Centre for Sustainable Development

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GOKHALE INSTITUTE OF POLITICS AND ECONOMICS

Site Selection Framework for Installing Smart Microgrids

Discussion Paper

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Contents

GLOSSARY:

Term	Definition
SMG (Smart Microgrid)	A localized electricity network that can operate connected to the main grid or autonomously (island mode), integrating DERs, advanced metering, and energy management systems.
DERs (Distributed Energy Resources)	Small-scale power generation units (e.g., solar panels, wind turbines) located near the point of consumption.
AMI (Advanced Metering Infrastructure)	A system of smart meters and communication networks enabling real-time energy data collection and two-way utility-customer interaction.
DMS (Demand Management Services)	Systems that incentivize consumers to reduce energy use during peak periods to balance supply and demand.
Energy Storage	Technologies (e.g., batteries) that store excess energy for later use, addressing renewable energy intermittency.
SCADA (Supervisory Control and Data Acquisition)	A centralized system for monitoring and controlling microgrid components in real time.
EMS (Energy Management System)	Software that optimizes energy generation, storage, and consumption within a microgrid.
Decarbonization	Reducing carbon emissions by transitioning to renewable energy and energy-efficient technologies.
Prosumers	Consumers who also produce energy (e.g., via rooftop solar) and may sell excess back to the grid.
NSGM (National Smart Grid Mission)	A government initiative to modernize India’s power grid through smart technologies.

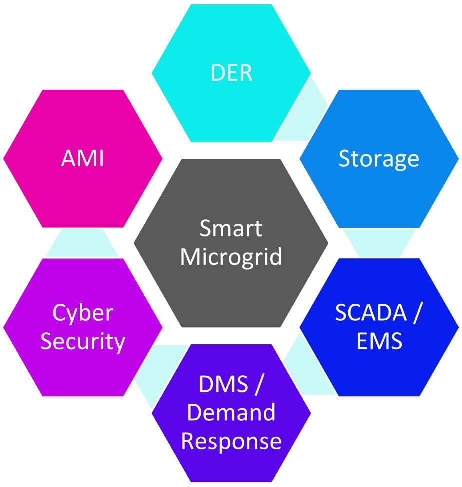
Interoperability	The ability of diverse systems (e.g., hardware, software) to work together seamlessly.
Demand Profile	Analysis of energy consumption patterns (e.g., daily load, seasonal variations).
Critical Loads	Essential services requiring uninterrupted power (e.g., hospitals).
Steady Base Load	Predictable energy demand (e.g., refrigeration).
Variable Load	Fluctuating demand (e.g., air conditioning).
Energy Efficiency	Measures to reduce energy waste (e.g., audits, efficiency projects).
Net Metering	A billing mechanism where consumers are credited for excess renewable energy fed back to the grid.
ToD (Time-of-Day) Tariff	Electricity pricing that varies by time to reflect demand fluctuations.
Social Impact	Benefits like job creation, energy access, and community resilience.
Renewable Capacity	Existing installations of solar, wind, or other renewable energy systems.
Usage Dashboards	Visual tools displaying energy data for monitoring and optimization.
KPI (Key Performance Indicator)	Metrics used to evaluate energy efficiency or system performance (e.g., peak demand, carbon emissions).

Land Availability	Suitable space for microgrid components (generation, storage, equipment).
Stakeholder Cooperation	Collaboration among teams, communities, and utilities.
Management Commitment	Leadership support for project alignment and funding.

1. Introduction to Smart Microgrid and its typical constituents

The traditional, centralized power grid is under increasing pressure. Demand for electricity is steadily climbing, driven by factors like population growth and technological advancements. The National Electricity Plan projects rise in peak power demand with an 8.7% increase from 273 GW in 2025 to 297 GW in 2026, and 34% rise to 366 GW by 2030. At the same time, the need to transition towards cleaner energy sources to combat climate change has become more urgent than ever. While renewable energy sources like solar and wind power offer a promising solution, their intermittent nature presents challenges for maintaining grid stability. Furthermore, aging infrastructure and the increasing frequency and intensity of extreme weather events can disrupt power delivery, causing economic losses and inconveniences for homes and businesses alike.

Smart microgrids offer a compelling solution to these challenges. These localized electricity networks are either connected to the main grid and work in online mode or they can be self-contained mini-grids disconnected from the traditional grid and operating autonomously. This island mode functionality ensures uninterrupted power during outages on the main grid, enhancing the reliability and resilience of local power supplies. This self-sufficiency is achieved through a combination of cutting-edge technologies.



Distributed energy resources (DERs) form the backbone of any smart microgrid setup. These are small-scale, on-site generation, storage units located near the point of consumption, such as solar panels on rooftops or wind turbines at suitable sites. By generating electricity closer to where it's used, DERs reduce reliance on long-distance transmission lines, minimizing energy losses and improving overall grid efficiency and reliability.

Advanced metering infrastructure (AMI) plays a crucial role in smart microgrids by collecting and metering detailed energy usage data from customers. This data empowers both utilities and consumers to make informed decisions. Utilities can use this information to optimize grid operations, identify peak demand periods, and tailor incentive programs for customers. Consumers, on the other hand, gain valuable insights into their own energy consumption patterns, allowing them to identify areas for potential savings and participate in demand response programs.

