarios with high price spikes are predicted for the electricity market as well as surplus scenarios with very low or even negative electricity prices. Adjusting consumption to the current electricity price therefore contributes to optimizing a company's electricity procurement costs and will become more strategically relevant in upcoming years. To achieve such optimization, it is necessary for a company to include corresponding terms for flexibility marketing in their electricity purchase contracts. In contrast to the strictly regulated balancing power markets, these bilateral agreements between companies and electricity suppliers can be freely negotiated and are not subject to any technical limitations.
- Balancing power** is an important ancillary service that serves to maintain system stability, and in particular to control the frequency in the electricity grid. Balancing production and consumption at all times is achieved within the framework of the electricity market, but in reality discrepancies can naturally occur between the amounts of electricity traded and the actual amounts of electricity consumed, which must then be equalized at short notice. As Figure 3 shows, balancing power is traded in different forms – primary balancing power (PBP), secondary balancing power (SBP) and minute reserve (MR) – depending on the required time to react. In order to be able to participate in the auctions for these balancing power products, each participating technical facility must first be prequalified. Prequalification involves providing evidence to the transmission system operator (TSO) that the facilities are technically capable to satisfy the technical requirements regarding reaction time and controllability. For DSF in Germany, balancing power is currently the most highly remunerated form of marketing, and therefore of interest to many operations. On the other hand, the technical requirements involved in taking part in these markets are often too high to be fulfilled by loads. Particularly with regard to automated control technology, most consumption processes require upgrading before they can participate in the balancing power market.

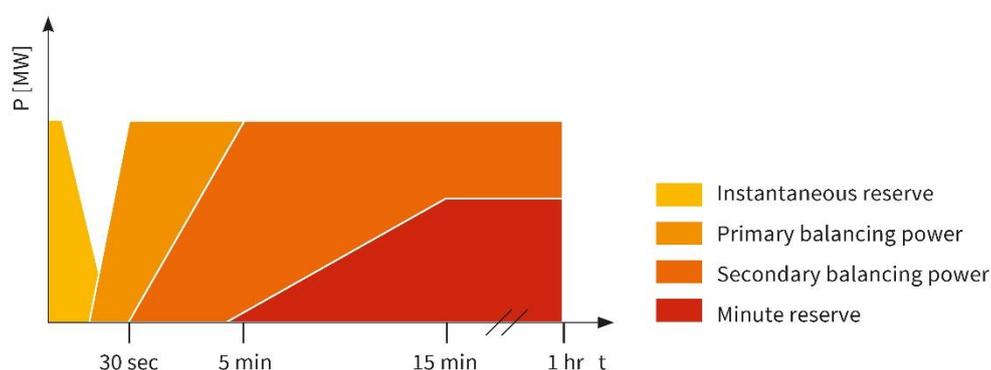


Figure 3 Temporal allocation of balancing power products

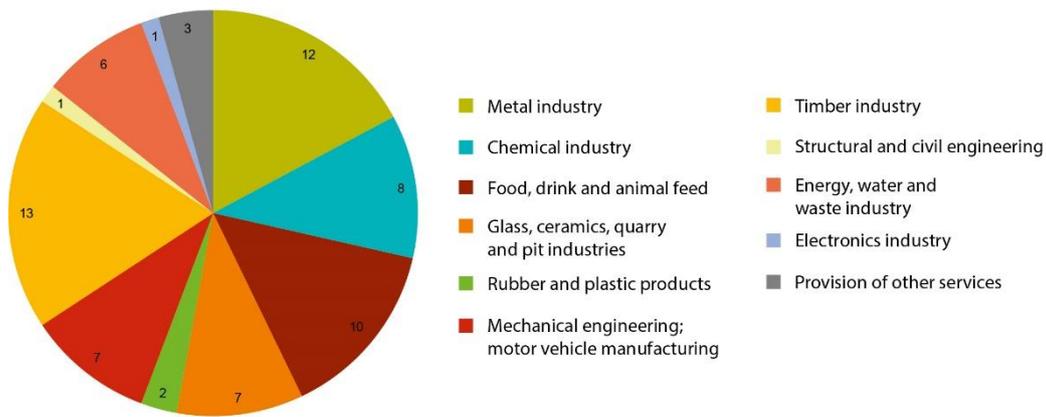
² Schenuit, Carolin / Vogel, Lukas (2018)

1.2 Industrial companies can benefit from marketing their flexible loads

DSF can open up a new source of income for companies, especially for industrial and commercial users. In the case of electricity-intensive companies, to a certain extent they can market their own flexible loads. Loads of smaller size can be marketed in association with other companies through a pooling system. In this case, the tasks of establishing and marketing the pool are carried out by a specialized service company (aggregator).

For industrial companies to provide DSF, they firstly need to identify their flexible loads, which are those electricity-consuming processes whose consumption can be temporarily increased, decreased or shifted to another point in time. Figure 4 shows the variety of industries and the different processes identified as potentially suitable for DSF in two pilot projects with German companies carried out by the German Energy Agency (dena).

