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### **Author**

Ghatikar, Girish

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# Expanding Buildings-to-Grid (B2G) Objectives in India

**Girish Ghatikar and Venkata Ganti**  
Lawrence Berkeley National Laboratory

**Chandrayee Basu**  
University of California Berkeley

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## **Abstract**

India faces significant challenges in providing a reliable electricity supply. This was manifest in a power grid failure that resulted in the country's worst blackout, which affected states where 50% of India's 1.2 billion people live. The Government of India is taking measures to address the situation of aging grid infrastructure and integrated demand-side management. The National Action Plan on Climate Change of 2008 outlines a National Mission on Enhanced Energy Efficiency with actions for electricity sector reform. The U.S.-India Energy Dialogue provides a mechanism for joint activities to address energy issues and electric grid integration. The scope of the buildings-to-grid (B2G) activities by Lawrence Berkeley National Laboratory (LBNL) have been delineated primarily based on the expertise of LBNL understanding responsive loads for Smart Grid deployments in the United States. This study leverages parallel Smart Grid activities by the Indian and U.S. stakeholders. Its goal is to establish a sustainable B2G collaboration between the U.S. and India, which will facilitate integration of demand-side systems with supply-side systems to advance India's electricity reliability goals. The study will motivate Indian electricity markets by disseminating U.S. experiences and technologies for the uptake of demand response (DR) pilot studies in India. The study delineates immediate and long-term intervention through systematic review of issues, U.S. experiences, and technologies that support local missions. It provides background and description of energy efficiency and DR framework through an organized review of the literature pertaining to various aspects of India's B2G activities. The results are short-term and long-term DR and energy-efficiency integrated action plans for pilot studies and transformative technologies for mitigation and adaptation of electricity reliability. The findings will aid Smart Grid market transformation and policy interventions through technology demonstrations. Based on the priorities identified, a plan for B2G technology pilot studies in India is proposed.

## **Executive Summary**

### **Introduction**

*Buildings-to-grid (B2G) integration* refers to the interface of the commercial building sector with the electric grid. This integration helps to maintain electricity system reliability by enabling buildings to contribute to changes in electricity supply and/or demand. In India, the potential for this strategy to save energy and help ensure the smooth addition of renewable energy to the grid is particularly good, since two-thirds of the commercial building stock that is anticipated to exist in 2030 has not yet been built and the development of India's Smart Grid is in its early stages.

Lawrence Berkeley National Laboratory (LBNL), a world-recognized leader in energy efficiency and Smart Grid research, is working with the Government of India to apply B2G integration knowledge to India, to support efficient electricity use in India's rapidly growing infrastructure. In return, that experience is providing new information on how to apply lessons learned in the United States to other countries and economies.

### **Purpose**

This study focuses primarily on existing and new commercial building B2G activities to promote the increased use of advanced demand-side management (DSM) strategies and technologies in India and facilitate a transition to an operational Smart Grid.

### **Objectives**

This study provides assistance to apply and expand the markets for B2G technologies in India, concentrating on increasing the understanding of the integration requirements between DSM systems and the modernizing Indian electric grid. This U.S.–India collaborative study sets the stage for integrated development of the Smart Grid and links it to clean energy solutions. In particular, it promotes pilot demonstrations of semi-automated and fully automated demand response (DR) technologies and responsive loads, suitable for the Indian markets.

### **Conclusions and Next Steps**

The Joint U.S.–India B2G collaboration initiative can act as a platform for LBNL and other relevant U.S. stakeholders to share expertise in Smart Grid technologies and apply the lessons learned from the U.S. deployments to the Indian context (e.g., DR and DER) in an integrated fashion to address both B2G integration and energy efficiency. The technological and policy overlap between DR and EE enabling infrastructure, as indicated in this study, will allow joint U.S.–India pilot studies to inform technical, market, and policy decisions for rigorous expansion of this standard to include grid integration.

To advance B2G objectives, collaborative research with key Indian partner(s) will be necessary to address the standards and technology, markets, and policy requirements. In particular, pilot(s) can address local and regional needs and their effectiveness for scaled deployments. The pilots must be aligned with the integrated DR and EE framework proposed in this study. The key areas of focus include collaborations with the U.S.–India energy stakeholders, integration of B2G objectives in Smart Grid pilots, and understanding the expanded objectives.

## 1. Introduction and Background

The United States (U.S.)–India 2nd Energy Efficiency Technology Cooperation Conference (EETCC) in 2009 resulted in the identification of research and deployment opportunities, as well as potential technical collaborations between the Government of India and the United States involving buildings and the Smart Grid (Sathaye et al. 2009). This study focuses primarily on expanding these objectives to buildings-to-grid (B2G) activities in India. The B2G integration refers to the interface of the commercial building sector with the electric grid to maintain electricity system reliability by leveraging the untapped and underexplored ability of the buildings to contribute to changes in supply and/or demand.

Consumption of electricity in India has been increasing exponentially over the past few decades. According to a Central Electricity Authority (CEA) report, the electricity deficit throughout India in 2013 is projected to be 10.6% (CEA 2012). India’s electricity demand is projected to reach 1,900 terawatt-hours (TWh) by 2021–2022 (MOP 2007), and its carbon dioxide (CO<sub>2</sub>) emissions from coal combustion are projected to reach 3.3 gigatonnes (Gt) in 2030—8% of the world total (based on a 2005 reference scenario) (IEA 2007). The commercial, residential, and industrial sectors account for 10%, 39%, and 24%, respectively, of the total 694,392 gigawatt-hours (GWh) of electricity consumption in the country. While commercial sector electricity use is a smaller slice of the pie today, this sector is facing the third-highest compounded annual growth rate (CAGR) over the past four decades (8.29% as of 2010–11), surpassed only by domestic and agriculture sector growth (MOSPI 2012). The present estimated peak power shortage in the country is 11% to 17% (CEA 2009).

According to studies conducted by Tata Power, a private utility in India, fully air-conditioned commercial buildings are contributing rapidly to this peak shortage. Air-conditioning in commercial and domestic buildings together makes ~40% of the electricity consumption in the utility’s consumer base (Tata Power 2012), thereby offering a potential resource for B2G integration in India. This potential will only increase with time, as 66% of the commercial stock projected to be in existence in 2030 is yet to be built (Kapoor et al. 2011), while electricity demand is growing at an annual rate of 12%–14% in the commercial sector (USAID-India 2013). To address the electricity peak and reliability issues, this study addresses the gap in established technical, operational, market, and policy objectives for identifying commercial building sector-based solutions to these issues.