A demand management services (DMS) is another key technology within a smart microgrid. This system helps utilities manage electricity demand by incentivizing customers to reduce their usage during peak periods. These incentives can take various forms, such as discounts on electricity bills or credits towards future purchases. By encouraging a shift in consumption patterns, DMS helps to balance supply and demand within the microgrid, reducing strain on the system and potentially lowering overall energy costs.

Energy storage technologies play a vital role in addressing the intermittency of renewable energy sources. These technologies, such as batteries or flywheel energy storage systems, can store excess energy generated during periods of high solar or wind production. This stored energy can then be released back into the grid when demand is high or renewable generation is low, ensuring a consistent flow of electricity within the microgrid.

All Smart Microgrids operate on a Digital backbone hence they are vulnerable to cyber-attacks by malicious actors. Robust cyber security measures are paramount for protecting smart microgrids from such cyber-attacks. Implementing robust cyber security measures is essential to safeguard the microgrid from disruptions and ensure its reliable operation.

Supervisory control and data acquisition (SCADA) systems work in tandem with energy management systems (EMS) to optimize grid operation in real-time. SCADA systems continuously monitor the microgrid, collecting data on factors such as power generation, demand, and equipment status. This data is then fed into the EMS, which uses advanced algorithms to analyze and optimize the microgrid's operation. The EMS can automatically adjust generation, storage, and demand response programs to ensure a stable and efficient flow of electricity within the microgrid.

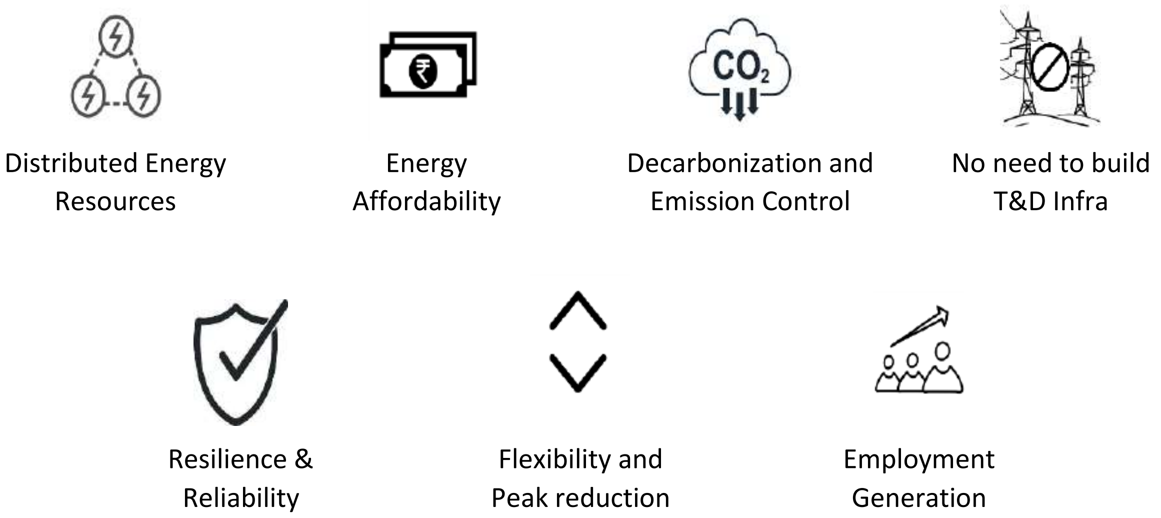
By integrating these advanced technologies, smart microgrids offer a multitude of benefits. They enhance the reliability and resilience of local power supplies by providing a continuous source of power during outages on the main grid. Smart controls within the microgrid optimize energy use, reducing losses and lowering overall costs. The integration of DERs, particularly renewable sources, promotes sustainability by reducing reliance on fossil fuels and greenhouse gas emissions. Additionally, demand response programs empower customers to actively participate in managing energy use and potentially benefit from cost savings. In essence, smart microgrids offer a pathway towards a more secure, sustainable, and efficient energy future, fostering a more robust and adaptable power grid for communities across the globe.

The Smart Microgrid (SMG) cannot be implemented using a standardized, cookie-cutter approach. Instead, it must be tailored to the identified site's load profile and other specific characteristics. As such, site selection becomes the most critical aspect of this project. The success of the SMG depends heavily on choosing the right site. This paper discusses various parameters that help in assessing the appropriateness of the identified site for the installation of a Smart Microgrid.

2. Background

2.1 Need For Smart Micro Grids:

The path to clean energy requires collaboration. Decarbonization hinges on a strong foundation of distributed renewable energy sources like solar panels and wind turbines, empowering consumers to become ‘prosumers’ who generate their own clean power. Minimizing wasted energy through better practices and technologies (energy efficiency) and optimizing energy use based on real-time needs (demand-side management) are also crucial pieces of the puzzle. Smart Microgrids are the perfect tool to seamlessly integrate these diverse strategies, creating a powerful tapestry for a sustainable energy future.



India's power sector is brimming with potential. Government and industry leaders recognize the transformative power of Smart Grids and Microgrids, presenting exciting business opportunities. Universal electrification, robust agricultural power supply, and 24/7 power availability for all citizens are India's primary energy goals.