Overview of sectors and number of participating companies:



Overview and number of process types:

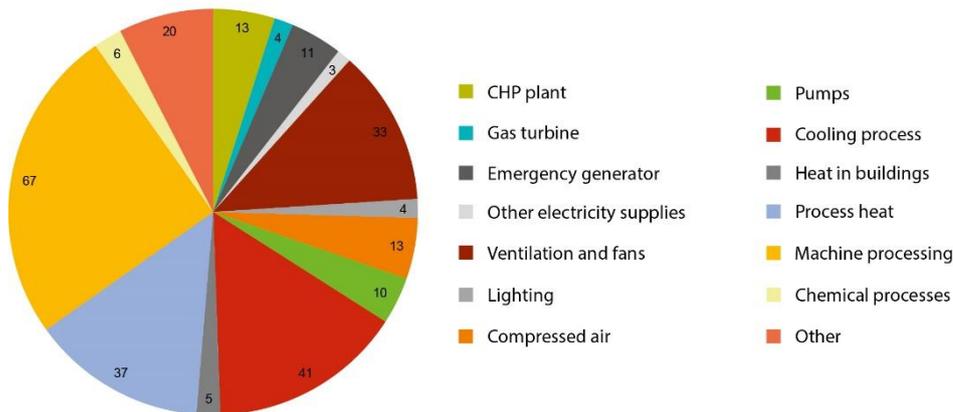


Figure 4 Overview of industries and processes involved in the Baden-Württemberg and Bavarian Pilot Projects Demand Side Management

Generally, the ability of a company to use flexible loads to provide DSF services does not depend on meta characteristics like industry sector or total electricity consumption, but rather on the technical specifications

of its specific processes. These include process controllability, reaction time and availability of energy storage. In many cases, ancillary processes like heating, cooling, pumps or emergency generators – as opposed to the main processes of industrial production – offer the best risk-revenue ratio for DSF services since they generally are much less critical to manage with respect to production output.

Market experiences in Germany indicate a shift of DSF services from balancing power markets towards spot market

Generally, in recent years, prices in Germany on both the balancing power market and the intraday spot market have decreased, mainly due to increased market activity and hence higher competition.

With respect to balancing power, from 2016 to 2017 the overall cost has declined by 26.5 percent, mainly due to a decrease in trading volume and at the same time an increase of the number of market participants.³ This has implications for the use of DSF since it reduces the possible revenues for the marketing of flexible loads on balancing power markets.

For the spot market, the picture is different. Indeed, the yearly average base price, i. e. the average price of all hours of the year, has declined by more than 33 percent in just six years. However, more important with respect to DSF is the yearly base peak spread, i. e. the spread between yearly average peak price (the average of all weekday hours between 8 a. m. and 8 p. m.) and yearly average base price has increased by 42 percent. This indicates that there is much more volatility in the spot market reflecting the volatility of electricity supply and demand. In addition, in the same time, the number of days in which at least one in 24 hours registered a negative price – meaning that there is a particular incentive for electricity consumption during these days – has increased by almost 143 percent (2011: 14 days; 2017: 34 days). Both observations highlight the generally increasing relevance of the spot market with respect to the marketing of load flexibilities by (industrial) electricity consumers.⁴

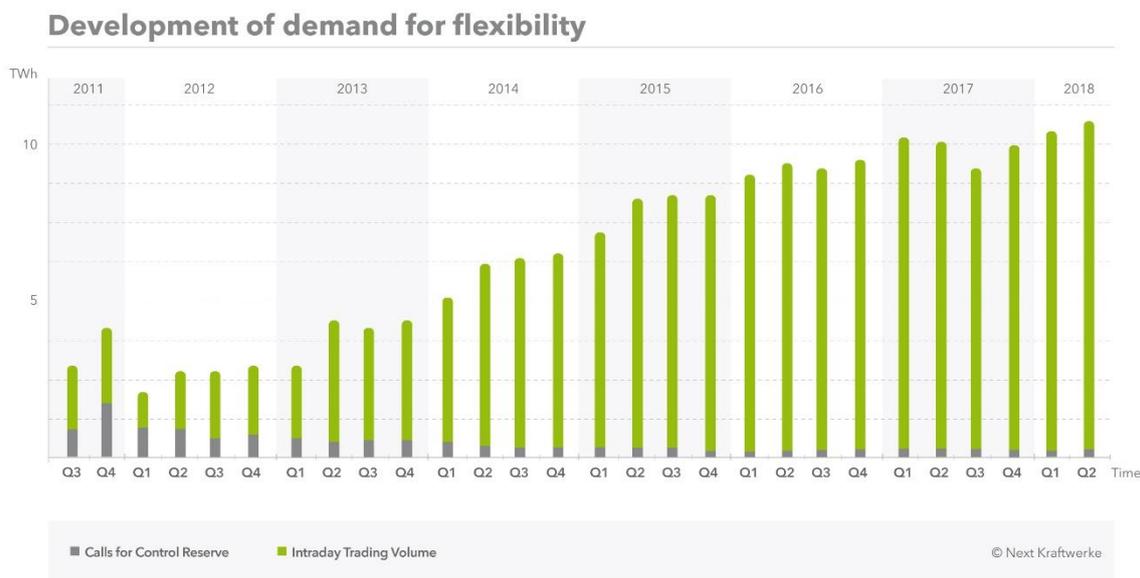


Figure 5 2011-2018 balancing market and intraday market volume [Source: Next Kraftwerke]

³ Bundesnetzagentur (BNetzA)/ Bundeskartellamt (2019)

⁴ EPEX Spot (2019)

As a consequence, a shift of market activities from balancing power markets towards intraday markets can be observed. Figure 5 shows the trading volume of the balancing power market and the intraday market from 2011 to 2018. It highlights that while the volume of balancing power contracted during these years (“calls for control reserve”) has decreased considerably, the amount of energy traded on the intraday market at the same time has significantly increased. This development can partly be ascribed to a reduction of traded time intervals on the intraday market to 15 minutes, which allows traders and aggregators to react much more precisely to the difference between reality and forecast, such as in the case of weather forecast variations which impact RE production. Further decrease of the gate closure time, i. e. the time before execution at which all trading activities have to be finalized, from 30 minutes towards 5 minutes for fulfilment of the traded contracts is currently being tested.

1.3 Large-scale smart energy showcase projects in Germany test advanced market-based approaches to utilize industrial load flexibilities

Various German research programs address the prospect of an energy supply that is increasingly based on decentralized and flexible RE and an energy grid with temporary congestions. In order to give an overview of ideas and solutions for the market integration of flexible loads that are currently discussed and tested in Germany and may also be relevant for the future development in China, the following sections introduces some of these programs.

