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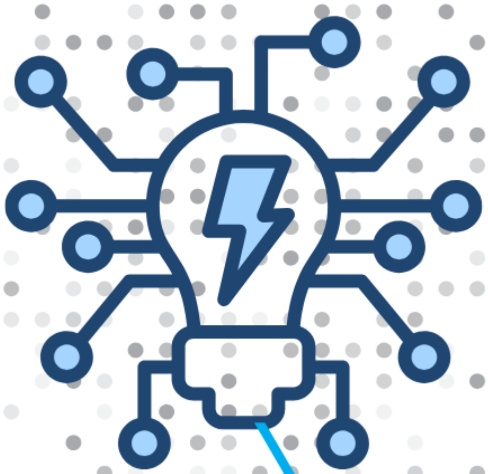
EU-INDIA CLEAN ENERGY & CLIMATE PARTNERSHIP

National Smart Grid Mission
Ministry of Power
Government of India

FSR GLOBAL
Regulatory Knowledge Hub

DEVELOPING INDIA'S INTEROPERABLE SMART GRID



Smart Grid Observatory India

POLICY BRIEF, 2025

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FSR Global

FSR Global is an independent regulatory hub of excellence focused on energy transitions in the Global South. Using a system thinking approach we aim at improving the quality of energy regulation by collaborating and co-creating knowledge with multi-stakeholders from the energy sector and beyond. FSR Global was established in India in 2019 by the European University Institute – Florence School of Regulation to help strengthen the global south-south and north south transcontinental knowledge exchange.

Complete information on our activities can be found online at: www.fsrglobal.org

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Policy Brief: Developing India's Interoperable Smart Grid

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MESSAGE FROM KNOWLEDGE PARTNER

Swetha Ravi Kumar
Executive Director, FSR Global

The World Utility Summit 2025 comes at a defining moment for the global energy sector. As we navigate the complexities of the energy transition, digital innovation is proving to be the bedrock of a cleaner, more resilient, and efficient power system. This year's discussions will explore how emerging technologies are reshaping the utility landscape, accelerating decarbonization, and ensuring energy security for all.

A key part of this transformation is the smart grid—a dynamic electricity network that integrates digital technologies to optimize energy distribution, enhance grid resilience, and unlock efficiencies through real-time data and automation. By embracing these innovations, we move closer to a future-ready energy ecosystem.

In this spirit, FSR Global will be introducing the Smart Grid Observatory-India (SGO), under the EU-India Clean Energy and Climate Partnership (EU-India CECP) and in collaboration with the National Smart Grid Mission, Ministry of Power, Government of India. The SGO will serve as a hub for innovation, fostering collaboration among policymakers, utilities, researchers, and industry leaders, and accelerating the adoption of smart grid solutions tailored to India's energy landscape.

Also, I am honoured to moderate the session 'Bytes & Breakers: Navigating the Digital Revolution in Utilities', which will delve into the profound impact of digital technologies on the utility industry. I look forward to an engaging dialogue with leading experts as we explore how digital transformation is shaping the future of energy.

I invite all stakeholders to engage with the Smart Grid Observatory-India, contribute their expertise, and be part of the movement toward a smarter, cleaner, and more sustainable power sector. The challenges ahead are complex, but with collaboration and innovation, we can build an energy system that is truly future-ready.

Looking forward to insightful discussions and meaningful collaborations at the World Utility Summit 2025.

Developing India's Interoperable Smart Grid

Introducing the 'Smart Grid Observatory (SGO)' – An ecosystem approach to innovation

Digitalization is revolutionizing the energy and power sector by leveraging digital technologies- – both Operational Technologies and Information Technologies - to optimize and improve the performance of energy systems. As a variety of new and emerging technologies are being deployed globally, it's prudent to assess and map the ongoing developments and the advantages these technologies provide. To facilitate this process, a new initiative called the **'Smart Grid Observatory (SGO)'** has been established in India under the EU-India Clean Energy Climate Partnership (CECP), in collaboration with the EU Delegation to India and the Ministry of Power - National Smart Grid Mission (NSGM), with FSR Global acting as the Chair and Secretariat.