However, the intermittent nature of renewable energy sources like solar and wind power presents a hurdle. Smart Microgrids are essential for integrating these unpredictable sources into the grid effectively. By enabling a highly adaptive response to supply and demand fluctuations, Smart Grids pave the way for widespread adoption of renewable energy in India.

India envisions a ‘secure, adaptive, sustainable and digitally enabled’ power sector, emphasizing reliable and high-quality energy access for all. Implementing Smart Grid systems presents challenges. High upfront costs and ensuring affordability for consumers are major concerns. Reliable communication networks are crucial, but they can significantly inflate initial hardware and infrastructure investments.

Interoperability – the seamless interaction of various devices and systems – is another challenge. While India's communication technology is competitive globally, ensuring compatibility within the utility environment remains a hurdle. Even with advanced technologies, integrating the entire hardware system to handle vast data volumes and manage diverse data formats flowing through the system necessitates robust data models.

By acknowledging these challenges and working towards innovative solutions, India can harness the immense potential of Smart Microgrids to create a bright, sustainable energy future.

2.2 Government Policies:

In 2015, India's Ministry of Power took a decisive step towards modernizing its energy infrastructure with the National Smart Grid Mission (NSGM). This central body oversees nationwide smart grid initiatives, streamlining efforts previously undertaken by the India Smart Grid Task Force. The NSGM envisions a smart grid ecosystem that drives efficiency and sustainability in the power sector. Key areas of focus include Advanced Metering Infrastructure (AMI), Substation Modernization, Distributed Generation, Real-time Monitoring and Control, Electric Vehicle (EV) Charging Infrastructure, Microgrid Development, and Power Quality Improvement. These initiatives aim to empower consumers, enhance reliability, promote renewable energy adoption, and improve overall power quality.

The Government of India provides crucial financial backing through the NSGM, offering a 30% subsidy on capital expenditure for smart grid projects. Further propelling innovation, the Department of Science & Technology (DST) has significantly contributed by funding smart grid research and development (R&D) efforts to the tune of approximately US$46.5 million. Leading the charge in innovation are India's esteemed academic institutions, including the Indian Institutes of Technology (IITs) and the Indian Institute of Science (IISc). These institutes actively collaborate with private industries on R&D projects funded by the DST, both nationally and internationally with countries like the US, UK, and Netherlands. Several of these projects are nearing completion.

By establishing a robust framework for smart grid development, fostering R&D, and promoting microgrid solutions, India is well on its way to a future powered by clean, reliable, and efficient energy.

3. Guide to Site selection for installing Smart Microgrids

Developing a smart microgrid is a strategic step towards energy independence and a sustainable future. But before diving in, it's crucial to select the ideal site for the microgrid. SMG consists of multiple technologies and components, that needs to work together. The sizing of this technologies/ components is also critical. This needs to be typically done by the energy experts/ consultants. Thus, the purpose of this framework is to provide a simple handy tool or a guidebook to the users to check the suitability of the site for installing the smart microgrid. This guide outlines following six key areas involved in site selection for smart microgrids:

1: Demand Profile (Understanding Your Energy Appetite)

The first step in selecting a smart microgrid site is understanding its energy appetite. This involves analyzing historical data to see how energy consumption fluctuates throughout the day, across seasons, and over time. We'll also identify the average and peak daily loads, along with the types of energy used (critical vs. non-critical, steady vs. variable, industrial vs. commercial, AC vs. DC). This detailed picture helps determine the microgrid's capacity and operational needs.

2: Energy Efficiency (Assessing Efficiency Efforts)

To assess the site's existing energy efficiency, investigate whether a recent energy audit has been conducted to pinpoint areas for improvement. Additionally, see if any energy efficiency projects have already been implemented to reduce overall energy consumption at the site. This combined investigation provides valuable insight into the site's current energy usage and potential for further optimization.

3: Exploring Past Experiences (Past Installation / Usage Experience)

Look beyond a blank slate! This step delves into the site's existing renewable energy infrastructure. Check for solar panels, wind turbines, or battery storage systems. See if the utility offers net metering for selling excess power back to the grid. Finally, explore the presence of advanced features like smart meters (AMI) for real-time data collection, SCADA systems for microgrid control, and user-friendly dashboards for monitoring energy use.

4: Billing (Analyzing Billing Structure)

Analyzing the billing structure involves understanding the site's historical average monthly energy cost and whether the local utility offers time-of-day pricing. This information is crucial for optimizing microgrid operations, as it can help tailor energy generation and consumption patterns to take advantage of lower electricity costs during off-peak hours.

5: Social Impact

Beyond just energy savings, consider the social impact of your microgrid. The project can create jobs during construction and operation, empower communities through ownership models, and bring reliable energy access to underserved areas.

6: Other Factors (Evaluating Broader Considerations)

Beyond the technical considerations of energy use and existing infrastructure, successful microgrid development hinges on several additional factors. Securing reliable data, assembling a team with relevant experience, and identifying potential funding sources are all crucial for informed decision-making. Finding suitable land and fostering cooperation with stakeholders, including the community and local utility, are essential for smooth project execution. Finally, strong commitment from leadership ensures the project receives the necessary resources and support to thrive.

In following sections, more granular parameters to be considered under each of the above areas are discussed in detail.

4. Parameters for Site Selection

4.1. Demand Profile:

Understanding the overall electricity consumption pattern of a locality or household is crucial. This includes factors like time of day (ToD) usage, seasonal variations, and overall energy needs.