1.3.1 Showcase Intelligent Energy Transition (SINTEG)

The SINTEG program tests in practice how electricity production and consumption can be flexibilized and coordinated with one another. In several regional projects that cover most parts of Germany, various approaches for the flexibilization of the energy system are being tested. For this purpose, the individual components of the electricity system are equipped with digital communication interfaces. These interfaces enable the components to send/communicate their operating status and to receive control signals. This allows the components to react flexibly to the electricity supply situation.⁵

C/sells: the local Altdorf Flex Market for small-scale flexibilities⁶

The project C/sells in the highly industrialized South of Germany is based on the idea of three guiding principles of the future energy system: 1. cellularity, 2. participation and 3. diversity. The Altdorf Flex Market (ALF) represents a platform for the use of existing small-scale flexibilities in the distribution grid – lower voltage level (230 V) and medium voltage level (up to 50 kV) – that is being implemented and tested in the context of a field test in Altdorf/Landshut (Eastern Bavaria) which is treated as a “cell” in the grid area of Bayernwerk Netz GmbH. By tapping local flexibilities like electric vehicles (EV) or heat pumps, it is expected that the grid capacity will be better utilized and both peak loads and production peaks will be reduced. As a result, the research partners expect to be able to integrate more RE and new electric consumers (such as electric cars) into the grid without having to expand the grid up to the last kWh or to curtail RE production⁷.

⁵ Bundesministerium für Wirtschaft und Energie (BMWi) (2018)

⁶ Zeiselmair, Andreas/ Bogensperger, Alexander/ Köppl, Simon/ Estermann, Thomas/ Wohlschlager, Daniela/ Müller, Mathias (2018); Köppl, Simon/ Zeiselmair, Andreas/ Estermann, Thomas (2019); FFE (2018)

⁷ Zeiselmair, Andreas/ Bogensperger, Alexander/ Köppl, Simon/ Estermann, Thomas/ Wohlschlager, Daniela/ Müller, Mathias (2018)

ALF serves as an interface between the grid operator and the decentral flexibilities in the area. The aim is to make various local small-scale flexibilities available for grid purposes through new, algorithm-based market mechanisms, especially for grid congestion management. This shall enable the use of flexibilities in a cost-optimal, safe and reliable manner. The grid operator makes a request to find a solution for any grid bottleneck. Flexibility providers in turn are owners, operators and marketers of flexibility options; they can offer their flexibilities (e.g. PV, EV, electric heat generation) on the platform. It is distinguished between active flexibility providers who offer their flexibilities at specific times and passive flexibility providers who allow the use of their flexibility based on a long-term contract with clearly defined use conditions.

ALF is an ongoing project and final results are expected in mid-2020. A technical evaluation of the first field test already proved that the smart meter infrastructure, which is seen as a precondition to exploit decentralized and small-scale flexibilities, is able to effectively control the participating flexibilities. By that, bottlenecks in distribution grid management can be relieved. For the ongoing real-life test of the market design itself, the question of how find a reasonable price point for the required flexibility was identified as a primary research question.

DESIGNETZ and its Proactive Distribution Grid⁸

The project DESIGNETZ distinguishes between local and regional areas of the electricity grid. A local sector can e. g. consist of power plants but also of private households and industrial companies that consume and produce electricity. If possible, the energy should be consumed or stored where it was generated. Grid operators can apply modern information and communication technology (ICT) with the goal for local areas to control their grid largely independently and report an overabundance of electricity from RE, the availability of free storage capacity, or a power demand that cannot be covered by own resources to the superordinate regional level. The regional area passes on excess electricity or feeds additional electricity into the local level. The design of the smart grid complies with the principle of subsidiarity, where matters are handled first at the lowest level of authority. According to that principle, DESIGNETZ project participants are connected to various local data nodes and form a local area with local power generation plants and local consumers. The local data nodes report their network status to regional data nodes, which in turn are connected to the central data node.

With respect to industrial DSF, there are two mechanisms being tested within DESIGNETZ:

- The Flex Electrolysis of Trimet Aluminium SE is a showcase for the adaptation of industrial processes to the new requirements for more flexibility of energy-intensive consumers that come with the energy transition. The approach is to develop a technology that enables flexibilization of the electrolytic cell of an aluminium smelter and thus the use of the electrolytic cell as an energy storage device (plus/minus 20 percent of the base load for up to 48 hours) eventually (see also section 2.3 of this report).⁹
- The Proactive Distribution Grid aims at developing a system for the market-based use of flexibility to address local bottlenecks in the distribution grid. By that, existing grid capacities shall be used more efficiently and grid expansion needs shall be reduced. Part of the project is the development of an interface for coordination between market and grid. An IT system was established that enables communication of flexibility requirements and timetables, integration of a grid condition forecast for the medium and low voltage level and provision of flexibility, particularly from (industrial) companies. The IT system was successfully

⁸ Bundesministerium für Wirtschaft und Energie (BMWi) (2019); Designetz/ Innogy (2019)

⁹ Designnetz/Trimet (2019)

implemented in a field test in Lengerich (Lower Saxony). Evaluations show that for the grid area in Lengerich a market-based provision of flexibility results in significantly lower costs (up to 80 percent less) compared to a purely conventional grid expansion. Even compared to regulated curtailment which allows for up to 3 percent peak shaving, savings of up to 50 percent are possible.¹⁰

1.3.2 SynErgie and its Energy Synchronization Platform¹¹

The large-scale research project SynErgie aims at enabling the energy-intensive industry to adapt its electricity demand to the increasingly fluctuating electricity supply. As a starting point, it focuses on key production processes of steel and aluminium production, the chemical industry, mechanical and plant engineering, as well as the paper, food, cement and automotive industries, which represent around 90 percent of the industrial net electricity demand in Germany. It is estimated that the application of flexibility measures could reduce the energy procurement cost of the industry by more than € 10 billion in 2020.¹²

SynErgie is working to automate the trade of energy flexibility. A digital Energy Synchronization Platform is being created based on a data model¹³ that allows for a standardized characterisation of flexibility. It consists of two parts, a market platform and an undefined number of corporate platforms, which have a common interface for data exchange and are capable of bi-directional interaction. The parent Energy Synchronization Platform defines stakeholders, technical interfaces, data flows, and regulations for a successful interaction and integration with the corporate platforms.

