STRONGER MARKETS, CLEANER AIR

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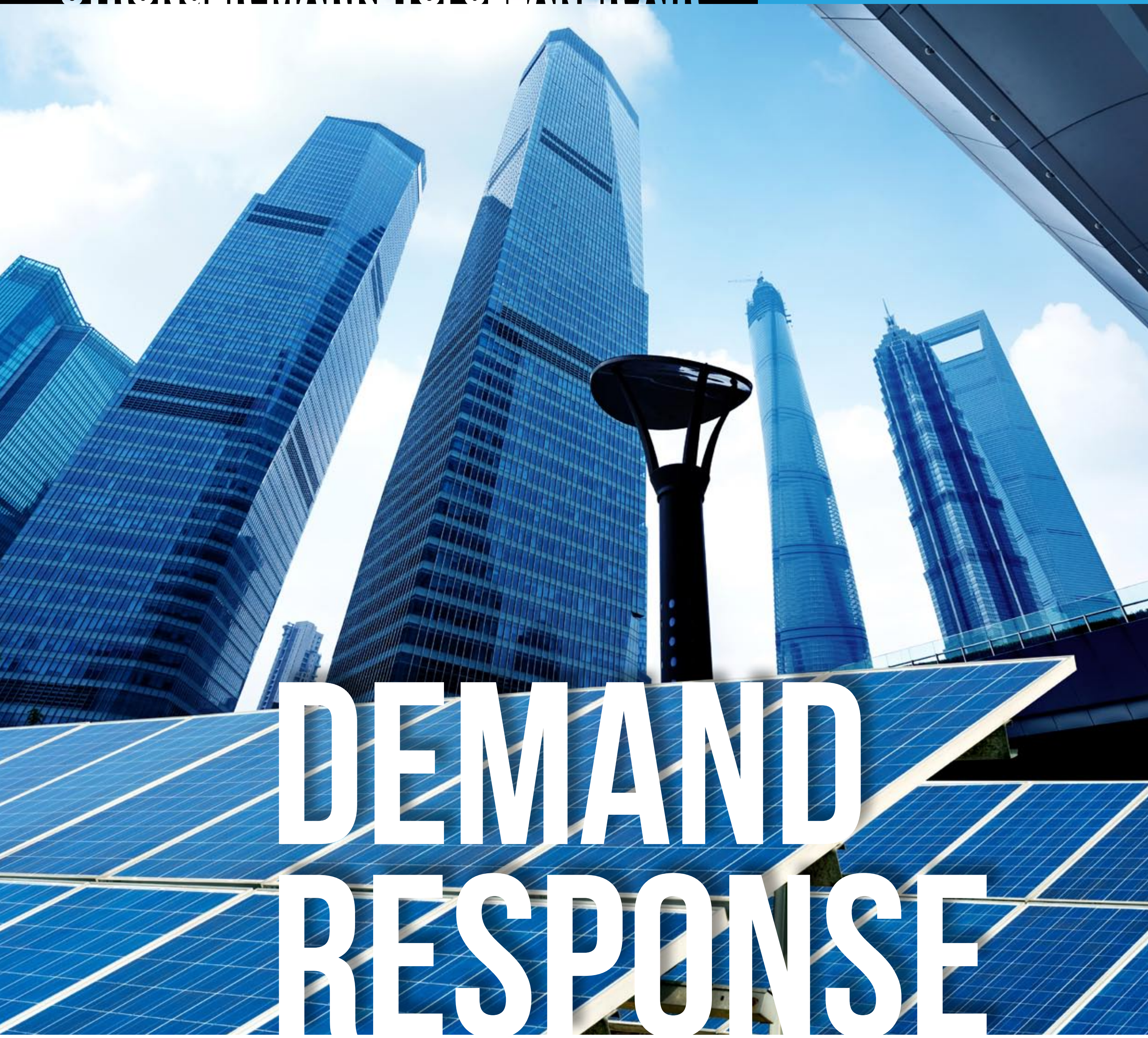

DEMAND RESPONSE

A High-Reward Solution to Reduce Energy Use, Emissions and Costs

September 2015

保尔森基金会
PAULSON INSTITUTE

Avoiding wastage: Increasing demand response in the power sector can help make China's grid more flexible and integrate more renewable energy.

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This paper is one in a series produced in 2015 by the Paulson Institute's Climate Change and Air Quality Program aimed at policymakers and influencers in China. The series provides recommendations on how policymakers can harness market forces to reduce emissions of both conventional pollutants and greenhouse gases that contribute to climate change. The topics covered by the series include power sector reform, electric power demand response, carbon emissions trading and building energy disclosure.

Contact: media@paulsoninstitute.org
Design by Jonathan Tsao, Chinabeat Ltd.

Stronger Markets, Cleaner Air

DEMAND RESPONSE

A High-Reward Solution to Reduce Energy Use, Emissions and Costs

Co-Authors

Mona Yew (游梦娜)
Natural Resources Defense Council

Merisha Enoe and Anders Hove
Paulson Institute

Chinese Strategic Advisors

Wei Zhang (张玮)	*State Grid Energy Research Institute*
Fuqiu Zhou (周伏秋)	*NDRC, Energy Research Institute (ERI)*

External Reviewers

Pierre Bull	*Natural Resources Defense Council*
Max Dupuy	*Regulatory Assistance Project*
Lucian Ion	*Siemens*
Wanxing Wang (王万兴)	*Energy Foundation China*
Wei Zhang (张玮)	*State Grid Energy Research Institute*

Those acknowledged as advisors and reviewers do not necessarily endorse the views expressed in the paper.

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On the grid: Demand response helps to reduce peak load on the grid at times of high electricity use, saving energy and reducing the risk of power outage.

CONTENTS

1. INTRODUCTION

With its heavy reliance on coal-fired power, the electricity sector is China's largest contributor to GHG emissions.

Demand response—a component of demand-side management—refers to modifying end-user energy consumption through changes in the price of electricity over time or with incentive payments designed to reduced electricity consumption during periods of high demand. China is well-positioned to deploy demand response on a large scale to accelerate achievement of its coal control and emissions reduction goals. This paper discusses the success factors behind demand response development in the U.S. and how more widespread development of similar programs—particularly those focused on industrial energy users—could help China reduce energy consumption, cut greenhouse gas (GHG) emissions, achieve ambient air pollution targets, and support the growth of new industries.

The purpose of this paper is to provide a few suggestions on how China can advance existing demand response efforts. Our goal is to outline ways in which a few market-oriented reforms could increase uptake of demand response solutions to better incorporate renewable energy and reduce emissions.

Power sector demand response is a strategic investment for China from both an economic and climate perspective. With its heavy reliance on coal-fired power, the electricity sector is China's largest contributor to GHG emissions. Thus, decarbonizing the power sector is paramount to meeting China's commitment to peak its GHG emissions by 2030. Demand response can help cut GHG emissions and conventional pollutants through several means.

First, demand response can help reduce the need for additional coal-fired power plants by dispatching resources when electricity demand is at its highest. Differences in peak and off-peak demand in China are increasingly large as electricity demand for air conditioning during summer months grows. Reducing peak demand not only improves grid stability, but also improves power system efficiency and reduces GHG and conventional air pollution emissions.*

Second, demand response is a flexible resource that can help China's relatively inflexible power grid integrate more renewable energy—an important consideration given the low availability of natural gas in China relative to in Europe or North America. Improved integration of renewable energy can reduce reliance on coal.

Finally, demand response supports China's market-oriented approach to power sector reform. This is because demand response programs are designed to target consumption behavior when electricity demand is at its highest (or lowest), enabling consumers to play an active role in supporting

* Coal plants take longer to start up and shut down. When coal plants are used for load following, this means that a number of coal plants must be kept running at low output levels during periods of low demand. This practice reduces the load factor of coal plants and results in the coal plants running at lower efficiency and producing higher emissions.

grid stability by adjusting consumption behavior on real-time basis. Demand response is also creating new business opportunities in energy efficiency products and services, such as applications for home energy management, low-energy appliances, and consulting services for commercial players interested in improving the energy efficiency of operations.

Demand response is far more than a resource reserved for emergency situations on the grid. Today demand response technologies can improve grid stability, reduce thermal plant emissions, improve wind and solar utilization, and better align generation and consumption patterns. The wealth of international experience in demand response, especially in the U.S., provides valuable lessons for Chinese policymakers.

This paper is organized around the following key points:

- The U.S. experience shows that there are substantial economic benefits of demand response. For example, demand response resources in the PJM Interconnection (a large independent system operator in the U.S.) saved utility customers up to US$ 1.2 billion in avoided investment from a single capacity auction.[1] As economic benefits lead to growth in the global demand response market, China should make sure it benefits fully from this trend.
- With well-defined policies to overcome barriers, demand response can help China improve power grid reliability and operating efficiency, reduce emissions, integrate a larger share of renewable energy into the grid, and avoid the need for more peak power generation.
- Demand response is promoting innovative technologies and business models that allow direct and easier communication between end-users and utilities, and provide consumers with real-time access to energy consumption data. These new models have the potential to improve or even revolutionize the way consumers and utilities manage energy use in the U.S., particularly as it relates to peak load reduction. Many of these innovations are applicable in China.

China has laid a solid foundation for demand response through demand-side management policies and pilot projects, as well as through widespread application of time-of-use pricing and interruptible power contracts. However, important institutional and market barriers remain. This paper's conclusion includes a short list of policy suggestions for resolving these issues and taking full advantage of the environmental and economic benefits of demand response.

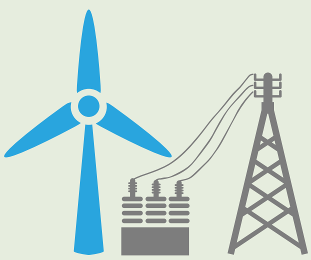
Demand response is promoting innovative technologies and business models that allow direct and easier communication between end-users and utilities, and provide consumers with real-time access to energy consumption data.

1.1 An introduction to demand response

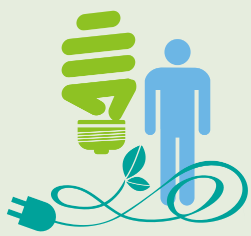
Demand response is an aspect of demand-side management (DSM), which refers to modifying utility customers' energy consumption to reduce energy demand (load) and defer the need for new power sources or additional transmission and distribution capacity along the electricity grid.[2] DSM measures can include both permanent demand reductions from energy efficiency (reduction of energy consumption while maintaining the same or higher level of comfort, output and quality) as well as temporary reductions from energy conservation actions (such as turning off lights when not in use), load management and demand response. Some common examples of demand response include temporarily halting production at an industrial facility or raising the temperature of an air conditioning unit in summertime to reduce electric load.

While demand response is a relatively new entrant to China's DSM landscape, it is garnering interest. The focus of this paper is primarily on demand response measures and programs that produce *dispatchable* reductions in power consumption by electricity end-users in response to a signal (such as pricing, financial incentives or a grid event) to meet a specific need (such as supply shortage, renewable integration or a grid system constraint). It should be noted that utilities in both China and the United States have implemented various rate designs (tariffs) such as time-of-use (TOU) and tiered pricing to promote energy use patterns that help optimize generation and grid asset utilization. While such pricing programs may also be considered a form of demander response, this paper focuses on demand response measures that directly reduce the need for dispatchable generation.