4.1.1 Average Daily Load

This metric indicates the average amount of power consumed daily. It helps assess the overall energy needs of the potential microgrid site. A stable average daily load suggests a good fit for a microgrid, as it allows for efficient sizing of generation and storage capacity.

SCORE	
0 (Not Suitable)	1 (Suitable)
RATIONALE	
• Average daily load exhibits significant fluctuations and unpredictability. • Microgrid experiences frequent instances of high load demand. • Limited capacity for load balancing and management. • High risk of grid instability and power quality issues due to load variability	• Average daily load exhibits minimal or moderate fluctuations and predictability. • Adequate capacity for load balancing and management (advanced demand-side management strategies preferred). • Moderate or low risk of grid instability and power quality issues, even during peak load periods.

4.1.2 Availability of different Load Types:
4.1.2.1 Critical vs. Non-critical:

Categorizing loads as critical (hospitals, laboratories, lifts) or non-critical (Park lamps, streetlights) helps prioritize power delivery during outages or limited supply.

<table>
<tr><th colspan="2">SCORE</th></tr>
<tr><td>0 (Not Suitable)</td><td>1 (Suitable)</td></tr>
<tr><td>Majorly critical load (More than 40 % of the total load)</td><td>Mix of critical and noncritical with predominantly non-critical load (Critical Load is less than 30% of the total load)</td></tr>
<tr><th colspan="2">RATIONALE</th></tr>
<tr><td>• Majority of loads are categorized as critical, requiring uninterrupted power supply.
• Limited flexibility in load prioritization during outages or limited supply.</td><td>• Predominantly non-critical loads with minimal impact on essential services during outages.
• Well-defined strategies for load prioritization, ensuring critical loads receive priority power supply.</td></tr>
<tr><td colspan="2">Critical loads are the one which are essential and cannot be powered down when needed. These include health (ventilators, oxygen concentrators, vaccine refrigerators), safety (security cameras, alarms, radar & surveillance systems, emergency response systems), and business continuity (data centers & servers, banking & transaction systems), etc.

Non critical loads are the one which can be powered down considering these are less essential and can be compromised in emergency cases. These include non-medical ACs, general lighting, entertainment systems, etc.</td></tr>
</table>

4.1.2.2 Steady Base Load vs. Variable Load:

Steady loads (refrigerators) are predictable and can be easily met by microgrid generation. Variable loads (air conditioners) fluctuate, requiring a flexible generation mix or storage solutions.

<table>
<tr><th colspan="2">SCORE</th></tr>
<tr><td>0 (Not Suitable)</td><td>1 (Suitable)</td></tr>
<tr><td>Highly variable load profile</td><td>Mix of steady base and variable load</td></tr>
<tr><th colspan="2">RATIONALE</th></tr>
<tr><td>● Very limited or highly variable load profile (e.g., solely seasonal agricultural loads).
● Microgrid design might be complex and uneconomical due to unpredictable load patterns.</td><td>● Presence of both steady base load (refrigeration) and variable loads (air conditioners).
● Predictable base load allows for efficient microgrid generation planning, while variable loads offer opportunities for load management strategies.</td></tr>
<tr><td colspan="2">Steady Load: Refrigerators, Internet modems & routers, Water filters, CCTV cameras, etc.

Variable Load: Washing machines, ACs, EV chargers, Ovens & electric stoves, Water heaters/ Electric geysers, etc.</td></tr>
</table>

4.1.2.3 Industrial/ Machine vs. Lighting/ HVAC:

Understanding the specific types of loads (industrial machinery vs. residential lighting) helps determine the microgrid's design and generation capacity. Industrial loads may require higher power while residential lighting may be lower power but require longer durations.

<table>
<tr><th colspan="2">SCORE</th></tr>
<tr><td>0 (Not Suitable)</td><td>1 (Suitable)</td></tr>
<tr><td>Solely high-power industrial loads (> 100 kW)</td><td>Diverse mix of loads</td></tr>
<tr><th colspan="2">RATIONALE</th></tr>
<tr><td>Industrial machinery often requires significant amounts of power, particularly during startup or operation. These bursts of high-power consumption can pose challenges for microgrid design.
Integrating substantial industrial loads necessitates robust infrastructure to handle peak demands, significantly increasing microgrid design complexity.
Unlike predictable lighting/HVAC loads, industrial machinery, has variable power consumption patterns depending on production schedules.</td><td>A mix of industrial, residential, and commercial loads creates a more predictable overall demand profile. This temporal distribution allows for better utilization of the microgrid's energy generation capabilities.
The presence of various load sizes, from high-power industrial machinery to lower-power lighting with longer durations, provides a more balanced energy consumption pattern.</td></tr>
<tr><td colspan="2">Industrial Load: Heavy industrial machinery, packaging machines, hydraulic presses, etc.

Lighting/ HVAC Load: LEDs, HVAC appliances, etc.</td></tr>
</table>

4.1.3 Currently Installed Renewable Capacity:

Existing renewable energy installations like solar panels or bio-gas plants can be integrated with the microgrid, reducing reliance on external power and increasing sustainability.