The SGO will function as an open digital platform that unites all stakeholders within the smart grid ecosystem, aiming to transform the power grid through the development of digital stacks, showcasing cutting-edge technologies, facilitating knowledge transfer, and creating demonstrative sandboxes (SGO, 2024).

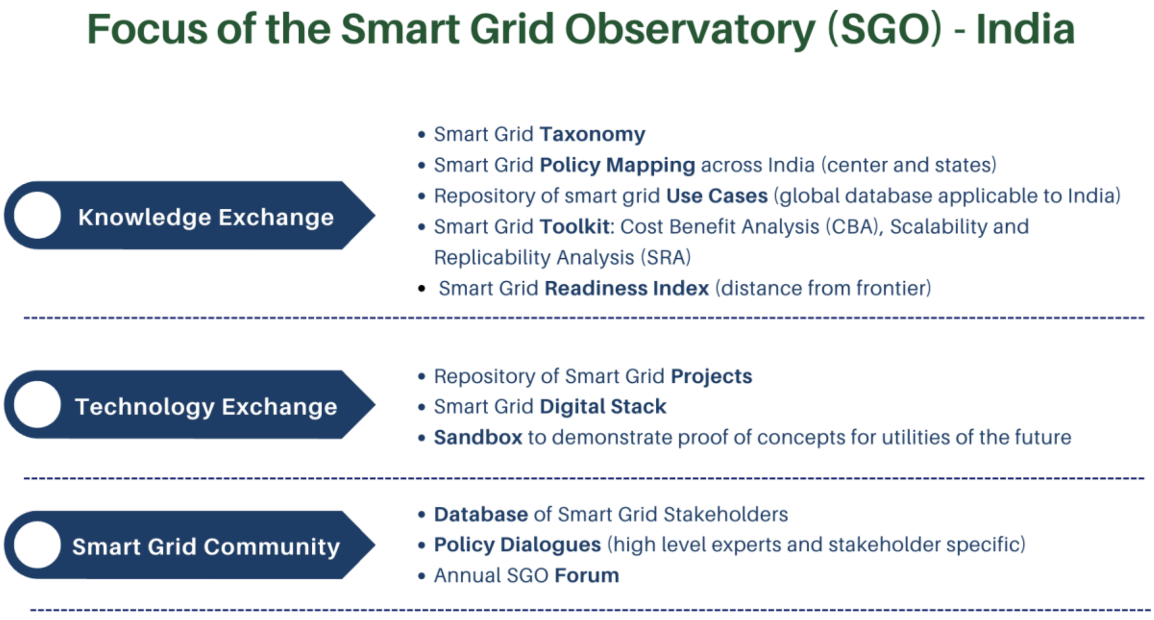


Figure 1: Focus of the Smart Grid Observatory (SGO) – India. Source, Author's own

SGO Stakeholders

Smart Grids for The Future

Smart grids play a pivotal role in India's ongoing digital and green transformation within the power sector. These advanced grids combine innovative digital technologies with traditional power infrastructure, facilitating efficient monitoring, management, and optimization of electricity distribution and consumption. At their essence, smart grids utilize state-of-the-art sensors, meters, and communication networks to collect real-time data on electricity usage, generation, and grid conditions (Choudhury, 2024). This wealth of data empowers both utilities and consumers to make informed decisions about energy consumption patterns, resulting in more effective resource allocation and reduced waste. The International Energy Agency (IEA) describes a smart grid as "an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users" (IEA, 2023).