INCREASING THE USE OF DEMAND RESPONSE CAN HELP:



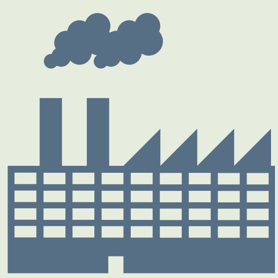
Integrate more renewable energy into the grid system



Increase consumer awareness of and control over energy use

Boost demand for energy efficient products

Reduce GHG and conventional air pollutants



Reduce the need for additional coal-fired power plants

Definitions

Ancillary services:	Frequency, voltage and system restoration services that use spinning (extra generating capacity that is already connected, operating, and available upon request of the grid) and non-spinning reserves (extra generating capacity that is available upon request of the grid but not connected to the system), as well as frequency regulation resources (such as energy storage)[3] to help grid operators maintain balance on electric power systems. Many ancillary services involve increases or decreases in electricity generation over short time periods, such as minutes, seconds or milliseconds. While coal plants in China currently provide most ancillary services, in other countries these services are often provided by natural gas generators, energy storage, demand response and even renewable generators.[4]
Demand response (DR)	An aspect of demand-side management (see below) that includes actions taken by utilities, system operators or customers to reduce energy load at specific times in response to price signals and other incentives during periods of high demand. Unlike energy savings from DSM, savings from demand response are time-dependent. Demand response resources are categorized as dispatchable and non-dispatchable.
Demand-side management (DSM)	The use of incentives – such as financial payments, rebates, or educational programs – to curtail overall energy consumption or shift energy use to off-peak times, reducing the need for additional investments in infrastructure and power plant operation to meet increases in demand for electricity.
Direct load control (DLC)	Programs that allow a utility to directly control consumer electricity use during periods of high demand by shutting down or cycling devices on and off.
Dispatchable DR	DR resources that grid operators can call on at any time by turning equipment on or off at a predetermined amount and period of time (such as several hours).
Dispatchable generation	Dispatchable generation can be dispatched instantaneously upon the request of power grid operators. Dispatchable generation includes thermal power plants (coal and gas) and hydroelectric dams. Solar and wind energy are non-dispatchable due to the high variability of their output.
Frequency regulation:	A service provided by ramping up or down generation power that could take seconds to minutes. Energy storage and thermal generation provide frequency regulation services.
Interruptible power contracts	Agreements between utilities and large (typically commercial or industrial) power customers for which consumers agree to reduce electrical consumption by a predetermined amount during electricity shortages. Consumers sign contracts in exchange for incentive payments or reduced rates.
Load factor	Average load divided by peak load over a specific period of time. Generally, thermal power plants that operate at high load factors have higher operational efficiency.
Load management	The use of measures such as time-of-use (TOU) pricing, direct load control, demand response programs and interruptible load tariffs to reduce electric loads during peak demand.
Net load	Total load minus non-dispatchable generation (such as wind and solar). As wind and solar capacity rise in proportion to local load, the net load becomes more variable, often requiring steeper ramps for thermal generation assets.
Non-dispatchable DR	DR resources that the grid operator cannot directly control or turn on or off in predetermined times and amounts. Time-of-use pricing is one example of non-dispatchable DR.
Peak load	A period of time (daily, monthly, or seasonally) when demand for energy is at its highest.
Time-of-use (TOU)	Electricity rates that are structured to charge higher prices during peak demand and lower prices when demand is low.
Variable renewable energy	Renewable energy such as wind and solar PV that cannot be dispatched (non-dispatchable) to the power grid instantaneously due to the variable nature of their power output. Variable renewable energy can be dispatched if energy storage is available.

2. THE CHANGING ROLE OF DEMAND RESPONSE AND LESSONS FROM THE U.S.

2.1 A brief history of demand response in the U.S.

Innovation, competition and an enabling regulatory environment are key factors that have allowed the U.S. demand response market to flourish. This section begins with a brief history of demand response in the U.S. and describes how programs have evolved over time to both complement and shape the development of an increasingly complex and flexible electricity grid.

Historically, U.S. utilities operated demand management programs such as direct load control and offered interruptible power rates to protect the grid against unanticipated contingencies.[5] Since safe operation and power grid reliability have always been paramount for utilities and grid system operators,[6] direct load control and interruptible power rate programs have become a main staple of utility demand response offerings.[7]

Over time, the U.S. energy landscape has become more complex and dynamic, necessitating a smarter and more flexible grid. Several factors have created a challenging and competitive environment in which regulators and utilities must ensure energy needs are met cost-effectively and in an environmentally responsible manner.[8] These factors include advances in renewable energy and distributed technologies, aging grid infrastructure (with increased stress expected from rising temperatures), and growing targets for clean energy and emissions reduction.

In California, for example, demand response is dispatched first along with energy efficiency as the preferred resource to meet energy demand and avoid fossil fuel or nonrenewable energy generation.

Against this backdrop, demand response has become a reliable resource that can help utilities avoid procuring peak generation or defer costly transmission and distribution capacity upgrades to meet peak or emergency events.[9] Incentive-based peak reduction demand response programs are increasingly common in the U.S. In 2008, customers nationwide enrolled in demand response programs capable of providing 38 GW of potential peak load reductions.[10] Today, utilities operate demand response programs to address system imbalances and alleviate grid congestion, as well as to displace inefficient generators and provide resources when wholesale energy prices are high. In California, for example, demand response is dispatched first along with energy efficiency as the preferred resource to meet energy demand and avoid fossil fuel or nonrenewable energy generation.[11] Myriad demand response programs are available to utility customers to participate at the price, load reduction amount, duration and frequency that are most appropriate for them. Efficient use of demand response resources during high demand avoids emissions associated with the operation and construction of additional peaking power plants,* as well as those emissions associated with the materials needed for plant construction.[12]

* An important caveat is that not all demand response resources are non-polluting. A study in the California Bay Area showed that 1% of the region's diesel-fueled backup generators had been used for non-emergency demand response, resulting in higher NOX and SO2 emissions than if utility peak load power plants had been used. In response to these challenges, California will begin tracking backup generators in 2015 to ensure that generators are used only for on-site electricity during grid emergencies as opposed to utilized for economic gain as a non-emergency demand response resource.

Demand response has also flourished in wholesale markets where available to provide energy, capacity ("resource adequacy") and ancillary services (operating reserves).[13] The PJM Interconnection,[14] a regional transmission organization (RTO) that facilitates the movement of electricity in the largest wholesale market in the eastern United States, is one example.[15] In September 2013, demand response helped prevent a large-scale blackout in the PJM region when the RTO dispatched more than 6 GW of demand response during a record peak in power demand of 144 GW associated with unusually high temperatures.[16] The following year, PJM procured 11 GW in demand-side resources in its three-year forward capacity market auction, representing 6.5% of total capacity procured.[17]

Looking ahead, the growth and penetration of variable renewable energy generation will pose new challenges in balancing the grid. Distributed solar in particular is changing the shape of the load curve in the U.S. as well as traditional peak periods on the grid system.[18] In extreme cases, over-generation from distributed solar during certain hours has resulted in negative electricity prices on the market.[19] Developments in energy storage technologies, electric vehicle integration, and bi-directional charging technologies are all contributing to the potential for additional demand response resources to serve as tools for integrating variable renewable energy.[20]

Enabling policies have been essential in ensuring the success of demand response programs in the U.S.

2.2 Enabling policies support demand response development

Enabling policies have been essential in ensuring the success of demand response programs in the U.S. This section highlights key policy developments at the federal level that have allowed demand resources to compete with generation resources, gain access to wholesale markets, and offer a variety of services, including energy, capacity and ancillary services. As the case study on California demonstrates, many state-level policies have also contributed to the development of a robust demand response industry outside of wholesale markets. Though China's electricity market differs from that of the U.S.,* some of the policies that have enabled demand response to succeed in the U.S. context can likely be adapted for China's unique circumstances.

The Energy Policy Act of 1992 (Epact) set the U.S. power sector on the path of deregulation by opening up the wholesale market. In particular, Epact allows for utility investments in energy efficiency and demand-side management to be "at least as profitable" as traditional supply-side investments.[26] These provisions provide the basis for utilities to implement demand response as a preferred cost effective resource and for demand response to participate in the wholesale market.

Two Federal Energy Regulatory Commission (FERC) Orders in 1996 solidified the formation of a competitive market and paved the way for demand response to participate competitively in the wholesale market. FERC Order 888 unbundled wholesale generation and power markets from transmission services and provided equal access to transmission

* The U.S. electricity market is composed of many regional and state markets that have a variety of different levels of wholesale power market development and demand response policies. The focus of this section is on national policy.

Source: Analysis Group, 2013

CASE STUDY: CALIFORNIA

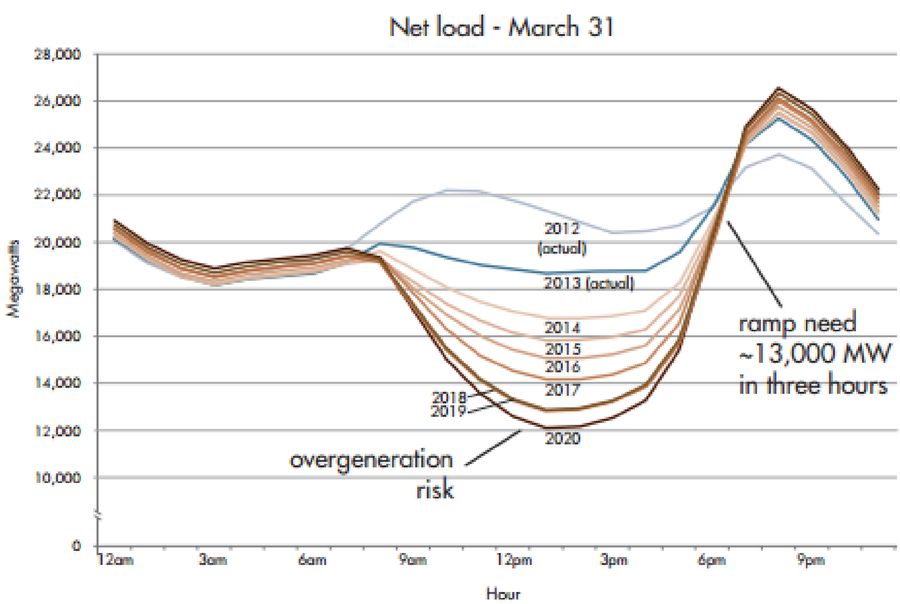
California has some of the most ambitious energy and environmental goals among U.S. states. It has passed legislation to reach 33% renewables by 2020 (not including large hydropower), reduce greenhouse gas emissions to 1990 levels by 2020, and implement policies to increase distributed generation and energy storage. The governor has also issued an executive order with a goal of reaching 1.5 million zero-emission vehicles by 2025.[21] All of these efforts are having an effect on energy demand and grid reliability. The California Independent System Operator (CAISO) has performed detailed daily electricity supply-demand forecasts from 2012 to 2020 to understand changing grid conditions, and has found that new operating conditions are emerging as a result of solar and wind, creating a dip in mid-day electricity net load and a sharply ramping spike in early-evening load. This effect is known as the "duck curve" due to its shape.[22] The key issues include:

- Short, steep ramps that require generation to be quickly turned on or off
- Over-generation risk when generation exceeds demand
- Decreased frequency response in the near-term, when fewer resources are online and available to automatically adjust for system needs.[23]

To ensure reliability under these new conditions, the independent system operator needs flexible resources to meet ramping needs, including the ability to quickly adjust up or down and do so several times a day if needed, and at the right location.[24]

The good news is that advances in control devices, communication technologies and smart meters are enabling full automation and seamless integration of communication between the utility or system operator and customers, and providing new options for fast demand response. For example, some utilities are operating automated air conditioner (or water heater) cycling programs that remotely cycle or turn off customer equipment during demand response events.[25]

THE DUCK CURVE



Daily electricity supply-demand forecasts have shown that new operating conditions are emerging as a result of solar and wind, creating a dip in mid-day electricity net load and a sharply ramping spike in early-evening load. This effect is known as the "duck curve" due to its shape.