This study, conducted by Lawrence Berkeley National Laboratory (LBNL) for the U.S. Department of Energy (U.S. DOE), therefore, **provides assistance to apply and expand the markets for B2G technologies in India, by increasing the understanding of the integration requirements between Demand Side Management (DSM) systems and the Indian electric grid modernization (also called the *Smart Grid*) activities, focusing primarily on existing and new commercial buildings.**

This study promotes the increased use of advanced DSM technologies in India that will facilitate a transition to an operational Smart Grid. Potential joint U.S.–India collaboration will enable



“leapfrogging” the B2G initiatives in India, where such activities are still at a nascent stage, and will link clean energy solutions to the development of an integrated Smart Grid. This study, specifically, acts as a catalyst for pilot demonstrations of semi-automated and fully automated demand response (DR) technologies suitable for the Indian markets. According to the U.S. DOE, demand response reflects “changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized” (U.S. DOE 2006). Evaluation and application of B2G integration technologies for DR can become the basis for Joint U.S.–India pilot demonstration(s), and an integrated transition to the Smart Grid to improve electricity reliability and energy efficiency in India. The Smart Grid transition requires the understanding of the building sector’s contribution toward sustainability and clean energy solutions from an integrated perspective (e.g., a building needs to be responsive to and provide feedback for an effective smart electricity grid), where energy efficiency and relevant DSM activities are incorporated into the overall contribution to the reliability of the electricity system, and to meet India’s clean energy goals.

### **1.1. India’s Clean Energy Vision and Strategic Partnerships**

Cooperation on energy is a central element of the U.S.-India strategic partnership. India’s Jawaharlal Nehru National Solar Mission is a major initiative of the Government of India and state governments to promote ecologically sustainable growth while addressing India’s energy security challenges. Its goal is to install 20 gigawatts (GW) of solar photovoltaic and to achieve price parity with India’s grid power tariff by 2022 (U.S. DOE 2012). In the 2009 Copenhagen Accord, India made a commitment to reduce its emissions per unit of gross domestic product (GDP) 20 to 25 percent below 2005 levels by 2020 (NRDC 2013). The U.S.-India Partnership to Advance Clean Energy (PACE) was launched in 2009 to accelerate the transition to high-performing, low-emission, energy-secure economies (U.S. DOE 2012). In November 2009, under PACE-R, which is the research component of PACE, the U.S. DOE and India’s Ministry of Science and Technology established a Joint Clean Energy Research and Development Center (JCERDC). Under JCERDC, the U.S.-India Joint Center for Building Energy Research and Development (CBERD) was established as an international consortium between the United States and India for research and development of building technologies for energy efficiency.

The PACE-R activity must complement PACE-D, the deployment component. Together, they lay the roadmap for India’s transition to Smart Grid. The United States Agency for International Development (USAID) is one of the organizations supporting PACE-D, which is also working toward the establishment of partner utilities for Smart Grid deployments within their areas of influence. The U.S. Trade and Development Agency (USTDA) funded a feasibility study and pilot project in supporting implementation of Smart Grid roadmap for the Calcutta Electric Supply Corporation Limited (CESC) that will evaluate the cost/benefit of smart meter- and automated meter reading-related investments into CESC’s distribution system (U.S. DOE 2012). The USTDA is also supporting Tata Power and Bangalore Electricity Supply Company Limited (BESCOM) in Smart Grid endeavors, which are discussed in later sections (U.S. DOE 2012).

## **1.2. India's Smart Grid Initiatives**

At present, India is seeing fragmented and independent Smart Grid endeavors by the national (Central) and local (State) governments, public-private collaborations, and private organizations, at different levels of maturity. Nationally, the Indian Ministry of Power (MOP) is working toward major power sector reform, which includes revolutionizing the grid with bi-directional information exchange. For the systemic growth of the Smart Grid in the country, the India Smart Grid Forum (ISGF) and India Smart Grid Task Force (ISGTF) are set up under the aegis of the Ministry of Power (MOP 2010).

The ISGF is a nonprofit voluntary consortium of public and private stakeholders with the prime objective of accelerating development of Smart Grid technologies in the Indian power sector. The MOP with sub- and nodal-agencies; Ministry of New and Renewable Energy (MNRE), Ministry of Communication and Information Technology (MCIT) and Department of Science and Technology (DST); governs the ISGTF. The ISGTF is an inter-ministerial body and is divided into seven workgroups with diverse focus areas, including Advanced Transmission, Advanced Distribution, Communication, Metering, Consumption and Load control, Policy and Regulation, and Architecture and Design (Tongia 2013).

### **1.2.1. Public Sector Initiatives**

Under the auspices of the seven working groups of the ISGTF, several activities encompassing market-based mechanisms for rapid Smart Grid adoption will be evaluated. These include demand-side financing, feed-in tariffs for individual renewable generators, and a differential tariff for reliable supply and transmission pricing models, including Locational Marginal Pricing (LMP) (ISGF 2013). These financial activities will be supported by simultaneous technical feasibility assessment of connectivity, network planning, and reliability of system operation.

Another major power-sector reform initiative of the Government of India is the Restructured Accelerated Power Development and Reform Program (R-APDRP). R-APDRP is an extension of the Accelerated Power Development and Reform Program (APDRP) launched by the MOP in 2000–2001 as a last means for restoring the commercial viability of the Indian Distribution Sector that was running at an alarming loss equivalent to 1.5% of the GDP (<sup>3</sup>MOP, n.d.). Geared toward urban areas—towns and cities with a population of more than 30,000—and some rural areas with high-density loads, this project will be implemented in two parts. Several of the R-APDRP projects that specifically pertain to the B2G project are as follows (<sup>2</sup>MOP, n.d.):

- Consumer indexing
- Metering of distribution transformers and feeders
- Automatic data logging for all distribution transformers and feeders and the Supervisory Control and Data Acquisition (SCADA)/Distribution Management System (DMS)
- Adoption of information technology applications for meter reading, billing, and collection
- Energy accounting and auditing
- Management Information System (MIS)

- Redressal of consumer grievances
- Establishment of IT-enabled consumer service centers
- Load balancing

Under the umbrella of PACE-D, USAID, and Nexant (Nexant 2012), the chief technology consultant for the USAID-funded PACE-D project in India will advance the infrastructure and the technology potential created under R-APDRP toward deployment.

### **1.2.2. Private Sector Initiatives and Public-Private Partnerships**

The ISGF has prepared a Smart Grid roadmap for National Smart Grid Mission to foster Smart Grid development over three plan periods. The short-term and long-term activities of the ISGF that pertain to B2G project will be:

- improvement in power quality and reliability,
- deployment of a time-of-use tariff,
- development of open-information exchange platforms to be shared by all market participants in real-time, including “prosumers” (consumers who produce energy and participate in energy market), and
- design of policies for DR-ready appliances.

The B2G project will facilitate proof-of-concept testing of DR infrastructure in commercial buildings, supporting the ISGF’s goal to deploy mandatory DR infrastructure for all customers with loads above 1 megawatt (MW) by 2013 and with those above 100 kilowatts (kW) by 2017. The ISGF will also oversee the development of Smart Grid technologies within India and assist in developing utility-specific strategic roadmaps by the twelfth plan period (2013–2017). It also envisions nationwide rollout of smart meters and development of national standards for smart infrastructure during the thirteenth plan period (2017–2022). This study is relevant to the ISGF roadmap for twelfth and thirteenth plan periods of India, which span from 2013 to 2022; five years each.