SCORE	
0 (Not Suitable)	1 (Suitable)
Not Available	Available
RATIONALE	
Sites with a higher existing renewable energy capacity are more suitable for smart microgrids for the following reasons: (1) Readily Available Resource: A high existing renewable capacity indicates a readily available source of clean energy for the microgrid to leverage. This reduces dependence on the main grid and fossil fuels. (2) Existing Infrastructure: Areas with significant renewable installations likely have some supporting infrastructure like transmission lines or substations. This can be partially utilized by the microgrid, reducing setup costs. (3) Technical Expertise: Areas with a strong renewable energy presence might have a more skilled workforce familiar with renewable technologies. This can be beneficial for microgrid operation and maintenance.	

4.1.4 Demand Growth Potential over next 3 years:

Anticipated future growth in energy demand helps determine the scalability of the microgrid. A microgrid should be designed to accommodate projected increases in power needs over the next few years. The timespan of three years is a common planning horizon used in many industries for forecasting and strategic planning. It strikes a balance between short-term volatility and long-term uncertainty, offering a stable basis for decision-making.

SCORE	
0 (Not Suitable)	1 (Suitable)
0-10 %	> 10 %
RATIONALE	
• A 0-10% growth indicates minimal or stagnant development in renewable energy. • This suggests limited future benefits for a microgrid in terms of grid integration or market opportunities.	• A growth rate exceeding 10% suggests a significant expansion in the renewable energy sector. • This creates a highly favorable environment for a smart microgrid due to: 1. Increased potential for collaboration and integration with upcoming projects. 2. A supportive policy landscape focused on clean energy. 3. A growing demand for grid stability solutions that microgrids can provide.

4.2. Energy Efficiency Parameters

4.2.1. Energy Accounting in Last 12 Months:

Recent energy audits provide valuable insights into how energy is utilized, guiding the design of smart microgrids to optimize energy consumption efficiently. By understanding consumption patterns and identifying areas for improvement, stakeholders can make informed decisions, ensuring the effectiveness of the microgrid system in meeting energy needs while minimizing costs. According to the Bureau of Energy Efficiency Ministry of Power, energy audits are mandatory for electricity distribution companies. However, it's not compulsory for every organization to conduct an energy audit. Therefore, the availability of an energy audit report becomes a crucial factor in assessing the readiness for SMG implementation.

Source:https://beeindia.gov.in/en/programmesdemand-side-anagementdiscom/energy-audit-in-discom

SCORE	
0 (Not Suitable)	1 (Suitable)
No energy audit report/ Available for less than 12 months	Energy audit report is available for last 12 months or more
RATIONALE	
A rating of 0 is assigned if no energy audit report is available, indicating a lack of valuable insights into energy usage patterns and potential inefficiencies OR available audit report is for less than 12 months indicating the shorter timeframe may limit the depth of analysis and effectiveness in guiding SMG design.	A rating of 1 is assigned if an energy audit report is available for last more than 12 months. This indicates a thorough understanding of energy needs and usage patterns, allowing for more informed decision-making in SMG design and optimization.

4.2.2. Efficiency Improvement Projects Undertaken:

The implementation of past efficiency improvement projects underscores a proactive approach to energy management, reflecting a commitment to sustainability and cost reduction. These initiatives lay the groundwork for further optimization through smart grid technologies, indicating the site's readiness for integration. By building on these efforts, smart microgrids can enhance energy efficiency and resilience, aligning with the site's sustainability goals and economic objectives.

SCORE	
0 (Not Suitable)	1 (Suitable)
RATIONALE	
No energy efficiency projects undertaken	Energy efficiency projects previously undertaken and it focuses on both sustainability goals of the organization and cost reduction strategies.

4.3. Past Installation / Usage experience, if any

4.3.1. Energy Storage:

Past utilization of energy storage systems demonstrates awareness of the significance of storing surplus energy for future use. Storage solutions, like batteries or pumped hydro storage, help balance supply-demand dynamics within microgrids, bolstering stability. Experience in storage implies readiness to deploy advanced energy management tactics, such as demand response, enhancing microgrid efficiency and cost-effectiveness.

SCORE	
0 (Not Suitable)	1 (Suitable)
No energy storage system available	Energy storage capacity (1/4th of the daily generation capacity)
RATIONALE	
A rating of 0 is assigned if there are no energy storage systems available. This suggests a lack of preparedness to manage surplus energy effectively, potentially leading to inefficiencies in microgrid operations.	A rating of 1 is assigned if the energy storage capacity exceeds 500KW. This indicates sufficient storage capacity to manage surplus energy effectively, enhancing the stability and efficiency of the microgrid system.

4.3.2. Net Metering, if any:

Net metering experience involves compensating renewable energy producers for surplus electricity fed back into the grid. Sites with net metering history have established protocols for crediting renewable contributions, fostering an environment conducive to distributed energy. This background simplifies integrating renewables into smart microgrids, promoting grid stability, and incentivizing sustainable energy adoption.

SCORE	
0 (Not Suitable)	1 (Suitable)
Not Available	Available
RATIONALE	
A rating of 0 is assigned if there is no net metering feature available, either due to a lack of renewable energy resources or insufficient energy production to resell surplus electricity. This indicates a limited ability to leverage renewable energy contributions and may hinder the integration of sustainable energy practices into the microgrid.	A rating of 1 is assigned when energy production is sufficient to allow surplus electricity to be resold to the distribution company (DISCOM). This demonstrates a capacity to leverage renewable energy resources effectively, potentially enhancing the financial viability of smart microgrid implementation while promoting sustainable energy practices.