Smart grids establish a two-way flow of electricity and data, which can be effectively visualized through the three-dimensional smart grid architectural model (SGAM) framework (illustrated in Figure 2). SGAM serves as "a reference model to analyze and visualize smart grid use cases in a technology-neutral manner" (CEN-CENELEC-ETSI, 2012). This framework highlights the importance of interoperability, which is seen as a crucial enabler for smart grids. The GridWise Alliance defines interoperability as the "capability of two or more networks, systems, devices, applications, or components to exchange information between them and to utilize the information exchanged" (GWAC, 2008). While the concept of interoperability is not new, the rapid growth of digital markets and services has intensified the need for appropriate regulations to govern interoperability effectively.

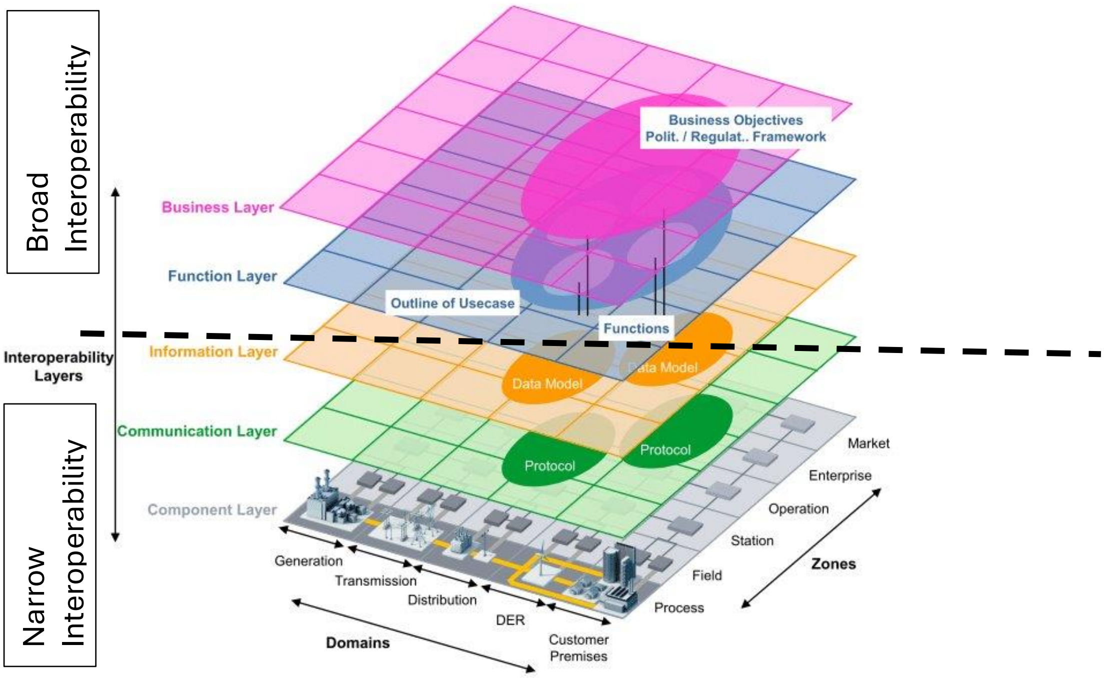


Figure 2: Focus of research within Smart Grid Architecture Model (SGAM). Source: Author adapted

Interoperability can be classified into two categories (Ravi Kumar, 2024),

- Narrow Interoperability: focuses on the level of devices and is used to describe technical systems. It typically covers interoperability among information and communication technology (ICT) systems.
- Broad Interoperability: focuses on the level of organisations. It considers that political, legal, regulatory, organisational, and social factors influence technical systems and their performance.

Moreover, interoperability among ICT systems is viewed as an enabler for the interoperability of organisations, meaning it enhances the ability of organisations to collaborate more efficiently and effectively.