Each corporate platform represents a modular, service-oriented, secure, and externally encapsulated information and communication system within a company. It enables the company to automatically trade its energy flexibility on the market platform via a standardized interface. The corporate platform contains the recording, aggregation, analysis, and optimization of the company's processes and production. Also the control and regulation of the industrial processes take place.

The market platform acts as an intermediary between corporate platforms and digital services that support the marketing of flexibilities and is supposed to make the electricity market more accessible for flexibility. The digital services are designed to help companies market their flexibility in a standardized manner. Services provided in the first funding phase include the connection to the spot market and balancing power markets, as well as the provision of forecastings for markets and grids, and a trading agent. In addition, an optimization service will be developed that maximizes the revenues that can be achieved through the use of flexibility in various flexibility markets. Within the market platform, the service broker as the central intermediary manages the communication between the flexibility providers and user, thus maintaining the function as a "single source of truth" for the flexibility traded on the market platform.

¹⁰ Designetz (2019)

¹¹ Bundesministerium für Bildung und Forschung (BMU) (2019; Reinhart et al/ Bauernhansel et al/ Fridgen et al/ Jarke et al/ Abele et al/ Bühner et al (2018)

¹² Bundesministerium für Bildung und Forschung (BMU) (2019)

¹³ Schott, Paul/ Sedlmeir, Johannes/ Strobel, Nina/ Weber, Thomas/ Fridgen, Gilbert/ Abele, Eberhardt. (2019)

2 Demand side flexibility in China: on the way to a more market-oriented approach

Large-scale curtailment of RE in some Chinese regions due to local oversupply causes a huge waste of sustainable energy. DSF from industrial and commercial consumers, from private consumers as well as from energy storage capacities can help to create a balance between supply and demand without the need for RE curtailment. Meanwhile, the industrial electricity consumption accounts for more than 70 percent of China's total electricity consumption, with around 30 percent alone coming from four energy-intensive industries: steel, nonferrous metal, building materials, and chemical engineering. Hence, industrial energy-intensive companies have a special role to play in flexibility utilisation in China. Encouraging these players to flexibilize their electricity demand can have a great impact on a better integration of RE.

2.1 The current directive and static framework is hindering an efficient integration of industrial flexibilities

Currently, there are no fully operational spot markets for electricity trading in China. However, in 2019 some pilot spot markets have been initiated, starting with Guangdong and finishing with the launch of Inner Mongolia's pilot spot market on 26 June 2019. Overall, 8 pilot spot markets are now in operation.

China's approach to integrate the (industrial) DSF potential is still based on a rather directive, static framework maintained by the grid operators with three main elements:

- orderly power consumption,
- peak-valley differences in electricity prices,
- pilot projects in some regions (see section 2.2).

None of the aforementioned measures address the issue of ancillary services for the electricity system (e. g. balancing power, see section 1.1). Generally, ancillary service markets are not yet well established in China. In July 2018, the National Development and Reform Commission (NDRC) proposed to use mechanisms such as peak-valley price differences and also ancillary service compensation to promote the deployment of energy storage technologies. Accelerating the establishment of an ancillary service market that integrates flexible loads is crucial to promote the energy transition. The recent creation of an ancillary service market in Guangdong province is an important pilot project in this context.

Orderly power consumption

According to the Administrative Measures for **orderly power consumption**, local governments should take administrative, economic, and technical measures to manage power consumption, and require orderly management according to the following order:

1. peak shaving, realized by shifting power consumption to other periods,
2. peak avoidance, realized through interruptible load,
3. power restriction,
4. power rationing.

This approach is primarily grid-oriented, with the goal to minimize the adverse impact of power supply shortage in some conditions for businesses and the society as a whole. Moreover, it is a highly directive measure that is led and promoted by the government and relevant government departments at all levels, mobilizing power supply enterprises and power consumers to participate and cooperate. Orderly power consumption is based on relatively rigid and static bilateral agreements between grid operators and (industrial) electricity consumers. Due to the increasing volatility of power supply and the subsequent grid requirements, these bilateral agreements are not regarded as adequate to efficiently address current and future challenges with respect to system security.

Peak-valley pricing

The introduction of **peak-valley differences in electricity prices** is seen as an important first step to steer the use of electricity and explore the potential of DSF. **Peak-valley pricing** aims at contributing to a more balanced supply and demand and adjusting the peak-valley difference of power consumption over time by establishing an economic incentive for industrial and big commercial consumers to shift their loads. At present, with a ratio of about 2:1 to 3:1, the peak-valley price difference in China is set in order to satisfy the goal of peak shaving. However, since both peak and valley prices are set in advance by provincial Development and Reform Commissions (DRCs) and no competition between stakeholders is foreseen, the mechanism cannot be regarded as market-based even though it entails the voluntary participation of consumers in a price-based system.

Generally, electricity prices in China vary from province to province and from sector to sector. In most regions, price schemes are distinguished between households, agriculture, ordinary industry, commercial businesses, and large industry. More specifically, industrial and commercial consumers only pay electricity unit prices (per kWh), while large industrial consumers have a two-part tariff with a basic electricity unit price and a demand charge. The demand charge includes the maximum demand and transformer capacity which enterprises can select according to their anticipated needs. Generally, the average electricity price for large industrial consumers is lower than the price that is paid by other industry and commercial consumers.