Of approximately five private Smart Grid initiatives identified (Reliance Power, ABB, Green World Investors, and Tata Power) (Green World Investor, 2012), Tata Power is one key public-private energy company in India adopting international demand management concepts like active DR programs for customers of demands greater than 500 kW, with a goal to minimize power costs during peak periods (Tata Power 2012). The DR activities of Tata Power include implementing a time-of-day (TOD) tariff,<sup>1</sup> providing energy conservation and load-shifting guidelines, conducting energy audits, providing technology and communication infrastructure to support Automated DR (AutoDR involves automation of an entire facility integrating end-use loads into building management systems, as defined in Subsection 3.3 of this report), and developing Measurement and Verification (M&V) methods.<sup>2</sup> Tata Power operates two DR models: (1) aggregator (manual/semi-automated), and (2) AutoDR (direct). Tata Power has

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<sup>1</sup> Such tariffs in the U.S. are commonly called, time-of-use (TOU) rates.

<sup>2</sup> Averaging hourly loads of four to five matching days with highest energy use generates hourly baseline load curve.

conducted customer load profile research, which shows the load growth shifting from industrial to commercial customers. The load research consists of automatic meter reading (AMR) data analysis, energy audits, and load survey. Total enrolled load under Tata Power's AutoDR scheme is 10 MW (Tata Power 2012). Tata Power Delhi Distribution Limited (TPDDL) also is undertaking automated metering infrastructure (AMI)-based AutoDR pilots in a 250-consumer base with loads  $\geq 300$  kW.

Working with the Indian Government and electricity service providers, IBM India is developing technologies for metering and DR load management (Seetharam 2012). More private utilities are adopting DR to ensure reliable power supply and manage costs during high volatility and peak periods (ISGF 2012).

## **2. Demand Response for India's Electricity Reliability**

Demand response as a key demand-side management strategy provides a cost-effective alternative to traditional supply-side solutions to address growing electricity demands during times of peak load or when prices are high. In India, fully air-conditioned commercial buildings are contributing rapidly to this peak shortage. Air-conditioning in commercial and domestic buildings together makes ~40% of the electricity consumption in the utility's consumer base (Tata Power 2012), thereby offering a potential resource for DR integration in India.

Although the primary goal of DR is to reduce electricity consumption during periods when the price of electricity is high or when system reliability is jeopardized, LBNL research has proven that DR has the capability to balance supply and demand at any time of the day (Watson et al. 2012; Kiliccote et al. 2009) and supports energy efficiency (EE) (Piette et al. 2008).

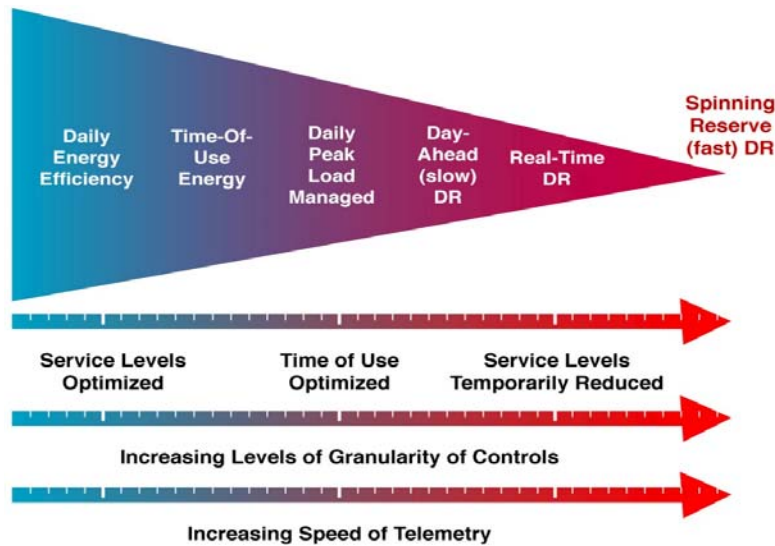
This section shows how and why DR projects in India will benefit from energy efficiency initiatives and vice versa; beginning with definitions of DR and EE and how they are relate to each other, and followed by the benefits and enabling technologies for DR in India.

### **2.1. Linking Demand Response and Energy Efficiency**

*Energy efficiency* refers to using less energy at all times, with no reduction in the service levels to the consumer, in an economic manner, irrespective of electricity peaks or price changes (Goldman et al. 2010). In contrast, *demand response* is a strategy that enables electricity customers to change their normal consumption patterns in response to changes in the price of energy over time and/or to increase grid reliability during peak periods or emergency situations, such as supply or demand changes. Programs for DR are usually designed primarily to curtail or shift load for short periods of time.

Figure 2.1 shows the links and infrastructure necessary for energy-efficient operations of buildings and their grid responsiveness. The left side of Figure 2.1 shows that the energy-efficiency operations for most times of the year. Each hour energy use can be optimized relative to the optimal energy services being delivered. Further right, for a few hours of the year, for

loads to be grid-responsive, service levels are temporarily reduced during DR periods. The second level arrow describes the granularity of control systems. The ability of DR technologies to interface with controls improves both energy management and grid responsiveness. The final arrow level describes telemetry requirements for grid reliability and price-response. On faster market requirements, like real-time DR, a more granular control and telemetry data is needed.



**Figure 2.1: Linking Demand Response and Energy Efficiency**

For adoption of DR automation technologies, energy efficiency standards like Energy Conservation Building Code (ECBC) in India can be enhanced to include mandates for countrywide DR technology adoption. The California Title 24 of Building Standards (USAID 2013; Building Standards Commission, n.d.) is an exemplar of such a model of integration of energy efficiency and DR standards. A similar endeavor with ECBC is under way in India, the details of which will be covered in Subsection 5.2.1, Standards and Labeling Programs.

## 2.2. Benefits of Demand Response

The most important benefit of DR is to improve resource efficiency of electricity production by creating a closer alignment between customers' electricity prices and the value they place on electricity. The DR benefits can be categorized into four key groups:

1. **Bill savings.** Participant financial benefits are bill savings plus incentive payments earned by customers that adjust their electricity use in response to varying electricity rates or incentive-based programs.
2. **Avoided capital and operating costs.** Reduce or eliminate the need to operate the expensive peak plants. Over the long term, sustained demand response lowers aggregate system capacity requirements, allowing load-serving entities (utilities and other electricity retail suppliers) to purchase or build less new capacity. Eventually these savings may be passed onto most retail customers as bill savings.

3. **Market pricing.** Market-wide benefits are from lower wholesale market prices while market performance benefits refer to DR value in mitigating suppliers' ability to exercise market power by raising power prices above production cost.
4. **Reliability.** Reliability benefits are the operational security and cost savings present when DR lowers the likelihood and consequences of forced outages and blackouts through cascading grid failure. Such outages impose financial costs and service interruptions on customers.

While the benefits from DR range across the Smart Grid, the largest benefits are intended for the end users or electricity consumers. The key DR program participants are the electricity service providers (e.g., utilities and independent systems operators) and the electricity customers (e.g., commercial, industrial, or residential facilities). The enabling technologies and open standards for AutoDR play an important role in enabling participants to avail themselves of the benefits of DR across diverse markets and/or programs (e.g., reliability, dynamic pricing). One such U.S. standard for DR and distributed energy resources is Open AutoDR or OpenADR (NIST 2010).