The Figure 2 is structured to show how different components and systems need to work together (interoperate) for a digitalized power sector to function efficiently. It distinguishes between broad interoperability (across different functions and stakeholders) and narrow interoperability (within specific technical domains). In essence, the image represents a framework for understanding how digitalization impacts the power sector, emphasizing the need for seamless communication, data exchange, and coordination among various stakeholders and systems. The various layers that enable narrow and broad interoperability are explained below:

Business (Roles & Responsibilities): Details the responsibilities of each stakeholder category. For example, TRANSCOs and SLDCs are responsible for cyber security policy, data management, and grid operation. System operators and DISCOMs handle real-time information systems and automated operations. Regulators focus on policies like energy efficiency and demand response.

Function (Monitoring/Flexibility): Describes the functions performed within the power system, such as monitoring asset conditions, controlling grid operations, managing blackouts, and ensuring grid stability. It also highlights the importance of demand and generation flexibility, as well as load forecasting.

Information: Specifies the data types and models used for communication and information exchange (CIM, IEC, COSEM).

Communication: Outlines the communication networks used at different levels, including Field Area Networks (FAN) for real-time monitoring and Wide Area Networks (WAN) for real-time markets and operations.

Component (System of Systems): Lists the physical components and systems involved, from generation management systems and DER storage to EMS, SCADA, substation automation, and distribution automation systems. It also includes components at the consumer premise, like smart devices and demand response management systems.

Key Takeaways to Enable India's Interoperable Digital Grids

By harnessing the power of data and technology, the smart grids pave the way for a more interconnected, efficient, and sustainable energy future. To achieve a high state of digitalization with different elements of the electricity value chain interacting with each other in a meaningful and data driven manner, multiple processes and stakeholders must work in tandem in a cross-sectorial and a holistic manner.

A series of expert group discussions were conducted in 2024, which included key experts from Europe and India from across stakeholders. Some of the key observations that were derived from these discussions are mapped to the SGAM interoperability framework.

Need for Updated Standards: Standards must evolve alongside technological advancements to remain relevant and effective. As new technologies emerge, it is essential that standards reflect these changes to ensure they support the latest innovations and practices. This alignment not only facilitates the adoption of new technologies but also enhances the overall efficiency and functionality of systems relying on these standards.

Establishing minimum data and format requirements is crucial for achieving interoperability among various systems and platforms. When standards are consistently applied, they create a common framework that allows different technologies to communicate and work together seamlessly. This interoperability is vital in today's interconnected world, where disparate systems must collaborate to deliver optimal performance and user experience.

Inclusive Standard Setting Process: An inclusive standard-setting process is essential, as it must consider the needs of all stakeholders, both public and private. Engaging a diverse array of voices ensures that the standards developed are comprehensive and address the various challenges faced by different sectors. By fostering collaboration among stakeholders, the standards can better reflect the realities of the market and the needs of the users.

Regular updates based on stakeholder feedback are crucial to maintaining the relevance of standards. The landscape of technology and user requirements is constantly shifting, and standards must adapt to these changes. By incorporating feedback, standard-setting bodies can ensure that their guidelines remain effective and meet the evolving demands of the industry.

India's participation in international standardization is vital for compatibility and influence. As a rapidly developing nation with a growing technological landscape, India must engage in global standard-setting initiatives. This involvement not only helps ensure that Indian technologies are compatible with international standards but also allows India to have a voice in shaping those standards, enhancing its influence on the global stage.

Balancing Standards and Innovation: While standards are necessary for consistency, they should not hinder technological advancements. Striking the right balance between maintaining robust standards and promoting innovation is key. Overly rigid standards can stifle creativity and slow down the adoption of new technologies, which can be detrimental in a fast-paced technological environment.

Flexibility in standards is essential for fostering future innovations. By allowing for adaptability within established frameworks, organizations can explore new ideas and approaches without being constrained by outdated regulations. This flexibility ultimately encourages technological growth and supports the development of groundbreaking solutions.

Financial Support for Technological Advancement: Targeted financial support is necessary for utilities to invest in new technologies. Without adequate funding, organizations may struggle to adopt the latest innovations, hindering their operational efficiency and competitiveness. Financial assistance can help utilities integrate new technologies that improve service delivery and enhance overall performance.