In April 2016, the State Council proposed to promote electricity price equalization for industrial and commercial consumers by allowing large commercial consumers to participate in direct electricity trading and by carrying out pilot projects in which commercial consumers independently choose between paying the average commercial tariff or the peak-valley price.

According to incomplete statistics, after NDRC issued the Notice on Reducing General Industrial and Commercial Electricity Prices in April 2018, 16 of 34 provinces, municipalities, and autonomous regions in China have issued peak-valley electricity price tables, including Beijing, Guangdong, Hainan, Hebei, Jiangsu, Ningxia, Gansu, Qinghai, Xinjiang and Chongqing.

In addition, 21 provinces, municipalities, and autonomous regions in China (Jiangsu, Zhejiang, Hebei, Shanxi, Anhui, Fujian, Shandong, Henan, Hubei, Guangdong, Hainan, Guizhou, Yunnan, Shaanxi, Inner Mongolia, Guangxi, Ningxia, Beijing, Tianjin, Shanghai, Chongqing) have adjusted their general industrial and commercial electricity prices. Among the provinces and cities that have not announced price adjustment plans are Gansu, Qinghai, Shanxi, Shanxi, Shanghai, Tianjin, Yunnan and Zhejiang.

Figure 6 shows the peak-valley price of industrial and commercial consumers in some provinces and cities, of which Beijing, Guangdong, and Jiangsu have a large difference in peak-valley price, while Shanxi, Hebei and

Ningxia have a low difference in peak-valley prices. Generally, a further widening of the peak-valley price difference is expected in various regions which will likely strengthen its relevance for (industrial) DSF.

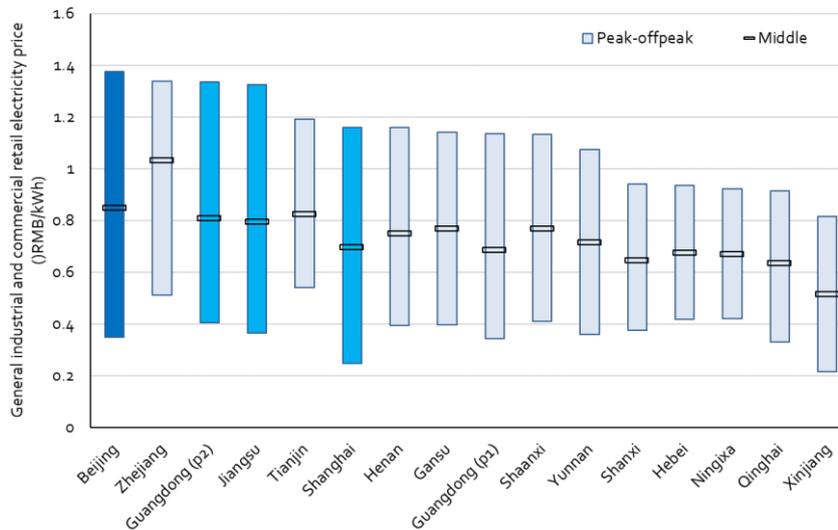


Figure 6 Peak-valley time-of-use price for industrial and commercial consumers in some provinces and cities¹⁴

Pilot projects

Technically, the peak-valley price system also provides a market opportunity for load aggregators that gather small-scale loads in order to optimize their joint electricity consumption within the existing price framework, thus contributing to the desired goal of peak shifting. However, reality shows that current peak-valley differences in electricity prices hardly represent a positive framework for an aggregator's business case. Vivid participation in pilot projects of virtual power plants (VPPs) that pool distributed generation, energy storage systems, and controllable loads (e. g., a VPP pilot project by State Grid Jibei in Qinghuangdao) and several upcoming load aggregation companies show that there is an interest in developing such solutions.

In recent years, China has initiated a transition from orderly power consumption to a more market-based approach that allows consumers to voluntarily and temporarily offer their load flexibilities in a competitive environment in return for obtaining subsidies, price concessions, or other incentives. Already in 2011, the NDRC launched a comprehensive **pilot project scheme**, selecting four cities (Beijing, Tangshan, Suzhou, and Foshan) as pilots for more market-based DSF and further release the DSF potential. The pilot projects that were concluded in 2015 aimed at reducing the peak load situation for electricity in industrial facilities and commercial buildings and at improving the efficiency of power consumption. For more information on experiences from recent pilot projects see section 2.2. Generally, it must be stated that the scope of these pilot projects and their effect on the Chinese energy system as a whole are still rather limited.

¹⁴ The data in the figure shows the peak-valley time-of-use price of less than 1 MW for general industry and commerce. Guangdong (1): Yunfu, Heyuan, Meizhou, Shaoguan and Qingyuan; Guangdong (2): Guangzhou, Zhuhai, Foshan, Zhongshan, Dongguan; the two-part summer peak-valley electricity price is referred to in Shanghai; and the peak-valley electricity price in dry season is referred to in Yunnan.

2.2 First experiences with dynamic integration of industrial load flexibilities in pilot projects

Primarily due to the issue of peak and valley loads and the corresponding challenges for grid operation, different approaches to use DSF are currently being tested in a number of pilot projects in China. While in some cases fixed prices for specific load flexibilities are offered, other projects are testing different forms of bidding processes, e. g. with a pre-defined maximum price. It is important to state that none of these projects have left the pilot status and that no long-term system for an implementation and rollout of these approaches to DSF was established. The pilot projects highlight that there are several positive examples and experiences of industrial consumers in China utilizing their flexible loads in order to address challenges of the energy system and at the same time also benefit economically.

2.2.1 Valley-filling bidding mechanism in Jiangsu Province

In 2017, Jiangsu Economy and Information Technology Commission issued a *Notice on Further Deepening the Power Demand Response Work* which specified basic principles for users to participate in a project for DSF. Amongst others, these are:

- voluntary participation and safe operation of electricity consuming companies,
- market-oriented negotiation for bilateral agreements between a provincial electric power company and power consumers,
- implementation of an agreement defining the parties' rights, obligations, and compensation standards.