4.3.3. AMI (Advanced Metering Infrastructure):

Past AMI usage signifies familiarity with cutting-edge metering tech for remote energy monitoring and management. AMI systems allow detailed data collection, enabling stakeholders to pinpoint usage patterns and optimize microgrid operations. Proficiency with AMI enhances operational efficiency, supporting precise demand-side management and facilitating smart grid integration. AMI serves as a fundamental building block for smart microgrid (SMG) implementation. Therefore, existing installation of AMI provides a strategic advantage for organizations or institutions.

SCORE	
0 (Not Suitable)	1 (Suitable)
Not Available	Available
RATIONALE	
A rating of 0 is assigned if AMI infrastructure is not already in place. This indicates a potential need to invest in AMI installation, which may delay or complicate SMG implementation.	A rating of 1 is assigned if AMI is already installed or can be easily implemented using cutting-edge technology. This signifies readiness to leverage advanced metering capabilities, streamlining the integration of SMG and enhancing operational efficiency from the outset.

4.3.4. SCADA (Supervisory Control and Data Acquisition):

Experience with SCADA systems showcases expertise in centralized monitoring and control of microgrid components. SCADA enables remote system oversight, ensuring swift response to operational events and optimizing energy flow. This proficiency strengthens microgrid management, enhances reliability, and enables agile responses to grid dynamics.

The automation of the distribution system function includes planning, construction, operations and maintenance (O&M) of the power system and interaction with the end users as an essential function for achieving the comprehensive benefits offered by Smart Grid. SCADA/Distribution Management System (DMS) shall be implemented along with sub-station automation in select areas for achieving comprehensive benefits associated with Smart Grid.

SCADA systems integrate with sensors and other measuring devices to collect data, which is then translated into usable information and relayed to a human machine interface (HMI) or other displays. SCADA systems have four levels of architecture:

Level 0: Field Devices

Level 1: Local Control Stations

Level 2: Supervisory Control

Level 3: Manufacturing Execution Systems (MES)

Level 4: Enterprise Business Systems

SCORE	
0 (Not Suitable)	1 (Suitable)
Not Available	Available

Source: https://builtin.com/data-science/scada

4.3.5. Usage Dashboards:

Prior usage of usage dashboards reflects a commitment to transparent, data-driven energy management. Dashboards empower stakeholders with intuitive interfaces for visualizing energy data, fostering informed decision-making and energy conservation. Experience with dashboards promotes user engagement, enabling consumers to optimize usage and cultivate an energy-conscious community within the microgrid ecosystem.

KPI in dashboard-

- Analyze energy consumption trends for informed decision-making and proactive energy management.
- Identify energy spikes and equipment issues promptly through real-time tracking.
- Energy cost analysis to make cost-saving decisions.
- Monitor carbon emissions to ensure sustainability and regulatory compliance using Carbon Emissions Tracking.
- Energy intensity measures for efficiency evaluation and improvement.
- Peak Demand Analysis monitors peak demand periods to cut expenses during peak hours
- Monitors equipment performance to enhance energy efficiency and pinpoint maintenance requirements.
- Reduce energy waste during extreme weather to improve efficiency and promote sustainability.

SCORE	
0 (Not Suitable)	1 (Suitable)
Doesn’t have any KPI	All necessary KPI
RATIONALE	
A rating of 0 is assigned if no dashboard is used or if the dashboard lacks the necessary KPIs for SMG installation, indicating a potential gap in data-driven energy management practices.	A rating of 1 is assigned if the dashboard includes all necessary KPIs for SMG installation, indicating readiness for advanced energy management and optimization within the microgrid ecosystem.

4.4. Billing

4.4.1. Average Monthly Bill Amount:

The average monthly bill amount provides crucial insight into potential cost savings achievable through smart microgrid (SMG) implementation. A lower average bill indicates efficient energy practices or favorable tariffs, while higher amounts suggest areas for improvement. Understanding this metric aids stakeholders in assessing the financial feasibility of deploying tailored SMG solutions.

SCORE	
0 (Not Suitable)	1 (Suitable)
Average bill amount <10k	Average bill amount >30k
RATIONALE	
With an ideal average bill amount set at 30,000 INR, organizations can identify scenarios where implementing an SMG would offset current energy expenses and potentially lower operational costs. Aligning the SMG investment with existing expenditure levels ensures cost-effectiveness and sustainable energy management. Given the cost involved in setting up and maintaining an SMG, organizations currently paying an average bill amount within the target range would find it ideal to invest in SMG implementation without incurring additional expenses. This approach not only addresses current energy needs but also offers long-term benefits in terms of cost savings and efficient energy management.	

4.4.2 ToD (Time-of-Day) Tariff Breakup:

Time-of-use tariffs adjust electricity prices based on demand throughout the day. Grasping these variations allows for optimized energy consumption, maximizing savings and grid efficiency. With smart microgrids, consumers can adapt usage patterns to capitalize on lower rates, enhancing both economic and environmental outcomes.