Additionally, financial incentives should encourage innovation and infrastructure upgrades. By providing support for the adoption of cutting-edge technologies, governments and organizations can stimulate growth within the sector. These incentives can lead to more robust infrastructure and a more dynamic technological landscape.

Addressing Vendor Diversity: The presence of multiple vendors can create compatibility issues that complicate system integration. When different vendors use varying standards, it can result in inefficiencies and increased costs for organizations trying to implement those technologies. Addressing these compatibility concerns is crucial for ensuring seamless operations across platforms.

Establishing clear hardware standards from the start is critical for interoperability. By setting definitive guidelines early in the development process, organizations can reduce the risk of compatibility issues later on. This proactive approach helps facilitate smoother integration and fosters a more cohesive technological ecosystem.

Inconsistency of Data Formats: The variability in data formats among operators, OEMs, and vendors poses a significant challenge in the smart grid landscape. This inconsistency hinders efficient data collection and analysis, making it difficult to derive actionable insights. To address this issue, it is essential to establish harmonized templates along with broad country-level guidelines on data resolution. By implementing these solutions, we can enhance the accuracy of analytics and support the scaling of smart grid technologies through improved data comparability.

Enhancing Communication Between Devices and Control Centers: There is a pressing need to improve communication efficiency between devices and control centers. The European Union has set a precedent by implementing regulations that facilitate seamless communication across the power sector. The overarching goal of these initiatives is to optimize the operational efficiency of smart grids, leading to better management of energy resources.

Approaches to Effective Communication Networks: A mixed strategy that combines both open-source and proprietary solutions is recommended for creating effective communication networks. The success of Spain, with its single platform for nationwide utility information, serves as a model. In India's context, it is vital to emphasize top-down and open-source methods to reduce dependency on specific vendors. Ensuring flexibility and scalability within the communication system is essential, along with the establishment of regulations that foster a sustainable and efficient smart grid ecosystem.

Cross-Sectoral Coordination: Cross-sectoral coordination is crucial for the successful implementation of smart grid technologies. An example could be collaborative efforts between the power and telecommunications sectors. Such coordination will result in improved integration and robustness of infrastructure, enabling it to meet the demands of modern energy systems effectively.

Standardize Data Need and Collection: The information layer is crucial for advancing effective smart grid implementation through robust data collection standardization measures. It is essential to define the methods of data collection, the types of data required, and the formats for data presentation. This standardization serves as a foundation for consistent and accurate analytics across the power sector. Additionally, ongoing capacity-building efforts are necessary to equip all stakeholders with the skills and knowledge needed to manage and utilize data effectively.

Data Privacy and Trust: Prioritizing data privacy and trust is vital from the beginning as part of policy and regulation. Building trust among stakeholders—including consumers, distribution companies (DISCOMs), and vendors—is essential for successful collaboration. Balancing the demands of consumers with the operational needs of DISCOMs and vendors presents a complex challenge. Hence, developing a clear and transparent regulatory framework that addresses the diverse interests of these groups is critical for progress.

Integration of New Technologies: Integrating new technologies with existing legacy systems, such as the Common Information Model (CIM), poses a significant challenge worldwide. While standardizing protocols among stakeholders is necessary, exploring the option of building new systems rather than retrofitting legacy ones may be beneficial, particularly in countries like India. However, this approach may encounter obstacles, such as the monopolistic influence of existing vendors, which can hinder innovation and flexibility in the energy sector.

Cybersecurity Measures: Robust cybersecurity measures are essential to protect grid infrastructure from potential threats and to ensure the safety and integrity of data. Additionally, open API formats are necessary to facilitate interoperability and seamless communication between different systems and platforms.