This forecasted net load for March 31 (2012-2020) shows steep ramping needs and over-generation risk.

Source: California Independent System Operator, 2013 systems by requiring transmission facility owners to make transmission services available on the open market. Order 889 established a web-based system allowing energy customers in the wholesale market to schedule and reserve capacity on regional energy grids.

The Energy Policy Act of 2005 expressly supported demand response as a U.S. policy. The Act sought to remove barriers at the national level by encouraging time-based pricing and other forms of demand response programs, calling for deployment of enabling technologies and elimination of barriers to enter energy, capacity, and ancillary service markets, as well as accrual of benefits to all those that form part of the same regional electricity entity.

The Energy Independence and Security Act of 2007 (EISA) directed FERC to conduct a national demand response potential assessment. Federal regulators in the U.S. recognized that the economic benefits of demand response could not be realized without greater efforts to remove institutional and market barriers. The EISA directed FERC to assess the total and achievable potential, identify barriers, and develop policy recommendations.

FERC Order 719 of 2009 permitted the bidding of demand response directly in the wholesale market.[27] This order helped improve the competitiveness of wholesale electric markets.

In 2011, FERC Order 755 cleared the way for demand response to be compensated at the market price for energy.[28] This order recognizes that demand response can be a cost effective alternative to a generation resource in balancing energy supply and demand, and requires that it be compensated accordingly.

A similar pending FERC Order, Order 745 would allow demand response resources to receive the local wholesale market price in both real-time and

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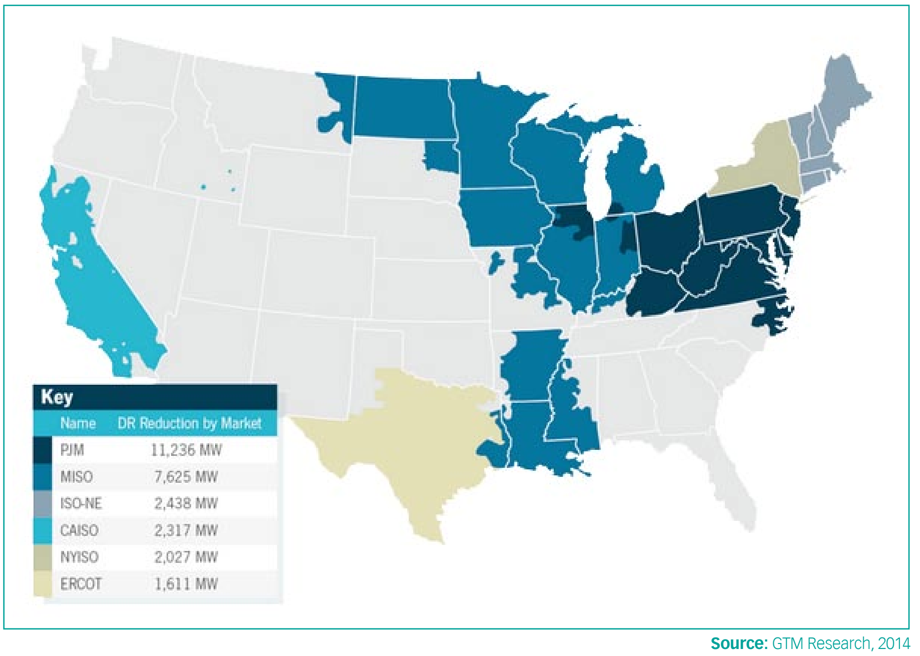
MAP OF MAJOR U.S. DEMAND RESPONSE MARKETS IN 2014



Source: GTM Research, 2014

day-ahead markets. As of this writing in September 2015, the order is facing U.S. Supreme Court review.[29]

At the state level, supporting policies and regulations have also enabled demand response to develop outside of organized markets. Today, demand response is an active part of both utility programs and wholesale energy markets across the United States.

Major lessons from the U.S. experience are that demand response can function effectively and reliably to reduce peak power load and provide other services such as capacity reserve. Demand response can also contribute equally with or without the development of an organized wholesale market, but policies and regulations are needed to overcome institutional and other barriers. While China's electricity market is structured differently from the U.S., it can enjoy substantial economic and environmental benefits by doing more to incorporate demand response services.

While China's electricity market is structured differently from the U.S., it can enjoy substantial economic and environmental benefits by doing more to incorporate demand response services.

2.3 Innovative technologies and business models lead to greater savings

Technological advances have enabled demand response to move beyond traditional load management programs. At the same time, demand response is helping to spur innovative technology applications and business models in the U.S. After four decades of development, new businesses are emerging to assist utilities in curtailing their customers' electricity demand to better match generation. The following section highlights business models and technologies that are enabling demand response development.

Most demand response programs today rely on utility companies to organize and dispatch resources directly to customers, but there is a growing market for demand response aggregation. While utilities have existing direct customer relationships that facilitate demand response, they may not have the expertise or motivation to bundle and manage customer load reductions. As a result, an entirely new industry of service providers – demand response aggregators – has emerged to fill this gap. For example, U.S.-based EnerNOC has grown to be the largest demand response aggregator in the world, reflecting the relatively advanced state of the U.S. demand response market.[30] Johnson Controls, GDF-Suez, and EDF Energy also provide demand response aggregator services. Markets in the U.S. and Europe have dozens of smaller aggregator participants.[31]

Utilities are also innovating to offer new services and technologies. Utilities in several states now provide customers with energy consumption forecasts and mobile alerts about energy saving opportunities.[32] They are also partnering with energy service companies and big data analysis companies (including startups like Opower and Retroficiency[33]) to give commercial and residential customers "virtual energy audits" using billing and other data. Furthermore, utility web sites provide links to sign up and manage participation in demand response programs.[34] Not to be outdone, other conventional power market players are also entering the market. NRG – a U.S.-based independent power producer – purchased a demand response provider, Energy Curtailment Specialists, along with its 2GW of demand reduction capability in 2013.[35]

TYPES OF DEMAND RESPONSE PROGRAMS AND MEASURES

Program	Description	Dispatchable	Purpose	Target Participants
Utility Programs				
Time-of-Use (TOU) Pricing	Varying rates during different time periods of the day, based on the cost of power during those periods	No	Encourage permanent load shifting away from peak hours	May apply to all customer classes
Targeted Load-Shaping Energy Efficiency	Targeting particular loads in a given area on the grid can yield permanent desirable load modifications.	No	Create permanent load shifting away from peak hours	May apply to all customer classes
Interruptible/ Curtailable Load Programs	Reduced electric rates or bill credit with commitment to curtail load during system contingencies; Penalties may apply for failure	Yes	Reliability, emergency response	Traditionally offered only to the largest industrial or commercial customers
Emergency DR	Incentive payments for load reduction during events	Yes	Reliability, emergency response	Large customers, Third-party aggregators
Aggregator Programs	Contractual payment to third party aggregators for delivering committed load reduction at agreed-upon price, typically in $/kW-year	Yes	Peak load reduction, environmental or economic DR, emergency response	Third-party aggregators
Peak Time Rebates	Rebates for load reduction related to forecasted baseline	Yes	Peak load reduction	Residential customers
Direct Load Control	Remote cycling or shut-off of customer equipment (such as AC, water heater) within agreed upon parameters for which customers receive rebates or bill credits	Yes	Peak load reduction	Primarily residential customers
Critical Peak Pricing	Based on TOU, much higher peak prices under specified triggering conditions	No	Lower market price and/or alleviate severe grid stress	Commercial/ industrial customers
Real-Time Pricing	Varying rate based on prices in the wholesale market; advance notice typically provided on a day ahead or hour ahead basis	Only if deployed with enabling technology	Price-following load reduction	Large commercial and industrial customers
Wholesale Market Programs				
Capacity Market Program	Reservation payment for load curtailment bid as system capacity. Penalties apply for failure to comply when called.	Yes	Capacity (treated as equivalent to generation)	Aggregators, Large customers
Ancillary Services Market	Payment load curtailments bid as operating reserves	Yes	Operating reserve	Aggregators, Large customers

Source: Natural Resources Defense Council, 2014; Regulatory Assistance Project, March 2015

Most significant, though, is that advances in metering, communications, forecasting, mobile IT, smart grid and energy management software and hardware have enabled the crossover of previously segmented industries and changed the way consumers and businesses think about energy. A case in point is Google's 2014 purchase of Nest – a provider of internet-enabled thermostats with remote control capability – for US$ 3.2 billion.[36] Apple is now also offering smart home thermostat technologies that, like Nest, could provide demand response functions while primarily serving as consumer electronics lifestyle products.[37] These evolving business models not only open new market and business opportunities for technology companies; they also raise consumer awareness of energy use patterns and make it easier for consumers to control and reduce energy use.

Other specialized technology companies are also finding their niche in demand response. For example, energy-storage company Stem markets closet-sized battery energy storage devices to hotels and other building owners.[38] The company claims its algorithms enable its batteries to predict and prepare for future building energy loads, flattening customer load and reducing demand charges and peak power consumption.[39] Stem plans to eventually aggregate a large number of batteries spread over a wide geographic area across California to boost their ability to balance renewable energy load and offer demand response services to the state's utilities.[40] In addition to battery storage, other resources with "natural storage capacity" such as water heating, ice storage for cooling and variably-controlled water treatment and pumping can all offer cost-effective and reliable demand response services.

> What is undeniable is the enormous economic benefit and electric bill savings provided by demand response programs.

To accelerate these changes, a public-private partnership headed by the U.S. National Institute for Science and Technology (NIST) launched the Green Button Initiative in 2011, providing utility customers easy and secure access to their own detailed energy usage data with a simple click of a Green Button on the websites of their electric utility.[41] Dozens of U.S. utilities now provide the Green Button on their websites or are committed to doing so. The decentralized, open-sourced nature of the standard encourages innovation and customer participation.

Time will reveal whether the changes underway in the U.S. have truly helped evolve utility business models, reduce energy usage, and flatten peak power consumption. What is undeniable is the enormous economic benefit and electric bill savings provided by demand response programs. Like the U.S., China can reap significant benefits by scaling up demand response.

2.4 Global demand response could be a US$ 12 billion market by 2023

The global market for demand response is maturing rapidly. While investment is still small at the global level, growth projections for demand response make it clear that market players expect it to play a major role in the operation of the power sector in future years. A Navigant study suggests that demand response capacity is expected to grow from 30.8 GW in 2014 to 197 GW in 2023,[42] with Asia Pacific potentially having as much demand response capacity as North America and representing 34.5% of global capacity.[43] The global market for demand response could reach US$ 12 billion by 2023.[44]

The economic benefits of demand response—particularly the avoidance of additional power generation—are perhaps the biggest contributor to this growth. Economic benefits have been demonstrated in the U.S. (particularly in California) for over four decades, and utilities across the country are finding that DSM and demand response are a cost-effective alternative to building new generation, as reflected in both program expenditure and long-term program operation across the electricity value chain. Baltimore Gas and Electric Company found that the capital cost of demand response in the U.S. is only US$ 165/kW compared to the cost of installing new generation capacity, which is estimated at US$ 600/kW.[45] These savings are expected to continue. According to a study by the Electric Power Research Institute (EPRI), demand-side resources have the potential to provide as much as 14% of peak load in the U.S. by 2020.[46]

The economic benefits of demand response—particularly the avoidance of additional power generation—are perhaps the biggest contributor to this growth.