### **2.3. Demand Response Enabling Technologies and Automated Demand Response**

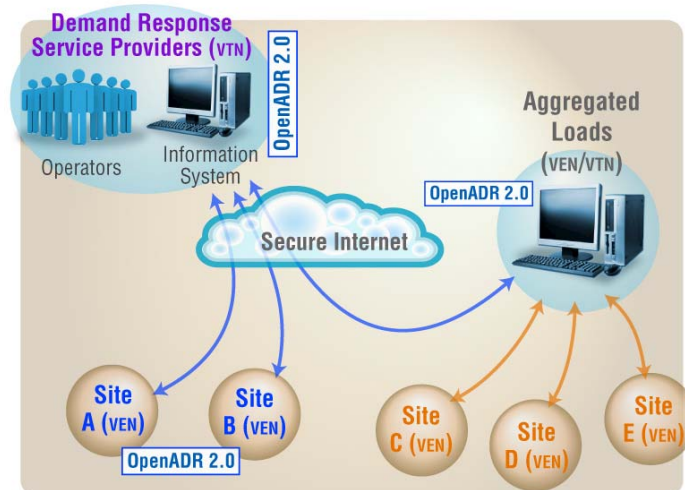
The level of automation at a particular facility participating in a DR program can be used to characterize the enabling technology solutions. It is useful to understand the functional capabilities of a facility's control systems, including the underlying technologies and software capabilities, to identify and quantify a facility's potential to participate in AutoDR and to maximize load-reduction savings without affecting day-to-day business or operations. A DR program can be implemented in three key ways:

1. **Manual DR:** This involves manually turning off or changing comfort set points, lights, or processes or each equipment, switch, or controller.
2. **Semi-Automated DR:** This involves automation of HVAC or one or several processes or systems within a facility using the building management system (BMS) or any other centralized control systems, with the remainder of the facility under manual operations.
3. **Fully Automated DR or AutoDR:** This involves automation of an entire facility with integration of end-use loads into a BMS and intelligently managed with no human intervention.

Implementing manual DR is labor intensive, and manual response can easily delay response or may not provide reliable results when needed. In semi-automated DR, the DR strategy is pre-programmed but requires a person to trigger it. AutoDR can be defined as a DR initiated by a signal from a service provider or other appropriate entity that provides fully automated connectivity to pre-programmed end-use control strategies within buildings (Piette et al. 2008). With the development of modern communications technologies, the DR strategy is becoming increasingly automated. Open automated demand response—standardized signals exchanged between a facility's monitoring systems, the utility company, and the independent system operators—increase the speed and efficiency, and reduce cost.

### ***Open Automated Demand Response (OpenADR)***

Auto-DR activities and pilots across the United States are using open communications to convey electric grid reliability and price signals to customers. At the forefront of the effort to ensure smooth and accurate communication among these systems is the U.S. National Smart Grid interoperability standard to communicate standardized DR and distributed energy resources (DER) signals (NIST 2013). This activity is coordinated by the National Institute of Standards and Technology (NIST) to provide standardized price and reliability-based information (NIST 2010). Through its extensive AutoDR activities, LBNL has created the OpenADR standard—an open specification to communicate DR and DER signals.



**Figure 2.2: Open Automated Demand Response Communications Architecture**

As shown in Figure 2.2, OpenADR communications enable electricity reliability and price information to be exchanged between the end user and the service provider using various transport mechanisms. Because OpenADR uses non-proprietary, industry-approved data models, companies can develop products around it and integrate it with their facilities’ HVAC and lighting controls, and other end-uses. The communication interfaces for OpenADR are platform-independent, interoperable, and transparent to end-to-end technologies and software systems. It helps manufacturers of building automation equipment design products for Smart Grid implementation and power aggregators incorporate DR into their work.

### **3. Demand Response and Energy Efficiency for B2G Integration**

To foster integrated demand response and energy-efficiency technology applications for building-to-grid integration, and to improve overall electricity system reliability, a contextual and integrated framework is needed for India. This integrated framework must assess both DSM and B2G requirements to interface with Smart Grid, and identify the requirements of communication standards and technologies, business, markets, and policy. This section outlines the integrated framework, which is based on building-to-grid and industry-to-grid activities in the United States. It is relevant to both the Indian scenario and the roadmap defined by the ISGF.

### 3.1. Demand-Side Activities for Buildings-to-Grid Integration

Based on the background research on India’s clean-energy goals, presented in Section 1.1, Table 3.1 outlines the integrated framework for India, describing the key requirements for B2G integration, technologies, and markets. Depending on the level of B2G integration (and, potentially, considering this as a phased approach) necessary, the requirements are classified as “basic” and “advanced.” The advanced level supports and expands all the requirements of basic level. These phased activities are determined based on initial knowledge of the baseline methodologies and policies in India and can be subject to further refinement through B2G developments. The baselines provide key measurement and verification of customer load shed to DR programs. The phases align with those of ISGF roadmap corresponding to twelfth and thirteenth plan period (2013–2022). This integrated framework must expedite the integration of B2G technologies in new commercial buildings to enable their participation in DR, and avoid significant future retrofit costs. The “basic” level of B2G integration requirements refers to:

- Priorities in technology intervention based on compatibility with onsite energy-efficiency enabling systems and commercial product availability (see Section 6 for opportunities).
- Use of existing buildings and controls to support basic grid integration capabilities, such as response to time-of-day (TOD) pricing schemes and reliability of DR programs.
- Leverage ongoing pilot initiatives and relevant policies (see Section 5 for initiatives).
- Align with the short-term goals and Smart Grid roadmaps by stakeholders, such as ISGF, ISGTF, Nexant, Tata Power, and others (see Section 2 for this investigation).
- Aid pilot demonstration of semi-automated DR technologies and strategies for commercial buildings, as identified by the U.S. deployments (Motegi et al. 2007).

The “advanced” level of B2G integration expands the “basic” level, and refers to:

- Priorities in technology intervention to maximize transition to the Smart Grid, renewables integration, distributed energy resources for a dynamic grid, and flexible load.
- Higher levels of automation, data collection, and real-time processing, with a focus on grid reliability, dynamic price responsiveness, and ancillary services.
- Upgrade or deploy technologies to advanced systems, controls to provide sophisticated functionality (such as onsite generation), and renewable energy system integration.
- Stronger alignment with long-term B2G integration goals delineated in national Smart Grid roadmaps and/or missions.
- Assist regulators with policies for codes and standards and mobilizing market transformation grid-responsive loads for existing and new buildings.
- Aiding demonstrations of advanced Auto-DR technologies and strategies for the future B2G integration through the U.S. experience (Watson et al. 2012; McDonald et al. 2012).
- Addressing cyber security issues in communications and interfaces pertaining to confidentiality of user information and integrity of DR systems.
- Assisting dispute resolution for unintended manual control action, and/or faulty actions for automated/semi-automated control schemes.