Active Market Involvement: Active market involvement is crucial for the widespread adoption and scaling of smart grid technologies. It is important to provide clear and favourable signals from the outset to encourage investment and participation from both private and public sectors. By fostering an environment conducive to innovation and competition, countries can accelerate the development and deployment of smart grid solutions.

Real time Insights: The foundation for effective data collection, management, storage, and analysis is crucial for developing digital models that can unlock the future potential of digital twins and comprehensive digital energy systems. These advanced models offer real-time simulations and insights, significantly enhancing decision-making and optimizing energy management. As the industry progresses toward these sophisticated technologies, it is vital to establish foundational steps that facilitate future advancements.

Creating Basic Data Lakes: While awaiting the ideal solutions, it is practical to start developing basic data lakes. These data lakes act as centralized repositories, providing a single source of truth for data analytics. By consolidating data from various sources, they enable stakeholders to conduct accurate and consistent analyses, which are essential for informed decision-making in energy management and policy development.

Standardization of Data Management: Implementing protocols for standardized data collection and storage is essential for ensuring data consistency and interoperability. Standardized methods will promote seamless integration and information sharing across different systems and stakeholders. This standardization will also support the scaling of digital energy solutions and foster innovation within the sector.

Infrastructure Upgrades and Workforce Development: Significant infrastructure upgrades are necessary to support this transition, including technological advancements and human resource development. IT infrastructure must be enhanced to manage the increasing volume and complexity of data while implementing robust cybersecurity measures to protect sensitive information. Concurrently, workforce capacity building through training and education is vital for equipping personnel with the skills required to effectively manage and leverage digital technologies.

Building Trust Among Stakeholders: Trust building among stakeholders is a fundamental aspect of this transformation. Establishing trust involves transparency, clear communication, and the implementation of reliable measures to safeguard data privacy. By creating an environment of collaboration and mutual understanding, stakeholders can work collectively to address challenges and drive the successful adoption of digital energy systems.

In the realm of digital transformation, the data value chain plays a pivotal role in unlocking the full potential of data within the energy sector. This value chain includes critical components such as data collection, management, and exchange, all of which are essential for optimizing decision-making and enhancing operational efficiency. By establishing a robust framework for the data value chain, organizations can ensure that their data is accurate, accessible, and actionable, ultimately enabling them to leverage insights for improved outcomes.

Data Governance: Establishing Trust and Integrity: At the heart of the data value chain framework lies the concept of data governance. This involves creating rules that address key elements like data trust and sovereignty. Effective data governance is crucial for responsible data handling, ensuring that there are clear policies in place to protect privacy and maintain data integrity. By implementing these governance rules, organizations can foster confidence among stakeholders, making certain that data is used ethically and in compliance with applicable regulations.

Defining Roles and Responsibilities: Clearly defining the roles and responsibilities of stakeholders within the data ecosystem is essential for promoting accountability and coordination. Each participant, from data providers to end-users, has a specific function that contributes to the data value chain's overall efficiency and effectiveness. By delineating these responsibilities, organizations can encourage collaboration and ensure that all parties are aligned in working toward common objectives.