3. DEMAND RESPONSE IN CHINA: PAST AND PRESENT

China has long deployed DSM to reduce peak load and balance electricity supply and demand on the power grid. This section discusses how China can take advantage of the many opportunities that exist to maximize the benefits of its demand response resources. The section is organized around three key themes: the history of demand-side management in China, recent policies and pilots that promote development, and existing barriers and growth potential.

3.1 Demand response programs in China are nascent

Broad DSM concepts were first introduced in China in the 1990s, but did not take off until the government encouraged DSM through a series of policies starting with the release of the 2011 DSM Rule.* As such, DSM as a whole, and demand response in particular, are still at a nascent stage.[47]

China has historically managed periods of excess peak demand through an administrative system of demand planning and rationing such as load shedding (curtailment) in which the grid cuts power supply to certain users.[48] In an effort to more rationally manage load shedding practices, the National Development and Reform Commission (NDRC) issued national "Measures on the Orderly Use of Electricity" in April 2011.[49] The measures specify that load shifting and peak load reduction should be prioritized before limiting or cutting power to end-users. It also encourages the development of interruptible power rates and high reliability rates, calls for an improved load control system and allows for compensation to eligible electric users for load interruption.[50]

Lessons learned from international experience and local studies on the benefits of DSM played a vital role in driving development of supporting policies.

Early DSM pilots promoted the "efficiency power plant" (EPP) and experimented with the use of price as a lever to avoid unwanted peaks in demand. In the early 2000's – a period characterized by widespread peak power shortages and load shedding in key manufacturing provinces[51] – DSM provided a welcome solution in the form of virtual power plants or EPPs that could deliver "nega-watts"** to offset peak demand. DSM efforts since this period have led to successful EPP pilots, notably in Jiangsu, Guangdong, and Hebei.[52]

China has also used pricing as a lever to smooth out extreme peaks in demand. Jiangsu Province initiated an interruptible power tariff pilot in 2002, which reduced peak load by 100 MW and increased off peak load by 40 MW.[53] Building on this success, the NDRC called for the use of price as a lever in 2003 – specifically, TOU rates for large industrial enterprises and critical peak pricing where appropriate.[54] The State Council also reiterated the importance of managing electricity use through peak shifting, load shedding and the use of pricing mechanisms and TOU rates to ease the gap between maximum and minimum demand.[55]

* The DSM Rule was released in November 2010 and became effective as of January 1, 2011.
** A nega-watt is a theoretical unit of power (measured in watts) that represents energy saved as a result of conservation measures or efficiency improvements.

3.2 Pilots facilitate policy improvements

Lessons learned from international experience and local studies on the benefits of DSM played a vital role in driving development of supporting policies. The 2011 DSM Rule was a significant policy milestone that not only reaffirmed the role of grid companies in implementing DSM, but also for the first time required major grid companies to achieve annual energy savings and peak load reduction targets beginning in 2011.[56] Notably, load reduction and energy savings resulting from the Orderly Use of Electricity mandate did not apply to the target.

Most important, the 2011 DSM Rule authorized key funding avenues that would enable the sustained development of DSM, and therefore demand response. Specifically, localities could pay for DSM through a city utility surcharge, revenue from differentiated power prices charged to energy intensive industries, and an energy savings and emissions reduction fund jointly funded by the central and provincial governments.[57]

All four pilots are actively mobilizing end-users and third-party service providers to achieve their respective goals.

3.3 City pilots show progress

Policy developments achieved in 2011 paved the way for additional pilots in 2012.[58] To further expand DSM in China, the Ministry of Finance and NDRC launched a Comprehensive DSM Pilot City program in July 2012 and provided financial incentives for both permanent and temporary demand reductions, otherwise known as demand response.[59]

All four pilots are actively mobilizing end-users and third-party service providers to achieve their respective goals. However, progress on implementing the demand response aspect has lagged behind the permanent load reduction efforts in all four cities.

Separately, Shanghai launched China's first large-scale Demand Response City Pilot in 2014. The city mobilized a team of international and domestic experts, the local grid company, the grid company research institute, and third-party

NDRC DEMAND-SIDE MANAGEMENT PILOT PROGRAM – 2015 TARGETS

City	2015 Load Reduction Goals (MW)			Targeted End-Users
	Total load reduction	Permanent reduction	Temporary reduction	
Beijing	800	650	150	Commercial buildings Industry Municipal facilities
Suzhou	1000	800	200	Industry Municipal facilities
Foshan	450	360	90	Industry Municipal facilities
Tangshan	Total load reduction – 400			Industry

Source: Beijing DRC, Suzhou People's Government, Foshan DSM Platform, and NDRC service providers to jointly develop and implement the pilot, and demonstrate the potential of demand response to improve power grid system efficiency in China.[60] Of the 33 commercial and public buildings and 31 industrial customers that signed up to participate, a total of 27 commercial and public building customers and seven industrial customers responded to declared demand response events in the summer of 2014, delivering a 10% average reduction in peak demand.[61] The initial success has been encouraging, and Shanghai is in the process developing a market-based mechanism and enabling policies to ensure continued and sustained growth of demand response.[62]

3.4 Demand response faces several barriers in China

Despite progress with pilots and generally positive policy developments, China's DSM and demand response programs are stuck in the sub-gigawatt range. Major barriers to demand response development include traditional profit structures in grid companies, funding limitations for projects, undervaluation of demand response benefits, and limitations in the power market. These barriers are described in more detail below.

Major barriers to demand response development include traditional profit structures in grid companies, funding limitations for projects, undervaluation of demand response benefits, and limitations in the power market.

Grid companies play a key role in DSM implementation,* but an inherent conflict of interest exists in profit structures: China's grid companies make money by selling – not saving – electricity.[63] DSM programs reduce electricity consumption and therefore reduce revenue and profits for the grid companies.[64] In other words, while DSM and demand response can bring enormous overall societal benefits, these benefits do not readily transfer to the grid companies' bottom line. Hence, grid companies have had little direct incentive to pursue DSM in the absence of government-mandated programs. The 2011 DSM Rule addresses this challenge in part by allowing grid companies to recover reasonable DSM expenditures; however, the cost recovery does not extend to lost revenue. The recently introduced transmission and distribution (T&D) pricing reform pilot, discussed at greater length in the next section, could set the precedent for a decoupling mechanism that would help remove this grid company disincentive.

Funding limits are another barrier. In the past, financing for China's initial DSM pilots has come from power supply discount charges, power capacity expansion fees, and fines for excessive power use.[65] However, these funding sources were discontinued in 2002 when power supply companies, in an attempt to expand the power market, began canceling rules that fined companies for excessive electricity use. The government reduced power supply surcharges and standard power expansion capacity charges in 2000 in an attempt to reduce the price burden on power consumers.[66] The 2011 DSM Rule addresses this hurdle by authorizing new funding avenues for DSM, but actual funding implementation is left to provincial government authorities and grid companies. As such, only a handful of provinces such as Ningxia and Jiangxi have authorized provincial DSM funding, and explicit cost accounting and cost recovery mechanisms for grid companies' DSM expenditures have yet to be established. Moving forward, China should consider developing

* The 2011 DSM Rule identified grid companies as the key implementers for demand side management, of which demand response is a component.

implementation guidelines for the procurement, allocation and expenditure of DSM funds, as well as explicitly allow for DSM cost recovery in the new T&D pricing reform pilots.

An absence of valuation methods for calculating the economic and environmental benefits of demand response has also hindered its development. The 2000 Power Conservation Management Measures called for integrated resource planning that included DSM.[67] However, China lacks the data and methodology needed to evaluate demand response as an alternative to conventional supply-side resources. The inability to quantify demand response benefits also leaves open key questions about the appropriate level of investment to support deployment, in particular investments in sophisticated hardware and software to enable automated demand response. China urgently needs to develop methodology for valuing demand-side resources.

From a capacity standpoint, the knowledge and implementation skills needed to promote demand response are extremely limited across the spectrum of key players involved in China's energy system, including government, grid company staff, aggregators, third-party service providers and end-users.[68] International organizations can play a key role in sharing international experience and best practices, and providing hands-on training and assistance to help build capability within the nascent industry.[69]

Finally, China lacks a comprehensive framework to capture the value of demand response and other flexible resources, and to enable demand response to compete with other forms of generation with or without a wholesale market. In addition, demand response is still not considered an aspect of ancillary services (services that enable the grid operator to balance electricity supply and demand over short time periods such as minutes and seconds) in China's power market. Furthermore, compensation schemes undervalue capabilities that ancillary services might provide, such as load-following and fast-ramping.[70] Grid companies can implement demand response programs in the absence of market-based programs if the inherent grid company disincentive at the institution level is removed.

3.5 Regulatory and policy developments favor demand response

Despite these barriers, China's current regulatory environment, combined with the country's increasing focus on air quality, climate change, and power sector reform, create a supportive environment for the development of demand response programs. Several supportive policies are described in further detail below:

- **Revenue Cap Regulation:** On November 4, 2014, the NDRC announced a Transmission and Distribution (T&D) Pricing Reform Pilot in Shenzhen, which caps the total revenue of the Shenzhen grid company and specifies a formula for calculating allowable revenue.[71] The revenue cap essentially decouples the grid company's revenue from sales, thus removing a critical disincentive for grid companies to actively implement DSM.* While this regulation falls short of expressly linking the revenue calculation

China's Central Communist Party and the State Council jointly issued a long-awaited guiding document on power sector reform in March 2015.

mechanism to the DSM cost recovery provision in the 2011 DSM Rule, in theory it could provide the missing mechanism for grid companies in China (if the mechanism is expanded to other regions) to claim legitimate DSM expenditure under the T&D pricing reform pilot.[72] Notably, the pilot regulation also includes a shared savings provision that allows the grid company to retain 50% of cost savings, essentially providing the added incentive for grid companies to proactively implement DSM and demand response.

- **National DSM Platform:** In an effort to promote DSM, the NDRC and the Ministry of Finance (MOF) developed a national DSM platform and released the National DSM Platform Management Rules in 2014.[73] Under the rules, the platform is designed to offer "the most comprehensive and authoritative DSM information for all stakeholders, including power users, electric energy service providers, grid companies, and relevant governmental agencies."[74] This opens the door for providing real-time data access and visualization capability to a wide range of stakeholders. According to the Rules, the platform will also promote information distribution, online monitoring, verification and certification, power supply-demand landscape analysis, and demand-side response.[75]
- **Grid Company DSM Services:** Grid companies have established subsidiary energy services companies (ESCOs) to provide DSM services, in part as a strategy to meet their DSM targets and to mitigate the negative impact from potential contractions in the electricity market.[76] This provides the opportunity for grid company ESCOs to develop new business models and serve as load aggregators to deliver demand response services.
- **Power Sector Reform:** China's Central Communist Party and the State Council jointly issued a long-awaited guiding document on power sector reform in March 2015.[77] This comprehensive document outlines a set of reform principles that will shape the direction of China's power sector – and its emissions trajectory – for years to come. Notably, the document stipulates "[from] the perspective of national security strategy, active implementation of demand-side management and energy efficiency management…" as one of the basic principles of power sector reform. It also calls for using DSM as a principal means of assuring power supply-demand balance as well as "[enhancing] supply-demand balance and energy conservation and emission reduction through information technology utilization, energy services cultivation and demand response implementation."
- The National Energy Administration (NEA) and NDRC respectively issued implementation documents on increasing renewable penetration and implementing demand response in DSM city pilots following release of the power sector reform guiding document.[78] Both documents referred to the importance of DSM and demand response, signaling recognition at the central government level of the critical role demand side resources

Despite barriers, China's current regulatory environment, combined with the country's increasing focus on air quality, climate change, and power sector reform, create a supportive environment for the development of demand response programs.