**Table 3.1: Framework for Buildings-to-Grid Integration in India**

Demand-Side Activities	Building-to-Grid Requirements	
	Basic	Advanced
Energy Efficiency	<ul style="list-style-type: none"> <li>• Energy Efficiency (EE) with higher investment for retrofits.</li> <li>• Promote new incentive programs.</li> </ul>	<ul style="list-style-type: none"> <li>• Energy efficiency improvements with integrated control and automation.</li> <li>• Installation of advanced energy efficient systems with considerable capital investment.</li> </ul>
Demand Response	<ul style="list-style-type: none"> <li>• Link DR with standard EE practices using semi-automated DR with advanced or day-ahead notification (e.g., TOD).</li> <li>• Apply well-studied DR strategies.</li> </ul>	<ul style="list-style-type: none"> <li>• AutoDR with end-to-end automation and advanced telemetry to communicate price or grid reliability information in “day-of” or ancillary services markets.</li> <li>• Aid ISGF goals for a 5% peak load reduction target using DR by 2017 in the 12th Five-Year Plan for India’s Smart Grid (ISGF n.d.)</li> </ul>
Building System Behavior	<ul style="list-style-type: none"> <li>• Encourage continuous energy management.</li> <li>• Semi-automated DR strategies.</li> </ul>	<ul style="list-style-type: none"> <li>• Fully automated dynamic building response to DR signals through BMS-based controls.</li> <li>• Pre-programmed responses (e.g., Global Temperature Adjustment for HVAC).</li> </ul>
Building Controls	<ul style="list-style-type: none"> <li>• BMS in commercial buildings programmed to manage HVAC and lighting loads for DR.</li> <li>• DR signals sent manually to building managers.</li> </ul>	<ul style="list-style-type: none"> <li>• Grid-integrated BMS with advanced control and automation technologies.</li> <li>• Potential of increased and reliable BMS response to DR and OpenADR integration.</li> <li>• Facilitate benchmarking and standardized report formats such as GreenButton (Green Button n.d.).</li> </ul>
Grid-Integrated Intermittent Renewables Resources (IRR)	<ul style="list-style-type: none"> <li>• Install renewable resources to supplement grid power.</li> <li>• Use on-site renewable generation for cost-effectiveness and reliability.</li> </ul>	<ul style="list-style-type: none"> <li>• Buildings enabled to feed excess generation from renewable resources to the grid and benefit from credits (e.g., net metering).</li> <li>• Identified by ISGF as a key priority in Smart Grid Roadmap for India. With a target of 33% renewable generation by 2027 (ISGF n.d.).</li> </ul>
Distributed Energy Resources and Storage	<ul style="list-style-type: none"> <li>• Use distributed generation and storage resources for DR and daily peak load management</li> <li>• Provide pre-cooling or load-shifting in buildings.</li> </ul>	<ul style="list-style-type: none"> <li>• Intelligent coordination to use/feed excess generation to electric grid during DR events.</li> <li>• Grid integration of advanced storage technologies (e.g., batteries, thermal energy).</li> </ul>
Microgrids	<ul style="list-style-type: none"> <li>• Integration of building-level Microgrids with basic metering technologies for accountability and local or grid reliability.</li> <li>• Use on-site generation, storage to island from grid power</li> </ul>	<ul style="list-style-type: none"> <li>• Develop advanced and community-scale microgrids with grid-integrated DER.</li> <li>• Enable flexible DR and islanding capabilities in response to grid signals.</li> </ul>
Electric Vehicles (EV)	<ul style="list-style-type: none"> <li>• EV charging stations at buildings and parking lots.</li> <li>• Enable charging integration with TOD rate schedules.</li> </ul>	<ul style="list-style-type: none"> <li>• Standards based grid-interactive facility charging stations (charge or discharge).</li> <li>• Full electric grid integration of EVs for vehicle-to-grid (V2G) capabilities to meet 10% EV penetration goals by 2027 (ISGF n.d.).</li> </ul>
Transactions and Market Design	<ul style="list-style-type: none"> <li>• Facilitate buildings to access price information from open markets using web-based and standardized platforms.</li> </ul>	<ul style="list-style-type: none"> <li>• Standards-based market/price transactions integrated with BMS and optimization.</li> <li>• Market design to facilitate transactive controls and data analytics.</li> </ul>

The requirements for both DR and energy efficiency are described earlier, and additional details on the demand-side activities from the framework in Table 3.1 are presented in Appendix A.

**Table 3.2: Framework for Standards and Technology**

<b>Communication Standards and Technology</b>		
	<b>Basic Strategy</b>	<b>Advanced Strategy</b>
Standards Assessment and Development	<ul style="list-style-type: none"> <li>Evaluate and adopt existing Smart Grid standards for B2G integration.</li> <li>Consider standards currently under consideration in the U.S., and as identified by India Smart Grid Knowledge Portal (<sup>3</sup>MOP n.d.)</li> </ul>	<ul style="list-style-type: none"> <li>Identify gaps in standards, against broader B2G integration and localized DR requirements.</li> <li>Develop standards to address local DR markets and understand integration with energy efficiency (e.g., ECBC)</li> </ul>
Price and Reliability Data Models	<ul style="list-style-type: none"> <li>Identify existing DR programs and tariff design B2G integration.</li> <li>Use existing standards for price and reliability (e.g., OpenADR)</li> </ul>	<ul style="list-style-type: none"> <li>Develop robust technologies and markets for price-responsive markets.</li> <li>Develop or adopt advanced standards and strategies for price-responsive DR.</li> </ul>
Open-Source Tools	<ul style="list-style-type: none"> <li>Evaluate and adopt existing open-source tools for B2G and DSM.</li> </ul>	<ul style="list-style-type: none"> <li>Develop an open-source ecosystem to foster open innovation for B2G.</li> </ul>
Decentralized Networks	<ul style="list-style-type: none"> <li>Point-to-point communication for current DR markets.</li> <li>Introduction of cloud-based B2G technologies and services.</li> </ul>	<ul style="list-style-type: none"> <li>Scaled cloud-based solutions for decentralized markets.</li> <li>Decrease enabling technology cost and enable grid-aware building controls.</li> </ul>
Data and Cyber-Security	<ul style="list-style-type: none"> <li>Identify data and cyber security issues for communication and information technologies.</li> </ul>	<ul style="list-style-type: none"> <li>Identification and adoption of cyber-security by technology vendors.</li> <li>Install intrusion detection systems and self-healing networks.</li> </ul>

### 3.2. Business, Markets, and Policy

Business cases, market design, and policy goals are important requirements of B2G integration and technology development. With information of well-tested technical requirements for grid integration, the stakeholders should develop business cases and market transformation with well-informed policies to accelerate and scale the market adoption of B2G technologies. The working groups 6, 7, and 8 under ISGF are postulated to address the key business, market and policy requirements and issues that are discussed herein (ISGF 2012). Table 3.3 provides a framework of two stages of non-technical B2G aspects to make a compelling business case to the industry and provide value to the customers for B2G technology adoption.