SCORE	
0 (Not Suitable)	1 (Suitable)
Not Available	Available
RATIONALE	
A score of 0 suggests no ToD structure or a weak one, limiting the microgrid's ability to exploit price signals and potentially reducing its overall economic benefit.	A score of 1 indicates a site with a well-defined ToD structure with a significant price difference between peak and off-peak hours. This creates a favorable environment for smart microgrids to leverage cost savings and revenue opportunities through optimized energy management.

Cost Savings Potential: ToD tariffs incentivize lower energy consumption during peak hours when electricity prices are high. Smart microgrids can optimize energy use by relying more on internal generation (renewable) during peak hours, reducing reliance on the main grid and lowering overall costs.
Revenue Opportunities: Microgrids can potentially sell excess energy back to the grid during peak hours when prices are high, generating additional revenue.

4.5. Social:

4.5.1. Social Impact, if any:

This factor considers how implementing smart microgrids might affect the community. It examines potential benefits such as improved access to affordable energy, increased resilience, and job creation. Assessing social impacts ensures that microgrid projects align with community needs and contribute to overall well-being.

The sub-categorization of this parameter is as follows:

Accessibility to Electricity (24/7); Standard of Living; Job Creation

SCORE	
0 (Not Suitable)	1 (Suitable)
Doesn't have social impact	Have social impact
RATIONALE	
A rating of 0 is assigned if the implementation of smart microgrids does not lead to any discernible social impact or positive social externality, such as job creation or community resilience enhancement. This suggests a potential gap in addressing community needs or leveraging microgrid benefits for broader social welfare.	A rating of 1 is assigned if the implementation of smart microgrids leads to tangible social impacts, such as job creation or improved access to affordable energy. This indicates that the microgrid project contributes positively to the community, aligning with its needs and promoting overall well-being.
Area already has 24/7 power supply or SMG implementation does not significantly improve reliability	SMG project ensures 24/7 power supply to previously underserved or unreliable grid areas. This improves energy access for critical infrastructure like schools, healthcare centers, and water systems.
No noticeable improvement in social services, education, or health infrastructure due to SMG.	SMG leads to measurable improvements in services like night-time lighting, digital learning, and cold storage for vaccines, and enhances overall community well-being.
No employment opportunities generated or local workforce not engaged in/ due to the project.	Project creates direct and indirect jobs (installation, O&M, monitoring), promotes local businesses (e.g., cold storage, mobile charging), and includes training programs for locals in energy-related skills.

4.6. Other Factors

4.6.1 Availability of Data

Easy access to relevant data is crucial for effective microgrid planning, operation, and optimization.

SCORE	
0 (Not Suitable)	1 (Suitable)
Limited or unreliable data	Reliable data
RATIOANLE	
Limited or unreliable data availability. ● There is minimal or no access to data on energy consumption patterns, weather patterns, or existing infrastructure in the target site. ● The available data might be outdated or unreliable, making it difficult to make informed decisions about the microgrid project.	Readily available and reliable data on relevant parameters. ● There is easy access to data on factors like energy consumption, weather patterns, and existing infrastructure. ● The data is reliable and up-to-date, allowing for confident decision-making and microgrid optimization.

4.6.2 Prior experience of working on similar initiatives

An area or a team with experience in microgrid projects or related initiatives can significantly benefit a smart microgrid development process.

SCORE	
0 (Not Suitable)	1 (Suitable)
No prior experience	Proven track record
RATIONALE	
No prior experience with microgrid projects in the region. • The development team lacks any experience with microgrid projects or similar renewable energy initiatives. • This can lead to a steeper learning curve and potentially higher project risks.	Proven track record of successfully implementing microgrid projects or related initiatives. • The development team has demonstrable experience in planning, designing, and deploying operational microgrids. • This experience is highly valuable as it reduces project risks and fosters efficient execution.

4.6.3 Availability of Space

Suitable space is necessary for housing the core components of a smart microgrid, including:

1. Generation: This could be solar panels, wind turbines, or other renewable energy sources.
2. Storage: Battery systems to store excess energy for later use.
3. Auxiliary Equipment: Transformers, switchgear, and control rooms for managing the microgrid's operation.

SCORE	
0 (Not Suitable)	1 (Suitable)
Limited or no readily available space	Identified space with appropriate size and characteristics

RATIOANLE

The space should be available in the form of land or rooftop. This available space should be shadow free/ south facing and secure. This approach focuses on the overall suitability of the space for the project rather than a specific size requirement. During the detailed project design phase, engineers will determine the exact space needs based on the chosen technologies and local regulations.

For a general understanding, consider the following approximation:

SMG Capacity	Estimated Space Requirement
Small (Up to 250 kW)	0.25 - 0.5 acres
Medium (250 kW - 1 MW)	0.5 - 1 acre
Large (Over 1 MW)	0.5 - 1.5 acres

These are just estimates, and the actual space use can vary based on:

1. Technology Choices: Wind turbines require less space footprint than solar panels for the same generation capacity. Battery storage needs also influence space use.
2. Project Design: A compact and efficient layout can minimize space requirements compared to a scattered layout.
3. Local Regulations: Zoning restrictions and permitting requirements can dictate minimum space size or specific layout considerations.

4.6.4 Leadership / Management Commitment

Strong commitment from an organization's top management is crucial for the successful development and operation of a smart microgrid project.