* The grid company will receive the same amount of approved revenue regardless of how much electricity is sold, thus removing the company's incentive to increase electricity sales.

can and should play in power sector reform. In addition, on April 2015, the NDRC issued a notice expanding the T&D pricing reform to four other provinces.[79]

The favorable conditions described above will help break down the policy and implementation barriers that have kept China's pilots from achieving scale, and help capture the service benefits that demand response resources can provide in furthering China's energy and emissions goals. The challenge is to build on these and develop more detailed regulations and policies to support demand response.

4. DEMAND RESPONSE CAN HELP CHINA MEET ITS DEVELOPMENT GOALS

China's experience with demand response has been encouraging, but the potential for demand-side resources to help meet larger policy objectives and provide emissions reduction is far greater than what has already been achieved.

4.1 Reducing the need for peak power and increasing grid system efficiency

Deteriorating air quality is forcing China to take action on air pollution, including through expanded electrification to reduce local coal consumption.[80] Urbanization has resulted in continued, albeit slow, growth in electricity demand, even as China's energy intensity falls.[81] In addition, summer air conditioning loads are contributing to higher year-on-year peak demand and widening the gap between maximum and minimum demand in major urban centers in China,[82] with the highest peak hours only occurring during a small fraction of the time during the year. For example, one study found that in Shanghai, the top 3% of the maximum load only occurred at about 20 hours per year from 2000-2004;[83] similarly, according to Zhaoguang Hu, a vice president and researcher at the prominent State Grid Energy Research Institute, roughly 5% of China's peak electric load (about 60 GW) is generated only about 50 hours per year.[84] The narrow peak not only affects the generation fleet, but also strains the local transmission and distribution grid system in terms of system balancing and grid congestion. There are economic consequences as well: A Lawrence Berkeley National Lab (LBNL) study suggests that as much as 10% of electricity system costs are associated with meeting demands that occur only 1% of the time in many systems in the U.S. and Australia.[85]

Demand response can help improve the efficiency of China's coal-fired power plant fleet.

China has encouraged end users to shift their power consumption pattern to off-peak periods through measures such as time-of-use pricing and interruptible power contracts. China can do more to reduce the need for peak power by developing additional demand response capability and products, and through long-term planning that spans beyond pilot-stage development. In the short term, large-scale demand response deployment can provide a more immediate solution to load reduction at specific times and locations as needed.

4.2 Demand response could reduce reliance on coal

Demand response can help improve the efficiency of China's coal-fired power plant fleet. Currently, China uses its coal-fired power plants to provide both base load electricity as well as ancillary services such as load-following and frequency regulation.[86] This means the plants must consistently adjust their power output (for example ramp up or down) in response to fluctuations in electricity demand, which reduces their efficiency and increases emissions.

Many of China's coal-fired power plants are among the newest and most efficient units in the world,[87] but only if they operate at optimal efficiency levels. For example, a subcritical coal-fired power plant operating at 50% power rating consumes 10% more fuel than one operating at maximum continuous rating.[88] In addition, emissions control systems such as flue-gas desulfurization and selective catalytic reduction (SCR) lose efficiency and effectiveness when plants operate below maximum capacity.[89] Maintaining a large fleet of coal-fired power plants to provide ancillary services reduces efficiency while increasing emissions.

One of the most valuable benefits of demand response is its proven ability to reliably deliver needed system load reduction on demand – in other words, serving the same function that a conventional peaking plant normally would, though with different operating parameters, thus avoiding the need for new capacity. By reducing the need for building and maintaining new coal-fired power plants that end up being used for only a small number of hours per year, demand response helps improve the utilization factor and operating efficiency of the existing fleet of coal-fired power plants.

Consumer society: Urbanization has resulted in continued growth in electricity demand, even as China's energy intensity falls.

4.3 Demand response can integrate variable renewable energy

China plans to significantly increase its wind and solar power capacity in the coming years: from 104 GW of wind at year-end 2014 to 200 GW by 2020, and 28 GW of solar at year-end 2014 to 100 GW by 2020.[90] However, adding more wind and solar to a regional grid also changes grid system operation. Wind and solar can fluctuate up and down over a relatively short period of time.[91] Sudden and unexpected down-ramps in wind and solar can create contingency events for utilities that require short-term responses.[92] Even though wind and solar are only a small fraction of China's total power supply now, they are highly concentrated in a few regions, meaning that these regions' net loads—the load after subtracting variable renewable energy supply—can swing wildly (also see the Paulson Institute's paper "Power Sector: Deepening Reform to Reduce Emissions, Improve Air Quality and Promote Economic Growth"[93]). When local demand for power is low, grid operators often curtail renewable generators' power supply, resulting in wasted energy. Data show that in 2013, China's wind power curtailment reached 11% (15 TWh),[94] and its average solar power curtailment reached 10% due to the grid's inability to absorb the power generated.[95]

Grid connection challenges and integration issues are standing in the way of China's ambitious renewable energy plans. Power grids need resources (such as power plants or demand response) that are able to back up wind and solar as needed. In China's current situation, as the amount of renewables on the grid increases, so does the need for more coal-fired plants for stand by generation. This is not only inefficient, but in extreme cases where the coal plant's load factor drops critically low and the emissions control equipment cannot operate, the plant may release pollutants into the atmosphere.[96] Another challenge is that renewable energy integration and demand response pilot projects are handled by different agencies in China. NEA is responsible for supply-side renewable energy integration while NDRC is responsible for promoting China's demand response pilots.[97]

Integrating renewables is a multi-faceted problem that will require a package of integrated measures. Demand response, especially when combined with other demand-side measures such as smart charging of electric vehicles, can be an integral part of the system. A recent study by the NDRC Energy Research Institute found that renewable energy could meet more than 60% of China's primary energy demand by 2050. But to do so, technological and institutional innovation is needed, including developing demand response mechanisms and energy storage on a large scale.[98] Policymakers must act now to develop the potential for demand response to provide the necessary grid support and enable the grid to become more flexible and responsive in integrating the vast amount of variable output from wind and solar power expected in coming years. An effective demand response program could result in some coal-fired power plants becoming obsolete (or in plants not being built in the first place), thus allowing the remainder of the power plants to operate at higher capacity and with improved efficiency. Countries and regions with high wind and solar penetrations, such as Germany, Spain, Italy, and Denmark, are already experiencing higher ramp rates for the fossil fleet.[99] Although Europe has been slow to adopt demand response,[100] European countries recognize

Car talk: Combined with other demand response policies, electric vehicles can improve the grid's efficiency by adding load during low-use hours and also help to incorporate more renewable energy into the grid.

that demand response can play a large role in reducing the need for fossil fuel investment. A European Commission study in 2013 found that demand response could potentially reduce peak load by 10%, eliminating the need for up to 60 GW of fossil fuel generation capacity.[101]

4.4 Electric vehicles and demand response

Chinese leaders have shown significant political will to develop China's electric vehicle (EV) industry—setting a target to reach 5 million EVs by 2020—in an effort to establish the nation as a world-class auto industry leader as well as a promising solution to the nation's air pollution, climate change and energy security challenges.[102] EVs – when combined with other demand side measures – have the potential to help smooth out regional load curves, improve power grid operation and efficiency, and help the grid absorb more renewable energy, especially variable energy generation like wind and solar power.

Just as demand response can shift load from peak hours to off-peak times, EVs can help add load during off-peak hours. Specifically, EVs can be charged at night when the load on the system is at the lowest to improve overall system resource utilization. In addition, with advanced weather forecasting and networking capability, EV charging could be scheduled in ways to reduce the demand for fast ramping capacity to back up wind and solar.[103]

Currently, several regions of the U.S. are taking the lead with vehicle-to-grid (V2G) pilot programs because of their early experience with a large number of electric vehicles.[104] U.S. utilities, including Southern Company and the two largest investor-owned utilities in California, Pacific Gas and Electric Company and Southern California Edison, have begun experimenting with integrating electric vehicles into demand response programs.[105] Pilot projects underway at utility companies and elsewhere aim to gauge the willingness of consumers to alter charging patterns in response to price signals. The potential for using V2G for demand response could be large. For example, a 2012 study by NREL estimated that under a 40% EV penetration scenario for 2050, annual EV electricity load in the U.S. would reach 356 TWh, of which roughly half could be directly dispatched by utilities.[106]

China could capture the full energy and environmental policy benefit of EVs by implementing smart charging infrastructure, developing innovative rate designs and incentive regulations, and integrating EV development with demand response efforts. In the long-term, a broader V2G policy approach could help EVs provide a range of value for the power system. Smart charging and vehicle batteries could even provide ancillary services such as load following or frequency regulation – and be compensated for doing so, thus improving EV ownership economics and further promote EV adoption.

In the long-term, a broader vehicle-to-grid policy approach could help EVs provide a range of value for the power system.

5. CONCLUSIONS AND SUGGESTIONS

There is huge potential for China to achieve emissions reductions through expansion of demand response programs. China can take full advantage of the benefits of demand response by mobilizing grid companies, developing capacity in the market, and building demand-side resource capability for integration of renewables. Reforms in the power sector offer an excellent opportunity to capture the value of demand response and profit from investing and operating flexible demand side resources. Specifically, China can take several steps in the areas of stakeholder incentives, market capacity, and demand-side capability:

Mobilize grid companies:

- Build on the T&D pricing reform pilot to decouple grid company revenue from sales volume, and explicitly allow grid companies to recover DSM expenditures and share in the resulting cost savings.
- Develop implementation guidelines for the DSM funding and cost recovery mechanism described in the 2011 DSM Rule.
- Require grid companies to optimize dispatch by prioritizing the cleanest and most economic resources, including demand response.

By 2050, renewable energy could meet **MORE THAN 60%** of China's primary energy demand. Demand Response can help make this possibility a reality.

- Ensure that diesel backup generators are monitored and only used for grid emergency situations and not for non-grid emergency events such as for economic gain as a demand response resource.

Build market capacity:

- Expand existing DSM and demand response pilots and encourage innovative policies and rate designs to support scale-up to the gigawatt level.
- Create a market for third-party demand response service providers (aggregators) and promote supportive business models.
- Develop standardized protocols to enable seamless communication, dispatch, real-time data collection and visualization, end-user response, and monitoring and valuation.

Develop demand-side capability for integration of renewables:

- Initiate pilot projects for using flexible demand side resources to integrate renewables, including developing and deploying flexible demand response products such as automated demand response and smart charging of electric vehicles.
- Develop data collection and analysis methodologies to quantify the benefits of demand response and enable demand-side resources to be valued on par with supply-side resources for the purpose of integrated resource planning.
- Develop mechanisms to monetize the benefit of demand response by allowing a variety of demand-side resources to provide ancillary services and be compensated at a fair price that is commensurate with the benefits provided.

Demand response should be built directly into China's electricity structure so that utilities, end-users, government, and society as a whole can benefit from the resulting reliability improvements, energy and cost savings, and emissions reductions.

China can take full advantage of the benefits of demand response by mobilizing grid companies, developing capacity in the market, and building demand-side resource capability for integration of renewables.