During the Spring Festival and National Day in 2018, influenced by the shutdown of factories for an extended vacation, the overall level of power load was very low, and there was a certain difficulty in consuming existing power from RE sources.

As a result, Jiangsu Provincial Price Bureau and State Grid Jiangsu Power decided to jointly carry out "valley-filling" demand flexibility measures from 00:00 to 08:00 and 12:00 to 17:00 from 1-3 October 2018. Hence, Jiangsu successfully initiated a bidding mode in which load aggregators and consumers directly could offer their flexible load and the flexibility incentive price they needed. The higher the load and the lower the incentive price, the greater the chances to be selected to participate.

For the early morning, a total capacity of 770 MW of flexible load was offered with incentive prices between RMB 1.33/kW and RMB 5/kW. For the afternoon, a total capacity of 1,120 MW of flexible load was offered with prices between RMB 1.33/kW and RMB 8/kW. Finally, a total of seven load aggregators and 43 single power consumers took part in this measure. From 1-3 October 2018, six activated demand side flexibilities cumulatively achieved 7,190 MW. On 3 October 2018, "valley-filling" at 02:15 and 15:45 reached the maximum of 1,280 MW and 1,420 MW. With a difference between peak and valley load of 10,703 MW on that day, the relevance and potential impact of this measure becomes very clear.

In this context, two particular experiences from industrial companies can be shared (see Figure 7). First, Jiangsu Leoch Battery Co., Ltd. in Jinhu County participated in this DSF measure by adjusting the operation mode of its energy storage equipment, contributing 53 MW in six calls and obtaining a total of RMB 120,000 without increasing its own expenses. Second, Jiangyin Xingcheng Steel Co., Ltd., with an installed capacity of 140 MW, reduced the output of its own power plant while adjusting the production shifts during three days of

the National Day holiday. The actual flexible load of this enterprise in the early morning and in the afternoon was 55.8 MW and 54.7 MW respectively, summing up to a total of RMB 661,700 as flexibility compensation.

	Jiangsu Leoch Battery Co., Ltd.	Jiangyin Xingcheng Steel Co., Ltd.
Flexible load	53 MW	55.8 MW (morning) 54.7 MW (afternoon)
Duration	6 calls	3 days
Compensation	120,000 RMB	661,700 RMB

Figure 7 Examples of industrial DSF in Jiangsu Province

2.2.2 Valley-filling and bundling of A/C loads in buildings in Shanghai

In the summer of 2018, State Grid Shanghai Electric Power Company successfully carried out different types of DSF programs focussing on urban controllable load resources such as industrial production, self-generation power plants, energy storage facilities and public charging stations.

On 18 June 2018, from 00:00 h to 06:15, State Grid Shanghai Power for the first time implemented a large-scale "valley-filling" DSF program. Overall, 88 single consumers and five load aggregators (involving 522 consumers) participated, increasing the maximum load in the system at times by 1,059.3 MW (872.8 MW on average). As a large company, Shanghai Expo participated in this program by increasing its power demand from the grid at times by 1.2 MW while at the same time decreasing its own power production, thus profiting from both reduced fuel cost and the compensation for the supply of DSF. Following up on experiences in the first two rounds, on 17 August 2018 a total of 389 single consumers and six load aggregators participated in the third round.

In addition, a "virtual power plant" project gathering air conditioning resources from commercial buildings was initiated, with 104 consumers and an accumulative flexible load of up to 55 MW participating. This highlights the potential for DSF of commercial office buildings. Shanghai Sieyuan Electric Co., Ltd., located in Minhang District, was part of the first batch of commercial, non-industrial air conditioning units joining the DSF pilot in Shanghai and offering flexible loads of 550 kW for a total of 17 days.

2.2.3 Bundling of A/C loads and use of battery storage in Henan Province

Influenced by continuous high temperatures in the summer of 2018 and the rapid growth of air conditioning loads, the maximum grid load in Henan Province reached 63,640 MW, breaking its own record for the fifth consecutive time with a yearly growth of 5,790 MW. In June 2018, Henan Development and Reform Commission released a *Notice on Carrying Out the Power Demand Response Practice Work in 2018*, notifying that users who confirmed participation in advance and completed the load reduction during a previously designated

period would get a compensation of RMB 12/kW/time; users who confirmed participation in real-time and completed load reduction after receiving the instruction would get a compensation of RMB 18/kW/time.

On 27 July 2018 from 12:30 to 13:30, in order to alleviate the short-term operation pressure of the power grid, Henan Province for the first time chose to implement the DSF measure in Zhengzhou, Zhumadian, Xinyang, and Lankao counties. The users in the pilot areas reduced their consumption on a voluntary basis in order to avoid high peak loads and could obtain compensation for doing so. Load aggregators were deemed as a single user to receive the compensation. The distribution of the compensation among the aggregated consumers and the aggregator should be agreed upon on a bilateral basis.

A total of 66 single consumers and one load aggregator summing up to a flexible load of 125.4 MW, primarily from industrial and non-industrial air conditioning and energy storage, participated in this DSF measure. A large-capacity battery storage station provided a flexible load of 8 MW alone, creating a precedent for the market operation of the battery storage industry.

2.2.4 Peak-valley price bidding in Shandong Province

In July 2018, Shandong Economy and Information Technology Commission issued the *Notice on Carrying out the Power Demand Response Market Pilot Work* (LJXDL [2018] No. 244) along with Shandong Provincial Price Bureau which introduced incentive-based measures for DSF to regulate the peak and valley loads. It required a bidding process in which participants needed to state their flexibility capacity and the required compensation price per kW, with a maximum price pre-defined at RMB 30/kW. Energy storage facilities and non-industrial users' central air conditioning had to bid under different conditions.