**Table 3.3: Framework for Business, Markets, and Policy**

Business, Markets, and Policy		
	Stage One	Stage Two
Demand Response Market Design	<ul style="list-style-type: none"> <li>• Conduct market study for buildings with potential for higher load shed and semi-automated strategies.</li> <li>• Analysis for technology incentives for DR programs.</li> </ul>	<ul style="list-style-type: none"> <li>• Develop programs for various buildings sizes, (small, medium, and large).</li> <li>• Establish structured incentives for B2G integration technologies.</li> <li>• Understand DR value of aggregation.</li> </ul>
Building Integration	<ul style="list-style-type: none"> <li>• Participation based on cost-effective enablement and existing controls.</li> <li>• DR economics driven by incentive programs against reduced capacity.</li> </ul>	<ul style="list-style-type: none"> <li>• Integrated low-cost hardware/software, standards, encourage B2G integration.</li> <li>• Controls integration to provide multiple value streams (e.g., EE and DR).</li> </ul>
Technology Evaluation	<ul style="list-style-type: none"> <li>• Develop requirements and technology selection criteria for B2G integration.</li> <li>• Technologies for varied DR markets and customer DSM strategies.</li> </ul>	<ul style="list-style-type: none"> <li>• Identify B2G technologies and service providers that meet the criteria.</li> <li>• Conduct end-to-end demonstration pilots with different DR technologies to assess capabilities and effectiveness.</li> </ul>
Measurement and Verification (M&V)	<ul style="list-style-type: none"> <li>• Conduct M&amp;V assessment for DR programs, building class, weather.</li> <li>• Establish reporting requirements based on market design.</li> </ul>	<ul style="list-style-type: none"> <li>• Develop M&amp;V methodology and DR baselines based on class of buildings.</li> <li>• Offer technologies, and utilities adopt M&amp;V designed for local markets.</li> </ul>
Building Codes	<ul style="list-style-type: none"> <li>• Identify gaps in building codes to meet B2G integration requirements.</li> </ul>	<ul style="list-style-type: none"> <li>• Develop and expand ECBC for B2G integration.</li> <li>• Enforce policies to encourage integrated DR and EE in buildings.</li> </ul>
Privacy	<ul style="list-style-type: none"> <li>• Identify customer data ownership and privacy requirements.</li> </ul>	<ul style="list-style-type: none"> <li>• Enforce policies for customer privacy.</li> <li>• Identify mechanisms to allow secure third-party access to energy use data.</li> </ul>

## 4. Potential for Integrated B2G and DSM Initiatives in India

Section 2 identified the various public-private initiatives in India under the auspices of ISGF, ISGTF, and R-APDRP, and private utilities such as Tata Power, directed towards Smart Grid deployment in India. Some of these initiatives included delineation of a technology deployment roadmap and development of partnership with international stakeholders and indigenous utilities for Smart Grid pilot studies. These pilots formed an essential part of U.S. research and deployment initiatives. This section identifies the ongoing and planned Smart Grid pilots in India that could benefit B2G integration, followed by a discussion on the existing and relevant policies and incentives in India.

### 4.1. Smart Grid Pilot Studies

Smart Grid pilot studies are conducted as part of ISGF and ISGTF Smart Grid roadmaps. The peak-load management and advanced metering infrastructure will be implemented in ten of ISGTF's proposed sites, which are located in the states of Haryana, Himachal Pradesh, Rajasthan, Chhattisgarh, Tripura, West Bengal, Karnataka, Andhra Pradesh, Assam, and Gujarat, covering a consumer base of 0.17 miles (ISGTF, n.d.). The key utility stakeholders participating in the ISGF pilots are (ISGF 2012):

1. Maharashtra Electricity Distribution Company Ltd. (MSEDCL)
2. Power Grid Corporation of India Ltd.
3. Bangalore Electricity Distribution Company Ltd. (BESCOM)
4. Tata Power Company Ltd.
5. Tata Power Delhi Distribution Ltd.
6. Reliance Power
7. Maharashtra State Electricity Transmission Company Ltd. (MSETCL).
8. Madhya Pradesh Paschim Kshetra Vidyut Vitaran Company Ltd. (MPPKVVCL)
9. GTL Ltd.

## **4.2. Demand-Side Management (DSM) Initiatives**

The Indian MOP launched the Bureau of Energy Efficiency (BEE) under the first Energy Conservation and Commercialization (ECO) project in India in 2002. This led to the development of energy-efficiency codes, Energy Conservation Building Codes (ECBC), for voluntary adoption (U.S. DOE 2012). Other voluntary codes that promote energy efficiency in India include Indian Green Building Council (IGBC) and Green Rating for Integrated Habitat Assessment (GRIHA). The National Mission for Enhanced Energy Efficiency has a target of 19 GW avoided capacity addition and carbon dioxide (CO<sub>2</sub>) emission mitigation of 98 million tons per year by 2014–2015 (Garnaik, n.d.).

### **4.2.1. Standards and Labeling Programs**

The Energy Conservation (EC) Act, signed in 2001, provides the legal and institutional framework for the Government of India to promote energy efficiency across all sectors of the economy (Stephane de la Rue du Can 2011). The need to improve energy efficiency was further emphasized in the National Action Plan on Climate Change (NAPCC), adopted in 2008. Standards and labeling (S&L) programs have been identified as one of the key activities for energy-efficiency improvement.

Phase 3 of the ECO project (ECO-III) outlined the objectives for EE deployments in India. It also assisted BEE in a technically rigorous implementation of the ECBC and moving commercial buildings toward performance-based benchmarks through standards development in the field of benchmarked energy use and measurement and verification of energy savings, which can support B2G initiatives (Kumar et al. 2010). Further actions to promote energy efficiency in Indian commercial buildings included development of an Energy Performance Index within the Star Rating Program and National Energy Conservation Awards of the BEE (BEE 2008; BEE 2009). Moreover, ECO-III has proposed a roadmap for net-zero-energy commercial buildings (NZEB) with a goal that all new constructions by 2030 should be NZEB (Kapoor et al. 2011). The framework for B2G activities in India that are proposed in this study is informed by the barriers and policy interventions for NZEBs identified in the above report. Here we assume that B2G technologies will form an integral part of net-zero-energy operation of future commercial buildings.

#### **4.2.2. Financial Incentives**

Following the release of India's first NAPCC, BEE proposed several programs to create rebate programs and financial incentives to the adopters of energy-efficient products. The financial incentives increased customer participation and penetration of energy-efficiency products and automation technologies. The incentive programs were rolled out by state-owned utilities under the directive of BEE and its stakeholders.

### **5. Opportunities for B2G Technologies in India**

Significant regulatory, policy, and promotional efforts in the area of Smart Grid and building energy efficiency, both at central and state governments have paved the way for B2G technology penetration in India. Such opportunities will be realized and further enhanced by the immense market opportunity created by proposed pilot demonstrations listed in Section 4. While Indian stakeholders and policy makers are learning quickly from relevant international activities, there are gaps in technologies. This must be addressed in order to meet the objectives of a Smart Grid roadmap and inform country-specific policies.

The pilot technology deployment roadmap presented in Section 4 was developed based on the technological gaps identified and parallel efforts of Indian stakeholders. We noted that there is current lack of interfacing technologies such as BMS systems that are programmable and can communicate with loads and cloud-based servers for DR signals. There is a good potential for U.S. technologies to support the B2G enabling technology market in India, while necessary market transformation policies should be in place to motivate customer participation. New skills are required for characterization, technology upgrade, site-specific DR strategies development, implementation, and performance assessment, in addition to creation of new job opportunities in India. The pilots conducted will help to define these skill sets in the Indian context and in identifying the potentials and gaps in training of the Indian workforce for Smart Grid preparedness. The study suggests that the investment in the U.S. Smart Grid had a positive impact on the economy. For the \$2.96 billion invested by the Government, the generated total economic output was at least \$6.8 billion (Energy.gov 2013).