ABOUT THE AUTHORS

Mona Yew

Mona Yew is the China Program Deputy Director at the Natural Resources Defense Council (NRDC) and also directs NRDC's China energy efficiency and demand side management (DSM) project. Mona leads NRDC's efforts in working with central and provincial government partners, grid companies and other organizations to scale up energy efficiency and demand side management in China. Since 2009, she has served as an expert advisor on DSM program design, implementation and evaluation, as well as led trainings on international best practices to government officials, grid companies and energy conservation center staff in China. She is also a Senior Advisor to the China-U.S. Energy Efficiency Alliance. Prior to joining NRDC, Mona worked at Pacific Gas and Electric Company (PG&E) for 17 years in both supply and demand side management, with particular emphasis in energy efficiency, clean energy technology and energy procurement. She also contributed to California's implementation of its landmark Global Warming Solutions Act (AB32) of 2006 by participating in the development and drafting of the Recommendations of the California Air Resources Board's Economic and Technology Advancement and Advisory Committee (ETAAC): Technologies and Polices to Consider for Reducing Greenhouse Gas Emissions in California.

Merisha Enoe

Merisha Enoe is Manager of Research at the Paulson Institute. She develops insights for the Institute's Climate Change and Air Quality Program, producing reports and recommendations for air quality improvement in northern China. Before joining the Paulson Institute, Enoe worked at the China Greentech Initiative, where she led the development and production of the China Greentech Report as well as several research projects on topics including shale gas development and the impact of national policies on clean technology adoption. Enoe received her BA in biochemistry and Mandarin Chinese from Middlebury College and her Master's in Environmental Management from Yale University.

Anders Hove

Anders Hove is Associate Director of Research at the Paulson Institute. He guides the Institute's research work related to China air quality and climate change, developing insights related to policy, market and technology solutions. He also provides research support for other Institute programs. Hove has more than 15 years of public and private sector experience related to energy policy and markets, including nine years on Wall Street and four years in China. He began his career as an energy policy analyst with the Rand Corporation in Washington, DC, then performed equity research in the electric utilities and oil services sectors with Deutsche Bank AG and Jefferies and Co. Hove has both a Master of Science and a Bachelor of Science in Political Science from MIT, and he is a Chartered Financial Analyst.

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REFERENCES

1. M. Gottstein and S. A. Skillings, "Beyond Capacity Markets – Delivering Capability Resources to Europe's Decarbonised Power System," IEEE, July 2012, accessed at www.raponline.org/document/download/id/4854.

2. "Delivering on the Promise of California's Demand Response Programs: An Opportunity for the State to Maximize the Flexibility of its Electrical Grid," California Senate Office of Research, June 2014, accessed at http://www.sor.govoffice3.com/vertical/Sites/%7B3BDD1595-792B-4D20-8D44-626EF05648C7%7D/uploads/SOR_Policy_Matters--Demand_Response.pdf

3. Frequency regulation is a high-power application of electricity storage. It has been identified as one of the best values for increasing grid stability. It typically costs between US$ 10 and US$ 60 per megawatt hour. "Frequency Regulation," Energy Storage Association, accessed on February 16, 2015 at http://energystorage.org/energy-storage/technology-applications/frequency-regulation.

4. "Effective Ancillary Services Market Designs on High Wind Power Penetration Systems," National Renewable Energy Laboratory, 2012, accessed at http://www.nrel.gov/docs/fy12osti/53514.pdf, page 4.

5. Doug Hurley, Paul Peterson and Melissa Whited, "Demand Response as a Power System Resource: Program Designs, Performance, and Lessons Learned in the United States," Synapse Energy Economics, May 2013, accessed at http://www.synapse-energy.com/project/demand-response-power-system-resource, page 19.

6. "The Duty of a Public Utility to Render Adequate Service: Its Scope and Enforcement," Columbia Law Review Volume 62, Number 2, February 1962, pages 312-313, accessed at http://www.jstor.org/stable/1120016?seq=1#page_scan_tab_contents.

7. "A National Assessment of Demand Response Potential," Federal Regulatory Commission, June 2009, accessed at http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf, page xi.

8. "Expanding and Modernizing the Electric Power Delivery System for the 21st Century," Electricity Advisory Committee Memo dated September 24, 2015, accessed at: http://energy.gov/sites/prod/files/2014/10/f18/ModernizingElectricPowerDeliverySystem.pdf.

9. Bob Taylor and Colin Taylor, "Demand Response: Managing Electric Power Peak Load Shortages with Market Mechanisms: A Review of International Experiences and Suggestions for China," Regulatory Assistance Project, March 2015, accessed at http://www.raponline.org.

10. Charles Goldman et al., "Coordination of Energy Efficiency and Demand Response," Lawrence Berkeley National Laboratory, January 2010, accessed at http://emp.lbl.gov/sites/all/files/REPORT%20lbnl-3044e.pdf, pages 2-3.

11. "Delivering on the Promise of California's Demand Response Programs: An Opportunity for the State to Maximize the Flexibility of its Electrical Grid," California Senate Office of Research, June 2014, accessed at http://www.sor.govoffice3.com/vertical/Sites/%7B3BDD1595-792B-4D20-8D44-626EF05648C7%7D/uploads/SOR_Policy_Matters--Demand_Response.pdf.

12. "PJM Economic Demand Resource in Energy Market," PJM State and Member Training Department, 2014, accessed at, http://www.pjm.com/Calendar%20Events/PJM%20Calendars/Training%20Events/2013/September/05/~/media/6BE10C20331147CFB740954976EE18D1.ashx; E. Huffaker, "Not All DR Created Equal: Assessing the Role of Backup Generation in Demand Response," UC Berkeley, 2013; "Order Instituting Rulemaking to Enhance the Role of Demand Response in Meeting the State's Resource Planning Needs and Operational Requirements," Decision Resolving Several Phase Two Issues and Addressing the Motion for Adoption of Settlement Agreement on Phase Three Issues, California Public Utilities Commission, Final Decision, December 4, 2014, accessed at http://docs.cpuc.ca.gov/SearchRes.aspx?docformat=ALL&DocID=143552239.

13. Fredrick Weston, "Demand Response as a Power System Resource: Recent US Experience," Regulatory Assistance Project, January 31, 2014, accessed at: http://fsr.eui.eu/Documents/Presentations/Energy/2014/140131Demand-SideResponseinTheElectricityMarket/140131WestonRick.pdf.

14. The acronym PJM originally referred to the states Pennsylvania, New Jersey and Maryland, but the PJM Interconnection now covers portions of many more states and jurisdictions, so the acronym is now used as a stand-alone.

15. "PJM Demand Side Response Overview," PJM, 2014, accessed at http://www.pjm.com/~/media/training/pjm-demand-side-response-overview-v2.ashx.

16. Katherine Tweed, "Demand Response Hits a New Record in PJM," Greentech Media, September 13, 2013, accessed at http://www.greentechmedia.com/articles/read/demand-response-hits-a-new-record-in-pjm; Katherine Tweed, "5 Demand Response Trends to Watch in 2014," Greentech Media, December 20, 2013, accessed at http://www.greentechmedia.com/articles/read/5-trends-to-watch-in-demand-response.

17. "PJM Capacity Market Secures New and Diverse Resources to Meet Future Electricity Demand," PR Newswire, May 23, 2014, accessed at http://www.marketwatch.com/story/pjm-capacity-market-secures-new-and-diverse-resources-to-meet-future-electricity-demand-2014-05-23; "U.S. Demand Response Market Outlook 2014," Greentech Media Research, September 18, 2014, accessed at http://www.greentechmedia.com/research/report/u.s.-demand-response-market-outlook-2014.

18. "Fast Facts: What the duck curve tells us about managing a green grid," California Independent System Operator, 2013, accessed at https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

19. "Renewables Face Daytime Curtailments in California – California, RPS, CAISO, negative prices, electricity, curtailments, overgeneration, duck chart," Chadbourne, November 2014, accessed at http://www.chadbourne.com/Renewables-Face-Daytime-Curtailmentsin-California_projectfinance/.

20. "California Vehicle-Grid integration (VGi) roadmap: Enabling vehicle-based grid services," California Independent System Operator, February 2014, accessed at http://www.caiso.com/Documents/Vehicle-GridIntegrationRoadmap.pdf. See Appendix C for a list of VGI activities.

21. "Fast Facts: What the duck curve tells us about managing a green grid," California Independent System Operator, 2013, accessed at https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

22. Fast Facts: What the duck curve tells us about managing a green grid," California Independent System Operator, 2013, accessed at http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf, page 3.

23. Jimmy Nelson, "Renewable Ancillary Service Markets for California's Duck Curve," accessed on May 6, 2015 at http://www.resource-solutions.org/images/events/rem/presentations/2014/Nelson_Jimmy.pdf.

24. "Fast Facts: What the duck curve tells us about managing a green grid," California Independent System Operator, 2013, accessed at https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

25. "National Demand Response Action Plan," Federal Energy Regulatory Commission, June 17, 2010, page B9, accessed at http://www.ferc.gov/legal/staff-reports/06-17-10-demand-response.pdf; Katherine, Tweed, "California's Fowl Problem 10 Ways to Address the Renewable Duck Curve," Greentech Media, May 14, 2014, accessed at http://www.greentechmedia.com/articles/read/10-ways-to-solve-the-renewable-duck-curve.

26. Energy Policy Act of 1992, October 24, 1992, accessed at http://www.usbr.gov/power/legislation/epa92.pdf.

27. Bo Shen, Chun Chun Ni, Girish Ghatikar and Lynn Price, "What China Can Learn from International Experiences in Developing a Demand Response Program," Lawrence Berkeley National Laboratory, June 2012, accessed at http://china.lbl.gov/sites/all/files/lbl-5578e-demand-response-eceeejune-2012.pdf, page 12.

28. This applies only to demand response (DR) resources participating in the day-ahead or real-time market administered by an RTO or ISO and does not apply to other DR programs operated for reliability or emergency conditions, nor compensation in ancillary services markets. (FERC Order 755)

29. Katherine Tweed, "Order 745 Raises Payments – and Questions – for Demand Response," Greentech Media, October 26, 2012, accessed at http://www.greentechmedia.com/articles/read/order-745-raises-payments-and-questions-for-demand-response; Bo Shen, Chun Chun Ni, Girish Ghatikar and Lynn Price, "What China Can Learn from International Experiences in Developing a Demand Response Program," Lawrence Berkeley National Laboratory, June 2012, accessed at http://china.lbl.gov/sites/all/files/lbl-5578e-demand-response-eceeejune-2012.pdf, page 12. Unfortunately the FERC Order 745 was overturned by the U.S. Court of Appeals in Washington D.C. in 2014.

30. Consolidated Financial Statements, United States Securities and Exchange Commission, Form 10-K, EnerNOC, Inc., Securities and Exchange

Commission, 2014, accessed at https://www.bamsec.com/filing/119312515089688?cik=1244937.

31. "Con Edison Demand Response Aggregator List," Consolidated Edison, accessed February 22, 2015, at http://www2.nationalgrid.com/UK/Services/Balancing-services/Demand-Side-Aggregators/; "Commercial Aggregation Service Providers," National Grid, accessed February 22, 2015, at http://www2.nationalgrid.com/UK/Services/Balancing-services/Demand-Side-Aggregators/.

32. "Mobile Apps," San Diego Gas & Electric, accessed February 22, 2015, at http://www.sdge.com/mobileapps; "Introducing Energy Engage Mobile: Maximizing customer engagement while increasing operational efficiency," Siemens, accessed February 22, 2015, at http://w3.siemens.com/smartgrid/global/en/products-systems-solutions/smart-metering/emeter/Pages/Energy-Engage-Mobile.aspx.