On 13 July 2018, Shandong Economy and Information Technology Commission and State Grid Shandong Electric Power Company initiated the pilot with an overall DSF quantity of 1,500 MW (including 50 percent as reserve). On 10 August 2018, the bidding process for DSF was conducted for the first time. 68 industrial enterprises and 30 non-industrial enterprises in Qingdao were determined as pilot enterprises. After some final preparations on the electricity grid side the project will enter the next phase of implementation. More detailed information is expected to follow shortly.

2.2.5 Flexible load aggregation and standardization efforts in Jibei

State Grid Jibei Electric Power Company is developing a virtual power plant pilot project, focusing on the application scenarios for the low-carbon Winter Olympics in 2022, including clean energy absorption, smart energy services, etc. The project aggregates distributed wind power, distributed PV, thermal boiler, heat pump, energy storage, industrial and commercial flexible load resources in Tangshan, Zhangjiakou, Qinhuangdao, Chengde and Langfang, and aims to increase visibility and controllability, provide peak shaving, frequency regulation and other ancillary services for power grid and to participate in electricity market.

The first stage of the project is located in Qinhuangdao, with 23 resources of 9 types, including distributed PV, heat pump, energy storage and industrial and commercial loads, with a total capacity of 104.5 MW. The maximum capacity of peak shaving reached 14.6 MW in summer and 24.6 MW in winter.

At the same time, State Grid Jibei is leading to develop the IEC standard on virtual power plant. On 5 March 2018, the IEC TS 63189-2 standard proposal on virtual power plant use cases was approved, which was proposed by State Grid Jibei.

The pilot projects described above highlight that there already is a lot of activity and relevant experiences have been made with respect to industrial demand side flexibility in China. Several industrial companies have participated in the different pilot projects and have offered flexible loads of significant extent to support the energy system while benefiting themselves as well. In Jibei province, standards for virtual power plants are even being developed. Consequently, the scaling-up of those experiences is now the necessary next step.

2.3 Case study: Demand side flexibility in the aluminium industry – the potential contribution of an energy-intensive branch

The example of the aluminium industry highlights the overall potential for DSF in China's industrial sector. Generally, the aluminium industry with its energy-intensive processes is predestined to offer its load flexibility to support the energy system stability (see also section 1.2). Compared with other users, energy-intensive industries have several advantages with respect to load flexibility. First, due to their big load capacities, a single consumer can provide relatively large amounts of flexible loads (usually at the megawatt level) that could otherwise only be provided if multiple small consumers get pooled together. Second, due to the steady load curve that shows little sensitivity to external conditions such as seasonal or weather changes, the load flexibility is only subject to slight fluctuations.

The core unit of aluminium production is the electrolytic cell which accounts for about 90 percent of the total electricity consumption. Typically, aluminium electrolysis requires a steady load curve in order to maintain the high quality of the product. However, experiences from the German aluminium producer Trimet show that with some technical alterations of the electrolytic cell, it can be used as a form of electricity storage without compromising the final product quality.¹⁵

When looking at the Chinese aluminium industry, the technical potential for DSF would be substantial when German experiences and conservative deductions are applied: based on a list of 217 Chinese aluminium smelters and their production capacity of 57.4 million t/a¹⁶, and assuming an electricity demand of 13.5 MWh/t primary aluminium, the total electricity demand of the Chinese aluminium industry can be estimated to amount to 774.9 TWh/a (i. e. 11.3 percent of China's total electricity consumption in 2018). With approximately 8.600 full load hours per year, the total breaking capacity sums up to 90.1 GW. Under the conservative assumption that with the application of the available flexibilization technology, the load can be temporarily (maximum 24 hours) increased or reduced by +/- 10 percent, the Chinese aluminium industry has a load flexibility of +/- 9.01 GW (i. e. up to 18.02 GW). If that potential was fully used, e. g. coming from the reduction level of 90 percent and then increasing it to the level of 110 percent for one full day (or vice versa), a maximum of 432.5 GWh of consumption would be shifted. After all, this corresponds to 2.3 percent of China's average daily electricity consumption in 2018.¹⁷

However, the experiences of a major Chinese aluminium company also point out the challenges of the current regulatory framework in China. An interview by the German Energy Agency (dena) with a major Chinese aluminium company revealed that great part of the flexibilization potential remains untapped. In parts, this

¹⁵ Trimet (2019); Designnetz/Trimet (2019)

¹⁶ Genisim (2019)

¹⁷ Statista Research Department (2019)

has to do with a lack of experience with the relevant technology that enables flexibilization of the aluminium electrolysis.

In addition, currently there is only the peak-valley price mechanism as a relevant “market” for any DSF. The economic incentive is set on optimization of power consumption along the time blocks of peak and valley prices: According to its own statement, with a price difference between peak and valley prices of about 0,3-0,4 RMB/kWh (see Figure 8) – hence, with the peak price being more than twice as high as the valley price – the company could save about 40 percent of its cost for electricity if all electricity was purchased at valley price level. This highlights the relevance of the peak-valley price difference which has already resulted in an internal guideline that ancillary processes like pumps or turbines should, if possible, be operated during times of valley price. However, even with this price spread, other energy storage technologies assessed by the corresponding company did not appear economically feasible.

兰州分公司峰谷平时间段		price: Yuan/kWh
Peak time	8:00-11:30	0.5591
	15:00-16:00	
	18:30-22:00	
valley time	23:00-7:00	0.2029
nomal time	7:00-8:00	0.381
	11:30-15:00	
	16:00-18:30	
	22:00-23:00	

Figure 8 Exemplary overview of peak and valley prices in Lanzhou, China

Moreover, even though the optimization along peak and valley prices by this company may have some positive effect on the electricity system by helping to shave the peak load, it does not fully address the requirements of the Chinese energy system. Firstly, the system of peak and valley prices is relatively static, a characteristic that does not comply with the requirements of an energy system based more and more on variable RE. Moreover, it does not cover the provision of ancillary services needed in real-time, such as balancing power. This may gain importance once the transition of the Chinese energy system comes to the point where fewer conventional power plants with their rotating masses provide fewer ancillary services and other actors such as RE, energy storage, advanced power electronics and flexible loads have to step in.