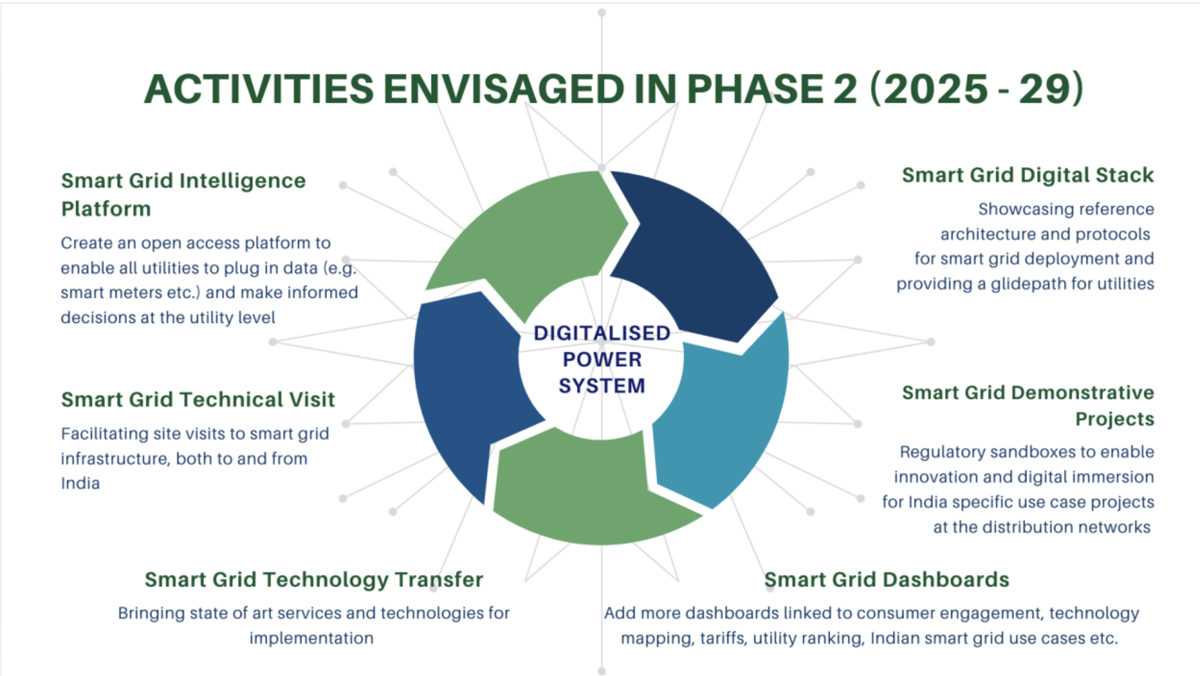
Fostering Open Communication: Open channels of dialogue between stakeholders are vital for addressing challenges and capitalizing on opportunities within the data ecosystem. Regular communication and information sharing enable stakeholders to align their efforts, identify best practices, and collaboratively tackle problems. This openness is essential for building trust and nurturing a culture of innovation and continuous improvement.

Collaborative Approaches - Forming Task Forces: To enhance coordination and integration across various sectors, cross-institutional task forces can be established, adopting a "whole of government" and “whole of society” approach. These task forces bring together representatives from both governmental and non-governmental organizations to collaboratively address complex issues that span multiple domains. By leveraging diverse expertise and resources, these task forces can develop comprehensive solutions to tackle the multifaceted challenges associated with data management and governance.

Taking Theory to Practice – Focus of SGO from 2025 - 2029

Adopting a systems approach is essential for creating a comprehensive digital framework for India's Smart Grid ecosystem. This involves incorporating the principle of digital public infrastructure to establish the **India Energy Stack (IES).** The IES is envisioned as a nationally shared digital public asset that offers a standardized, modular, and secure framework for managing, monitoring, and innovating within the energy sector. It integrates advanced data exchange protocols, real-time analytics, and open APIs, empowering utilities, renewable energy producers, consumers, and innovators alike. By facilitating seamless interoperability and ensuring strong privacy and security, apart from providing a modular architecture the IES is set to propel India's transition towards a sustainable, resilient, and intelligent energy future.

In the next phase, the 'Smart Grid Observatory (SGO)' will focus on designing and developing the India Energy Stack, beginning with a use case aimed at creating a utilities intelligence platform. Additionally, the SGO will develop dashboards that concentrate on consumer insights, technology mapping, and smart grid indexing. Alongside these knowledge and information dashboards, a significant aspect will be capacity building to help all stakeholders grasp the latest developments and their relevance to India. Finally, as a community-driven ecosystem, the SGO will enable ideas to evolve into demonstrative projects based on the use cases identified within the SGO framework.



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https://smartgridobservatory.org/Partners

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