33. Stephen Lacey, "Who Will Emerge as the Opower of Commercial Building Efficiency?," Greentech Media, March 17, 2014, accessed at http://www.greentechmedia.com/articles/read/Will-There-Ever-Be-an-Opower-of-Commercial-Building-Efficiency; Katherine Tweed, "Building Genome Project: Retroficiency Takes a City-Wide Approach to Efficiency," Greentech Media, April 16, 2014, accessed at http://www.greentechmedia.com/articles/read/retroficiency-building-genome-project; Jeff St. John, "Honest Buildings: 250,000 New York City Buildings Online," Greentech Media, May 9, 2012, accessed at http://www.greentechmedia.com/articles/read/honest-buildings-250000-new-york-city-buildings-online.

34. "InterAct – Energy Management Tools," Pacific Gas & Electric, accessed February 22, 2015, at http://www.pge.com/en/mybusiness/save/energymanagement/interact/index.page.

35. "NRG Acquires Energy Curtailment Specialists," Zacks, August 23, 2013, accessed at http://www.zacks.com/stock/news/107467/nrg-acquires-energy-curtailment-specialists.

36. Rolfe Winkler and Daisuke Wakabayashi, "Google to Buy Nest Labs for $3.2 Billion," January 13, 2014, accessed at http://www.wsj.com/articles/SB10001424052702303595404579318952802236612.

37. Mikey Campbell, "Apple Store now selling ecobee3 smart thermostat, stokes 'smarthome' competition," Apple Insider, Monday, November 17, 2014, accessed at http://appleinsider.com/articles/14/11/17/apple-store-now-selling-ecobee3-smart-thermostat-competitor-to-googles-nest-products.

38. Martin LaMonica, "A Startup's Smart Batteries Reduce Buildings' Electric Bills: Stem uses data analytics and large batteries to cut electricity costs in commercial buildings," MIT Technology Review, November 6, 2012, accessed at http://www.technologyreview.com/news/506776/a-startups-smart-batteries-reduce-buildings-electric-bills/.

39. Martin LaMonica, "A Startup's Smart Batteries Reduce Buildings' Electric Bills: Stem uses data analytics and large batteries to cut electricity costs in commercial buildings," MIT Technology Review, November 6, 2012, accessed at http://www.technologyreview.com/news/506776/a-startups-smart-batteries-reduce-buildings-electric-bills/.

40. Eric Wesoff and Jeff St. John, "Stem Wins Big with 85MW of Energy Storage in SCE Procurement," Greentech Media, November 5, 2014, accessed at http://www.greentechmedia.com/articles/read/Stem-Wins-Big-With-85-MW-of-Energy-Storage-in-SCE-Procurement.

41. "Green Button," U.S. Department of Energy, accessed on February 22, 2015, at http://energy.gov/data/green-button.

42. Leon Walker, "Demand Response Capacity to Reach 196.7 GW in 2023," Energy Manager Today, June 5, 2014, accessed at http://www.energymanagertoday.com/demand-response-capacity-reach-196-7-gw-2023-0101626/.

43. Brett Feldman, "Global Demand Response: Market Analysis and Forecasts," Navigant, October 16, 2014, page 23.

44. Brett Feldman, "Global Demand Response: Market Analysis and Forecasts," Navigant, October 16, 2014, page 26.

45. Theodore Gates Hesser, "The Future of Demand Response: Connecting the Dots between Smart Grid and Large Scale Wind Integration," Natural Resources Defense Council, September 2010, accessed at http://www.maproyalty.com/downloads/the-future-of-demand-response.pdf, page 7.

46. Theodore Gates Hesser, "The Future of Demand Response: Connecting the Dots between Smart Grid and Large Scale Wind Integration," Natural Resources Defense Council, September 2010, accessed at http://www.maproyalty.com/downloads/the-future-of-demand-response.pdf, page 18.

47. Barbara Finamore et al., "Demand-Side Management in China: Benefits Barriers and Policy Recommendations," Natural Resources Defense Council, October 2003, accessed at http://www.nrdc.org/air/energy/chinadocs/dsm.pdf, page 15.

48. "Integrating Renewables into Power Systems in China: A Technical Primer Power," Regulatory Assistance Project, December 2014, accessed at http://www.raponline.org/document/download/id/7459

49. "有序用电管理办法" [Measures on the Orderly Use of Electricity], National Development and Reform Commission, April 21, 2011, accessed at http://www.sdpc.gov.cn/fzgggz/jjyx/zhdt/201104/t20110428_408780.html.

50. "有序用电管理办法" [Measures on the Orderly Use of Electricity], National Development and Reform Commission, April 21, 2011, accessed at http://www.sdpc.gov.cn/fzgggz/jjyx/zhdt/201104/t20110428_408780.html.

51. "China's Power Sector: A Backgrounder for International Regulators and Policy Advisors," Regulatory Assistance Project, accessed at https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CAQFjAA&url=http%3A%2F%2Fwww.raponline.org%2Fdocument%2Fdownload%2Fid%2F13&ei=1vU1VZuvFMG0oQSlg4Ao&usg=AFQjCNFyMP7aCxPhZ3A-6dBphiJxkaKUbQ&bvm=bv.91071109,bs.1,d.aWw&cad=rjt, page 2.

52. "广东实施首个能效电厂项目" [Guangdong Implements its First Efficiency Power Plant Project], BJX, March 2, 2009, accessed at http://news.bjx.com.cn/html/20090302/205645.shtml. Guangdong launched a 106 MW EPP project in 2009 with funding support from the Asia Development Bank; "我省启动60万千瓦规模能效电厂建设" [Hebei Launches a 600 MW Scale Efficiency Power Plant Construction], Hebei Province Power Demand Side Management, March 29, 2010, accessed at http://www.hbdsm.com/html/xwzx/gn/10563.html

53. "China's Power Sector: A Backgrounder for International Regulators and Policy Advisors," Regulatory Assistance Project, February 2008, accessed at www.raponline.org/document/download/id/13, page 13; Barbara Finamore et al., "Demand-Side Management in China: Benefits, Barriers, and Policy Recommendations," Natural Resources Defense Council, October 2003, accessed at http://www.nrdc.org/air/energy/chinadocs/dsm.pdf.

54. "国家发展改革委关于运用价格杠杆调节电力供求促进合理用电有关问题的通知" [Notice from the NDRC on Using Pricing Signals to Balance Supply Demand and Promote Rational Use of Electricity], April 25,2003, accessed at http://www.nea.gov.cn/2011-08/16/c_131052527.htm.

55. "国务院办公厅关于加强电力安全工作的通知" [Notice from the Office of the State Council on Strengthening Electrical Safety], Office of the State Council, December 5, 2003, accessed at http://www.gov.cn/gongbao/content/2004/content_63087.htm.

56. "发展改革委等部门发布'电力需求侧管理办法'" [NDRC Announces Demand-Side Management Measures], November 18, 2010, accessed at http://www.gov.cn/jrzg/2010-11/18/content_1748085.htm.

57. "Best Practices in Designing and Implementing Energy Efficiency Obligation Schemes," Regulatory Assistance Project, June 2012, accessed at www.raponline.org/document/download/id/5003, page 42.

58. "电力需求侧管理城市综合试点工作中央财政奖励资金管理暂行办法" [Interim Measures on Financial Incentives from the Central Government for Demand-Side Management Pilot Program], Ministry of Finance, July 3, 2012, accessed at http://www.gov.cn/zwgk/2012-07/16/content_2184152.htm; "市政府关于印发苏州市电力需求侧管理城市综合试点实施方案的通知" [Notice on the Suzhou DSM Municipal Integrated Pilot Plan], People's Government of Suzhou, March 27, 2013, accessed at http://www.jiangsu.gov.cn/jsgov/sx/shengxs/suzhous/201304/t20130401_379610.html; "关于开展北京市电力需求侧管理城市综合试点工作的通知"[Notice on Implementing Beijing's Integrated DSM Pilot Project Work], Beijing Development and Reform Commission, July 17, 2013, accessed at http://www.bjpc.gov.cn/tztg/201308/t6493571.htm. "市政府关于印发苏州市电力需求侧管理城市综合试点实施方案的通知" [Municipal Government Notice on Implementing a Comprehensive Demand-Side Management Pilot Program for the City of Suzhou], People's Government of Suzhou, March 27, 2013, accessed at http://www.zfxxgk.suzhou.gov.cn/sxqzf/szsrmzf/201304/t20130401_216828.html; "佛山市电力需求侧管理城市综合试点工作领导小组办公室关于印发'佛山市电力自动需求响应试点项目实施工作方案（2014-2015）'的通知," [Foshan City Electricity Demand Response Platform], People's Government of Foshan, January 21, 2015, accessed at: http://www.fsdsm.gov.cn/zwgk/899.jhtml; "唐山市三季度综合试点工作进展情况" [Third Quarter Progress for the Tangshan Pilot], National Development and Reform Commission, August 28, 2014, accessed at http://www.ndrc.gov.cn/fzgggz/jjyx/dzxqcgl/201410/t20141028_631166.html.

59. "电力需求侧管理城市综合试点工作中央财政奖励资金管理暂行办法"[Interim Management Methods for DSM Pilots], MOF and NDRC, July 3, 2012, accessed at http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201207/t20120710_665194.html.

60. Discussions with Shanghai Municipal Commission of Economy and Information, National Resources Defense Council, 2015.

61. Discussions with Shanghai Municipal Commission of Economy and Information, National Resources Defense Council, 2015.

62. Discussions with Shanghai Municipal Commission of Economy and Information, National Resources Defense Council, 2015.

63. Guy Liu and Liang Zhang, "Understanding the Performance of the Electric Power Industry in China," Asian Economic Papers 11:2, 2012, accessed at http://bura.brunel.ac.uk/bitstream/2438/8895/2/Fulltext.pdf.

64. "Recommendations for Power Sector Policy in China," Regulatory Assistance Project, October 2013, accessed at http://www.raponline.org/document/download/id/6869.

65. Zhaoguang Hu, David Moskovitz, Jianping Zhao, "Demand-Side Management in China's Restructured Power Industry: How Regulation and Policy Can Deliver Demand-Side Management Benefits to a Growing Economy and a Changing Power System," 2005, accessed at https://openknowledge.worldbank.org/handle/10986/18000.

66. Zhaoguang Hu, David Moskovitz, Jianping Zhao, "Demand-Side Management in China's Restructured Power Industry: How Regulation and Policy Can Deliver Demand-Side Management Benefits to a Growing Economy and a Changing Power System," 2005, accessed at https://openknowledge.worldbank.org/handle/10986/18000.

67. "节约用电管理办法"[Measures for Electricity Conservation], State Economic and Trade Commission, December 29, 2000, accessed at http://www.zbeic.gov.cn/art/2011/8/4/art_2320_89734.html.

68. To date, Shanghai is the only city in China that has implemented a large-scale demand response pilot program. The NDRC called for scaling up capacity through in-person meetings and exchanges to promote and disseminate best practices and cases, and strengthen communication and training through web-based training platforms. "国家发展改革委、财政部关于完善电力应急机制做好电力需求侧管理城市综合试点工作的通知: 发改运行[2015]703号"[NDRC Document Number 713 (2015): Notice regarding Comprehensive DSM City Pilot Implementation to Improve Electric Power Emergency Response Mechanism], National Development and Reform Commission, accessed at http://www.sdpc.gov.cn/zcfb/zcfbtz/201504/t20150409_677004.html.