Thus, with the right flexibilization technology and given a more sophisticated and market-oriented system that fully reflects the requirements of the energy system while also allowing for the necessary return on investment, the aluminium branch in China could potentially contribute much more to the stability of the electricity system than today while also benefitting economically.

3 How to foster the use of industrial demand side flexibility: Monetization, market structures and information

Industrial DSF is crucial to support the grid integration of RE. The electricity system of the future will need to incorporate existing and future flexible loads efficiently. Based on the above analysis of the status quo in China and experiences with DSF in Germany, there are several suggestions how to improve the regulatory framework for industrial DSF in China.

Create adequate compensation for DSF to reflect its system value

All relevant market players need to have a financial or other interest to engage in DSF. The level of remuneration for (industrial) companies or aggregators who are providing and bundling flexible loads needs to adequately compensate for their efforts.

For industrial companies, the peak-valley price difference can be seen as a starting point for utilization of DSF. Even though it is a static tool that cannot fully reflect real-time grid requirements for flexibility, it puts a price on the ability to flexibilize (industrial) loads. It may therefore serve as an intermediary measure on the way to a more market-based system. The peak-valley price spread needs to be high enough to allow for necessary investments in flexibilization technology and to cover differing opportunity costs for the shifting of production.

Build on experiences with bidding mechanisms from pilot projects

In the short term, experiences with bidding mechanisms from existing pilot projects (see section 2.2) should be taken up and extended. Tenders can be seen as an important element for the transition towards market-based structures, as they already contain some key elements of a valid market, e. g. the organized matching of supply and demand, and a more advanced degree of competition and transparency compared to the status quo. The expansion of these tenders both regionally and in terms of number and scope is therefore the logical next step.

Strengthen the business model for load aggregators

Aggregators play a decisive role for the gathering of loads, particularly from private or commercial consumers, thus helping to tap as much of the existing DSF potential as possible. Even though they are not a precondition for industrial DSF, they can still function as an accelerator for the use of industrial flexibilities. The experiences of the different pilot projects in China show that currently the role of aggregators is not yet well established and that existing aggregators have no resilient model for making profits. Consequently, the aggregators' role and their business model should be strengthened by creating a regulatory framework that considers and enables this market role.

Implement transparent wholesale markets that can provide price signals for short-term DSF

Utilizing their flexible loads should generally be a free decision of market players based on the potential added-value and business case. A smart market setup with the right incentives is needed to make this work in order to achieve a macro-economically efficient solution. Coercion (e. g. in the form of obligatory bilateral agreements) should only be exerted upon systemically relevant loads that are able to ensure system stability

in case all other means are exhausted. With the use of clear and dynamic price signals, the different fields of application for DSF can be incentivized and used (overall and local balance of supply and demand, overall frequency control, and local grid congestion management).

Hence, in the medium term, plans for a full-fledged, competitive Chinese power market with dynamic price signals in wholesale markets should be implemented. International examples provide insights on how well-designed market structures are a necessary precondition for the efficient implementation of DSF into the energy system. These include a clear definition of the traded products, a relevant market size and a maximum degree of openness and technology neutrality that allow for competition, as well as transparency and freedom from discrimination.

With the spot market of Inner Mongolia in operation since 26 June 2019, all 8 pilot spot markets are now in operation. These innovative provinces may provide an optimal environment to test new regulations, develop new standards and try out different ways to ensure participation of industrial consumers. With Guangdong province as an example with particularly advanced structures including a test market for ancillary services, the pilot spot markets could therefore be used as a starting point for the scaling-up of market-based industrial DSF.

Establish ancillary services markets and open them up for industrial DSF

Ancillary services markets might provide another possible field of activity for industrial DSF. Experiences from Germany show that load flexibilities require a fairly open set of technological and structural conditions, e. g.

- pragmatic technical prequalification requirements,
- small minimum capacity offer sizes (1MW or smaller),
- short tender cycles (blocks of a few hours, not days or weeks),
- diversified product types such as positive and negative balancing power, etc.

The test market for ancillary services in Guangdong province could therefore be used to test regulations that encourage the market participation of industrial load flexibilities. Here as well, experiences with bidding mechanisms from pilot projects could turn out to be very valuable in this context.

Enhance stakeholder involvement and information

Given the complexity of DSF, stakeholder involvement and information are also critical. In order to successfully develop (industrial) DSF, there needs to be a high degree of knowledge regarding the framework conditions among all relevant stakeholders. This may require marketing campaigns, educational efforts, and pilots for industrial consumers to gain and share experiences.

At the beginning, multilateral exchanges among relevant stakeholders (grid operators, existing load aggregators, major industrial companies, etc.) would help to create a common understanding of industrial DSF and its purpose. Support for the necessary energy sector reforms could be derived from such exchange.

Following up on this, information campaigns could be used to spread knowledge about the functionalities of demand side flexibilities and promote it as a relevant part of efficient grid management for a successful energy transition and as an opportunity for an industrial company's long-term energy management strategy.

International experiences show that the establishment of DSF within (industrial) companies is a complex process. Load aggregators can play a relevant role in providing information aimed at industrial companies,

identifying flexible loads, and defining steps towards marketing these potentials. Practical experiences regarding the successful marketing of flexible loads through pilots with both industrial companies and aggregators could be used and highlighted as positive examples.

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Abbreviations

DRC	Development and Reform Commission
EV	Electric vehicle
NDRC	National Development and Reform Commission
RE	Renewable energy
VPP	Virtual power plant