#### **5.1. Potential Market for B2G Technologies**

In 2012, Frost & Sullivan estimated the business potential of building energy management Systems (BEMS) to be approximately \$939 million by 2016, across all the building types (Frost & Sullivan 2012). The estimated market size for BEMS integration with energy management potential in the commercial sector was \$37.5 million in 2011 (Frost & Sullivan 2012). Since the B2G activity is still in nascent stages and requires integration with the BEMS and other building systems, we believe that the market size of the B2G technologies in the commercial sector is much larger. Demand response and EE intervention in the commercial sector can bring this percentage down incrementally with higher technology adoption. The goal of the pilots would be to facilitate technology penetration through skilled labor generation and proof-of-concept testing of the U.S. technology application in India. Table 5.1 lists key U.S. B2G technology and service

providers in this sector. This list was based on ongoing LBNL work in the B2G domain, members from the U.S–India Energy Cooperation Program (AMCHAM India, n.d.), and those with presence in India. However, there may be other vendors who meet these criteria.

**Table 5.1: List of Service Providers in U.S. Markets with a presence in India**

	General Electric	Honeywell	IBM	Ingersoll Rand-Trane	Carrier	Schneider Electric	Siemens Building Controls	Johnson Controls	Customized Energy Solutions	Emerson Climate Technologies
<b>Technologies</b>	Building Energy Management System	•	•		•		•	•		•
	Metering and Sensors, SCADA	•	•				•	•		•
	Smart Appliances	•					•			
	Advanced Lighting Systems and Controls	•	•				•	•		•
	HVAC Technologies (Commercial)	•	•		•	•		•		•
	Compressed Air Systems and Controls	•			•	•		•		•
	Demand Response Automation Systems	•	•	•				•	•	
	Renewable Energy Products	•	•				•	•		
	Thermal Energy Storage				•	•				•
	Energy Storage Batteries	•						•	•	
	Microgrid Management Technologies	•		•			•	•	•	
	EV Chargers	•					•	•		
<b>Services</b>	Energy Efficiency		•		•		•	•		•
	DSM Planning, DR, Ancillary Services					•		•	•	
	Building Retro-commissioning		•			•	•	•		•
	Renewable Integration Services	•	•			•	•	•	•	
	Automated Demand Response Enablement	•	•					•	•	
	EE and DR Performance Contracting		•		•	•	•		•	•
	Microgrid Design	•						•		
	Cyber Security and Privacy			•						
	B2G Interfaces	•	•	•				•		
	Compliance Reporting & Certification services - LEED, ENERGY STAR, ECBC	•	•			•	•	•		

## **5.2. Demand Response Potential Market in Commercial Buildings**

India's power demand is expected to grow five-fold by 2030 from the current estimated 160 GW. Of this 9% to 10% is attributed to the commercial buildings (Kapoor et al. 2011; Kumar et al. 2010). The energy demand in this sector is growing annually 12% to 14% due to both rising energy intensity and floor space (Kapoor et al. 2011), currently at 1.022 billion square meters (Kumar et al. 2010). At this growth rate, the projected commercial footprint by 2030 will be 344 GW, which is 40% growth over the current electricity use. The ECO-III project estimated that 66% of the commercial stock that will exist in 2030 is yet to be built (Kapoor et al. 2011). Most commercial buildings have centralized controls and facility management services, which will make B2G technology integration easier and faster. While there is a need to reduce energy use and demand management, there is an equally strong potential for grid-integration technologies such as reasonably priced advanced building controls for EE and DR in future construction. Tata Power, on the other hand, has already demonstrated a 20% energy savings across all of its commercial customers and 50% energy savings in IT Park, from its DR projects (Tata Power 2012). Therefore, both by urgency of needs and techno-economic viability, we select the existing and growing commercial sector, primarily small and large office buildings and shopping malls, as our primary target for B2G pilots. Once technology feasibility is demonstrated through pilots, the framework could extend to domestic buildings, with proper policy intervention.

## **6. Conclusions, Recommendations, and Next Steps**

The Joint U.S.–India B2G collaboration initiative can act as a platform for LBNL and other relevant U.S. stakeholders to share expertise in Smart Grid technologies and apply the lessons learned from the U.S. deployments to the Indian context (e.g., DR and DER) in an integrated fashion to address both B2G integration and energy efficiency.

The technological and policy overlap between DR and EE enabling infrastructure, as indicated in this study, will allow joint U.S.–India pilot studies to inform technical, market, and policy decisions for rigorous implementation of ECBC across the country and the expansion of this standard to include grid integration. With a reported electricity deficit of 10.6% in 2013 and peak power shortage of 11% to 17%, the potential for DR is immense. The market potential for B2G technologies to provide DR and grid integration is growing steadily. Smart Grid modernization and deployment activities can be key drivers to identify the feasibility of the commercializing U.S. technologies and services for Indian applications.

The following sections describe specific conclusions and next steps.

### **6.1. Conclusions**

India's Smart Grid pilots include Peak Load Management, which is a key component of demand-response deployments in the United States. Lawrence Berkeley National Laboratory and other key U.S. stakeholders (public or private) will coordinate closely with the Indian Government and local utilities and/or systems operators to share knowledge of U.S. B2G deployments and

identify how that experience can address Indian needs. The U.S. technology vendors outlined in this study have significant experience in the B2G integration, and they can provide support to address standards and technology, business, market design, and policy directions.

The evaluation of pilots under this B2G collaboration initiative could serve as a test bed for studying, analyzing, and recommending global technologies and assessing their feasibility in the Indian context. The ISGTF Communications Workgroup and the ISGF public-private collaboration will benefit from the U.S. technical experience in the development of interoperability standards. These standards include bi-directional communications, metering hardware, end-use DR strategies, M&V methodologies, and experience of the U.S. deployments to advance demand-side integration with the Smart Grid in India. Through bilateral collaborations, these activities could assist in identifying technological gaps that may necessitate solution updates/adaptations or even new solutions.

## **6.2. Next Steps**

To advance B2G objectives, collaborative research with key Indian partner(s) will be necessary to address the standards and technology, markets, and policy requirements. In particular, pilot(s) can address local and regional needs and their effectiveness for scaled deployments. The pilots must be aligned with the integrated DR and EE framework proposed in this study.

### **6.2.1. Collaborations with the U.S.–India Energy Stakeholders**

Working with a key Indian utility such as Tata Power that is conducting AutoDR pilots is necessary for evaluation of key findings for scaled deployments. Assistance to public-private partners such as Nexant (through the USAID program) and its relevant initiatives on national Smart Grid deployments is key in formulating functional requirements for communication channels, comparative study of communication technologies, proof-of-concept testing of model of Smart Grid management, setting up test beds in India, and sharing best practices in interoperability.

### **6.2.2. B2G Integration with Smart Grid Pilots**

While delineating the sites for commercial pilot studies in India, LBNL and other partners can leverage the site-preparedness of the pilot sites in fourteen Indian states under the purview of ISGTF's initiative, ten of which include B2G technologies like advanced metering infrastructure and peak load management. The commercial building sector with centralized and controls automation would be good candidates for AutoDR. Site-preparedness will include obtaining legal approval from the respective state electricity boards, getting government regulations in place, and using existing budgetary plans for technological evaluation and upgrades. The pilot studies undertaken by the key Indian stakeholders and the U.S. partners could mutually benefit from sharing best practices, tools, technologies, lessons learned, feasibility assessments, and impact analyses. The utility members of ISGF will likely facilitate the earliest DR implementations in India.