69. "国家发展改革委、财政部关于完善电力应急机制做好电力需求侧管理城市综合试点工作的通知: 发改运行[2015]703号"[NDRC Document Number 713 (2015): Notice Regarding Comprehensive DSM City Pilot Implementation to Improve Electric Power Emergency Response Mechanism], NDRC and MOF, accessed at http://www.sdpc.gov.cn/zcfb/zcfbtz/201504/t20150409_677004.html.

70. Kahrl, F., and Wang, X., "Integrating Renewables into Power Systems in China: A Technical Primer — Power System Operations," Regulatory Assistance Project, 2014, accessed at: http://www.raponline.org/document/download/id/7459.

71. "国家发展改革委关于深圳市开展输配电价改革试点的通知: 发改价格(2014) 2379号" [NDRC Notice Regarding Transmission and Distribution Pricing Reform Pilot in Shenzhen NDRC Pricing (2014) Number 2379], NDRC, accessed at http://www.sdpc.gov.cn/fzgggz/jggl/zcfg/201411/t20141104_639669.html.

72. The 2011 DSM Rule allows grid companies to recover reasonable expenditures. Thus, the approved DSM expenditures should be included in the calculation of the allowable revenue.

73. "国家发展改革委办公厅关于做好国家电力需求侧管理平台建设和应用工作的通知" 发改办运行[2014]734号 [Notice Regarding the Construction and Application of National DSM Platform], Office Operations Document, Number 734, NDRC, 2014, accessed at http://www.sdpc.gov.cn/zcfb/zcfbtz/201404/t20140415_606978.html.

74. "国家发展改革委办公厅关于做好国家电力需求侧管理平台建设和应用工作的通知" 发改办运行[2014]734号 [Notice Regarding the Construction and Application of National DSM Platform], Office Operations Document, Number 734, NDRC, 2014, accessed at http://www.sdpc.gov.cn/zcfb/zcfbtz/201404/t20140415_606978.html.

75. "国家发展改革委办公厅关于做好国家电力需求侧管理平台建设和应用工作的通知" 发改办运行[2014]734号 [Notice Regarding the Construction and Application of National DSM Platform], Office Operations Document, Number 734, NDRC, 2014, accessed at http://www.sdpc.gov.cn/zcfb/zcfbtz/201404/t20140415_606978.html.

76. "国网推进节能减排, 打造绿色央企节能范本"[State Grid Promotes Energy Conservation and Emissions Reduction Creating a Model for a Green Enterprise], State Grid Corporation, June 19, 2014, accessed at http://www.sgcc.com.cn/ztzl/newzndw/zndwzx/gnzndwzx/2014/06/307410.shtml.

77. "关于进一步深化电力体制改革的若干意见(中发(2015)9号)文"[Guidance on Deepening Power System Reform], State Council, March 15, 2015, accessed at http://www.ne21.com/news/show-64828.html.

78. "国家发展改革委国家能源局关于改善电力运行调节促进清洁能源多发满发的指导意见" 发改运行[2015] 518号 [Guidance on Improving Electric Power Operations and Promoting Increased Generation of Clean Energy] NDRC Operations Document No. 518 (2015), NDRC and NEA, March 20, 2015, accessed at http://www.sdpc.gov.cn/zcfb/zcfbtz/201503/t20150323_668203.html; "国家发展改革委、财政部关于完善电力应急机制做好电力需求侧管理城市综合试点工作的通知: 发改运行[2015]703号"[Document Number 713 (2015): Notice Regarding Comprehensive DSM City Pilot Implementation to Improve Electric Power Emergency Response Mechanism], NDRC, April 7, 2015, accessed at http://www.sdpc.gov.cn/zcfb/zcfbtz/201504/t20150409_677004.html.

79. "关于贯彻中发[2015]9号文件精神加快推进输配电价改革的通知"[Notice on Speeding up Power Transmission and Distribution Price Reform], NDRC, April 15, 2015, accessed at http://www.gov.cn/xinwen/2015-04/15/content_2846902.htm.

80. "国务院关于印发大气污染防治行动计划的通知: 国发〔2013〕37号"[State Council Notice on Air Pollution Prevention and Control Action Plan], State Council, September 10, 2013, accessed at http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm.

81. Xiao Xin et al., "Study on the Relationship between Urbanization Process and Electricity Demand Growth," accessed at http://d.wanfangdata.com.cn/Periodical_zgdl201502028.aspx.

82. "上海呈现国际大都市用电特征最大空调负荷比重达40%"[Shanghai's Air Conditioning Demand Reaches 40% of Total Load Among International Cities], INDAA News, March 19, 2012, accessed at http://www.indaa.com.cn/dwxw2011/zhxw/201203/t20120319_956456.html.

83. Li Chonghe, "DSM is an important method to support the sustainable development of power sector," Shanghai Energy Conservation, 2005, Number 3, accessed at http://www.doc88.com/p-5159947659662.html.

84. Jeff St. John, "Can China Create a Demand Response Industry from Scratch," Greentech Media, March 9, 2015, accessed at http://www.greentechmedia.com/articles/read/can-china-create-a-demand-response-industry-from-scratch

85. Bo Shen et al, "Addressing Energy Demand through Demand Response: International Experiences and Practices," Lawrence Berkeley National Laboratory, June 2012, accessed at http://drrc.lbl.gov/sites/all/files/lbl-5580e-deman-response-azurejune-2012.pdf. Page 2.

86. Kahrl, F. and Wang, "Integrating Renewables into Power Systems in China: A Technical Primer — Power System Operations," Regulatory Assistance Project, 2014, accessed at http://www.raponline.org/document/download/id/7459, pages 36-37.

87. Charlotte Hussy et. al, "International comparison of fossil power efficiency and CO2 intensity - Update 2014," Ecofys, September 5, 2014, accessed at http://www.ecofys.com/files/files/ecofys-2014-international-comparison-fossil-power-efficiency.pdf, page 28.

88. "Power Generation from Coal Measuring and Reporting Efficiency Performance and CO2 Emissions," International Energy Agency, Coal Industry Advisory Board, 2010, accessed at http://www.iea.org/ciab/papers/power_generation_from_coal.pdf, page 20.

89. "Managing Large-Scale Penetration of Intermittent Renewables," Massachusetts Institute of Technology, An MIT Energy Initiative Symposium, April 20, 2011, accessed at https://mitei.mit.edu/system/files/intermittent-renewables-full.pdf.

90. "Energy Development Strategic Action Plan (2014-2020)," State Council June 7, 2014 accessed at http://www.gov.cn/zhengce/content/2014-11/19/content_9222.htm.

91. Michael Mulligan and Brendan Kirby, "Utilizing Load Response for Wind and Solar Integration and Power System Reliability," U.S. National Renewable Energy Laboratory, Conference Paper NREL/CP-550-48247, July 2010, accessed at http://www.nrel.gov/docs/fy10osti/48247.pdf.

92. Michael Mulligan and Brendan Kirby, "Utilizing Load Response for Wind and Solar Integration and Power System Reliability," U.S. National Renewable Energy Laboratory, Conference Paper NREL/CP-550-48247, July 2010, accessed at http://www.nrel.gov/docs/fy10osti/48247.pdf.

93. "Technology Roadmap: China Wind Energy Development Roadmap 2050," International Energy Agency, 2011, accessed at https://www.iea.org/publications/freepublications/publication/china_wind.pdf, page 13; Peter Meisen and Steffanie Hawkins, "Renewable Energy Potential of China: Making the Transition from Coal-Fired Generation," Global Energy Network Institute accessed at http://www.geni.org/globalenergy/research/renewable-energy-potential-in-china/Renewable%20Energy%20Potential%20in%20China.pdf, page 4.

94. Guo Xiaoxiong, "The National Energy Board Held a Communications Meeting on Monitoring in the Wind Industry," China National Renewable Energy Center, 2013, accessed at http://www.cnrec.org.cn/hd/2014-02-25-412.html.

95. "弃风弃光率居高不下储能 "跻进" 能源战略计划" [Solar and Wind Curtailment Rates Remain High as Energy Storage is Listed in the Energy

Strategic Plan], December 17, 2014, accessed at http://news.bjx.com.cn/html/20141217/574080.shtml.

96. "Managing Large-Scale Penetration of Intermittent Renewables," Massachusetts Institute of Technology, An MIT Energy Initiative Symposium, April 20, 2011, accessed at https://mitei.mit.edu/system/files/intermittent-renewables-full.pdf.

97. "可再生能源发电并网驻点甘肃监管报告"[Report on Renewable Energy Integration Stagnation in Gansu], NEA, July 18, 2014, accessed at http://www.nea.gov.cn/2014-07/18/c_133494355.htm; "国家能源局开展可再生能源发电并网专项监管进一步助推可再生能源发展"[NEA Steps up Supervisory Work on Renewable Energy Integration to Boost Renewable Energy Development], Zhejiang Provincial Development and Reform Commission, January 23, 2014, accessed at http://www.zjdpc.gov.cn/art/2014/1/23/art_982_625400.html.

98. "China 2050 High Renewable Energy Penetration Scenario and Roadmap Study", Energy Research Institute, National Development and Reform Commission, April 2015, accessed at http://www.efchina.org/Attachments/Report/report-20150420.

99. "Flexible generation: Backing up renewables," Eurelectric, November 2011, accessed at http://www.eurelectric.org/media/61388/flexibility_report_final-2011-102-0003-01-e.pdf.

100. Thomas Schulz, "Demand Response as a Market Component in Europe," EnerNOC, September 2014, accessed at http://www.demandresponsesmartgrid.org/Resources/Documents/Case%20Study%20Interviews/EnerNOC-Entelios%20ADS%20case%20study%20-%20CSI%20Presentation%20(140912)%20FINAL.pdf.

101. "Incorporating demand side flexibility, in particular demand response, in electricity markets," European Commission, Commission Staff Working Document, SWD (2013) 442 final, May 11, 2013, accessed at http://ec.europa.eu/energy/sites/ener/files/documents/com_2013_public_intervention_swd07_en.pdf.

102. "2014年政府十大政策力推新能源汽车"[Ten Government Policies Push for New Energy Vehicles in 2014], China EV Net, January 4, 2015, accessed at http://news.ddc.net.cn/newsview_57115.html.

103. Scott Peterson and Vanessa Schweizer, "Plug-In Electric Vehicles and Renewable Energy Integration," Carnegie Mellon University, accessed on April 22, 2015 at https://wpweb2.tepper.cmu.edu/rlang/RenewElec/V2G%20White%20Paper%20v4.pdf.

104. "California Vehicle-Grid integration (VGi) roadmap: Enabling vehicle-based grid services," California Independent System Operator, February 2014, accessed at http://www.caiso.com/Documents/Vehicle-GridIntegrationRoadmap.pdf.

105. Katherine Tweed, "SCE Tests Electric Vehicles for Demand Response," Greentech Media, February 2015, accessed at http://www.greentechmedia.com/articles/read/sce-tests-electric-vehicles-for-demand-response; "Electric Transportation: Southern Company – Leading the Way in Electric Transportation," Southern Company, accessed on May 20, 2015 at http://www.southerncompany.com/what-doing/energy-innovation/smart-energy/smart-choices/electric-car.cshtml.

106. Trieu Mai et al., "Renewable Energy Futures Study," U.S. National Renewable Energy Laboratory, 2012, accessed at http://www.nrel.gov/docs/fy12osti/52409-1.pdf.

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