### **6.2.3. Expanded Objectives to Smart Grid Pilots**

While the interface with the existing B2G-relevant initiatives in the Indian Smart Grid pilots is a good start, the U.S. support could be minimal (evaluation and best practices) or significant, depending on the level of engagement and interest in both countries. This support could include the following:

- Identification of key sector participants for the DR (commercial sector) in India.
- Training of energy services companies or third-party implementers affiliated to public-private utilities in India to identify critical versus non-critical loads for DR and integrated DR and EE audits.
- Assistance in delineating DR strategies for individual sites and guidance of relevant bodies in pre-programming DR strategies in buildings controls software based on site survey, load characterization, and identification of automation of DR strategies.
- Assistance with server and client installations for AutoDR; development of communications protocols and operational support.
- Assistance with developing a framework for the installation of performance monitoring instruments and data acquisition for DR performance evaluation as part of measurement and verification (M&V) standards.
- Assistance with assessing a readiness timeline for DR implementation
- Providing support for the evaluation of operational performance of DR infrastructure as part of M&V standards
- Assistance with evaluating DR performance using AutoDR experience and providing findings and best practices for India, including support for a cost-benefit analysis framework for informing policy decisions regarding scaled deployments.
- Assistance with enhancing building codes to incorporate DR-related recommendations.

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## Appendix A

This appendix elaborates on the demand-side activities from the framework in Table 3.1 and identifies relevant pilot opportunities and aligned supporting activities in India based on our background research.

### **Building System Behavior and Building Controls**

Building control systems and end-use participation is a key requirement for buildings-to-grid (B2G) integration. A (BMS), for example, is installed in buildings for energy management and/or monitoring of the mechanical and electrical equipment such as HVAC, lighting, power systems, fire systems, and security systems. These control systems use widely accepted protocols such as, BACnet, LonWorks, Modbus, and others to communicate with the sensory and actuation network within the building. While such systems are imperative to B2G integration and automation, our background research shows that there has been very limited market penetration of these systems in India, in spite of existing vendors offering a huge market opportunity, as described in Section 5. Furthermore, similar to our framework, ISGTF is identifying the BMS capabilities necessary for various stages of Smart Grid deployment.

### **Grid Integration of Intermittent Renewable Resources (IRR)**

Complying with National Solar Mission, India will see a sharp rise in renewable generation sources, resulting in integration challenges for the grid operators, posed by the variable generation profiles. The Smart Grid roadmap for India had set reasonable targets for grid-integrated renewables: 30 gigawatts (GW) by 2017, 70 GW by 2022, and 120 GW by 2027 (ISGF n.d.). The amount of energy generated by solar photovoltaic (PV) and wind turbines varies significantly with weather conditions, creating complexities to match the supply with demand. Using DR, analytics, and communication technologies, building demand can be optimized to change in real time with the supply changes from renewable resources. During peak demand, buildings can reduce loads and use any excess local generation. Buildings can increase the load by pre-cooling (e.g., nights when the wind is blowing) to improve the overall stability and reliability of the grid.

### **Distributed Energy Resources and Storage**

The term *distributed energy resources* (DER) is used for local generation systems such as reciprocating engines, combustion turbines, microturbines, fuel cells, solar PV, wind turbines, other types of small modular energy generation, and thermal energy storage and other storage systems. Thermal storage is an effective load-shifting and energy-storage technology for India, as a majority of the commercial buildings load is air conditioning (40% in Mumbai, according to Tata Power). These technologies can be installed in buildings to improve energy efficiency and grid reliability, to reduce energy costs, and to provide other benefits. In most cases, DER are used for local energy management; however, by integrating them with the electric grid, the effectiveness and utilization of these technologies can be enhanced. The B2G infrastructure established as part of proposed pilots in the “basic” phase can be scaled up for managing grid reliability in face of grid integration of DER, through faster throughput and higher levels of automation.

## **Microgrids**

Microgrids have been gaining a lot of traction in India, to develop a local infrastructure to reduce dependency on an unreliable electricity supply. With increasing penetration of renewables and DER, buildings can be designed to disconnect themselves from the electric grid and operate in “island mode.” The ISGF Roadmap includes development of 500 medium (500 kW to 2 MW) microgrids and 100 large microgrids (> 5MW) with a distribution management system in both island and connected mode, within the scope of the National Smart Grid Mission (NSGM) during twelfth plan period (ISGF). The enabling technologies within microgrid environments will facilitate the disconnection and reconnection of the building from the grid based on external grid conditions such as high prices or peak demand. This technology has potential for building integration in later stages of B2G enablement.

## **Electric Vehicles**

India has aggressive plans to promote the adoption of electric vehicles (EVs). The National Electric Mobility Mission Plan (NEMMP) aims to put as many as 7 million EVs on the road by 2020 (Department of Heavy Industry 2012). The NEMMP emphasizes the need to address challenges resulting from extra generation to support the EV charging. Although the initial phase of EV chargers could be standalone, based on the time-of-day rate schedules, they may have to be integrated and interact with the grid.

## **Transactions and Market Design**

At present, wholesale price at the bulk generation and transmission level are not represented at the demand-side resources. The concept of market-based transactions or “transactive energy” is being considered in the U.S. to improve grid reliability and flexibility of demand-side resources based on value streams (customer and/or the grid) (Resnick Institute 2012). The GridWise Architecture Council (GWAC) describes *transactive energy* as the technique for managing the generation, consumption, or flow of electric power within an electric power system through the use of economic or market-based constructs while considering grid reliability constraints. The future application of transactions requires a paradigm shift, supported by a good market design and policy. Technologies that support advanced B2G requirements can facilitate price-based market transactions, and they need alignment with the overall grid integration roadmap.

## **Communication Standards and Enabling Technologies**

Communication standards and technologies are key to integrate EE and DR. These include technologies for monitoring, communications, and control system integration. While the costs of retrofits to existing buildings for DR may be higher, standards can natively support technologies for EE and DR, and can be installed at lower cost in new buildings.

Two-way communications with strong emphasis on cyber-security is a key component of B2G technologies. These cyber-security requirements must entail availability, integrity, and data confidentiality, as described by the ISGF (ISGF 2013). A combination of standards for DR and telecommunication technologies will enable grid operators to improve grid stability, facilitate the integration of renewable energy sources, and give consumers the data to monitor and manage

their energy consumption. Utilities can also use these data to better understand critical aspects of the grid, such as load factors, usage patterns, equipment condition, and voltage levels to identify and alert grid operators and building managers of potential failures or outages. The ISGTF Communications Workgroup and the ISGF public-private collaboration will benefit from the U.S. technical experience and technologies for the development of interoperability standards for bi-directional communications, metering hardware, end-use DR strategies, M&V methodologies, and experience of the U.S. deployments, and will be able to use them to advance demand-side integration with the Smart Grid in India (ISGF). Table 3.2 describes communication standards and technologies for the basic and advanced strategies used to achieve B2G integration.