SCORE	
0 (Not Suitable)	1 (Suitable)
Limited or Uncertain Commitment	Demonstrated Commitment
RATIONALE	
1. There is a lack of clear or public statements from top management regarding their support for the microgrid project. 2. The project might not be well-aligned with the organization's overall strategic goals, suggesting a potential lack of commitment or long-term vision.	1. Top management has publicly expressed their support for the microgrid project. 2. The project is clearly aligned with the organization's sustainability or energy goals, indicating a strategic commitment and long-term vision.

4.6.5 Structural Changes at the Site Location

Planned structural changes at the site can significantly affect the long-term feasibility, stability, and economic viability of a SMG. Since SMGs involve substantial capital investment in generation, storage, and associated digital infrastructure, any major construction or redevelopment within the next five years may require relocation, dismantling, or redesign of installed systems. Therefore, understanding the consumer's future development plans is essential for de-risking the project and ensuring long-term continuity of the SMG.

<table>
<tr><th colspan="2">SCORE</th></tr>
<tr><td>0 (Not Suitable)</td><td>1 (Suitable)</td></tr>
<tr><td>Major structural changes</td><td>No major structural changes</td></tr>
<tr><th colspan="2">RATIONALE</th></tr>
<tr><td>

The consumer anticipates significant construction, redevelopment, expansion, demolition, or major reconfiguration of the site within the next five years.
Such changes may necessitate shifting, redesigning, or discontinuing SMG infrastructure, leading to:

Loss of investment,
Interruption of microgrid operation,
Mismatch between initial system design and future site layout.

This poses high financial and operational risks to both the consumer and any third-party investor.

</td><td>

The consumer confirms no substantial structural changes or redevelopment activities for at least the next five years.
Ensures long-term stability for SMG placement, asset utilization, and economic returns.
Indicates a stable environment for deploying infrastructure, enabling optimal SMG performance and predictable cash flows.

</td></tr>
</table>

4.6.6 Scalability & Future Expansion

Future expansion potential is a critical consideration in SMG planning. As consumer demand evolves, the load at the site may increase due to new processes, equipment, or occupants. To accommodate this future growth, adequate physical space must be available to install additional generation units, storage systems, or associated infrastructure.

SCORE	
0 (Not Suitable)	1 (Suitable)
Load growth expected but no scope for additional space OR load growth expected but unclear expansion feasibility	Load growth expected with clear availability of space for expansion OR no significant load growth expected
RATIONALE	
• The site anticipates an increase in load due to future development, new equipment, additional consumers, or planned expansion. • This results in potential underperformance in later years, limiting the economics of the microgrid as well as its ability to scale. • Lack of expansion capacity creates long-term operational and financial constraints, making the site less suitable for SMG implementation.	• Load growth is anticipated and the site has sufficient land/rooftop/structural space for expanding SMG infrastructure. **OR** • Load growth is minimal or not expected in the foreseeable future, reducing the need for expansion. • Long-term flexibility supports improved return on investment (ROI) and operational reliability.

4.6.7 Willingness of Consumers

Willingness of the consumer is a key determinant of SMG project success. It reflects the consumer's interest in adopting the microgrid, readiness to invest, and openness to various financing models (CAPEX/OPEX). A proactive consumer facilitates smoother implementation, reduces delays, and strengthens long-term sustainability of the SMG.

SCORE	
0 (Not Suitable)	1 (Suitable)
Consumer not willing to adopt SMG or invest through any financial model	Consumer demonstrates clear willingness to implement SMG and participate through CAPEX/OPEX
RATIONALE	
• Consumer shows reluctance toward SMG adoption. • Unwilling to invest under CAPEX or pay under OPEX/service models. • Potential delays, low engagement, and higher project risk.	• Consumer expresses clear interest in SMG adoption. • Ready to participate through either CAPEX, OPEX, or hybrid models. • Indicates strong alignment, smoother execution, and long-term viability.

4.6.8 Availability of Water for Operations & Maintenance

Certain SMG components, such as solar PV cleaning, cooling systems, and general site upkeep require periodic water usage. Availability of adequate and reliable water supply ensures sustained performance of generation assets and reduces maintenance disruptions. Limited water availability may impact energy output and increase operational costs.

SCORE	
0 (Not Suitable)	1 (Suitable)
Water availability is limited	Reliable and adequate water availability
RATIONALE	
• Irregular or inadequate water supply. • Inability to meet routine cleaning and maintenance requirements. • May reduce generation efficiency (especially for solar PV) and increase O&M costs.	• Consistent access to required water quantity. • Supports regular cleaning, cooling, and site maintenance. • Ensures optimal performance and smooth O&M operations.

4.6.9 Readiness of Local DISCOMS

This parameter evaluates the preparedness of the local distribution companies (DISCOMS) to support the integration and operation of a smart microgrid. It assesses the factors like regulatory compliance, technical capability, financial stability and willingness to collaborate.

SCORE	
0 (Not Suitable)	1 (Suitable)
DISCOM lacks readiness	DISCOM is partially or fully prepared
RATIONALE	
• No clear policy for grid interconnection or net metering • No prior experience with microgrids • Resistance to decentralized energy models • Poor financial health	• Potential for progress in the aspects mentioned but may require additional negotiations and policy adjustment. • DISCOM ensures smoother approvals, better grid integration, and long term operational stability.

5. Final Scoring Criteria

We have classified the above parameters in two categories based on their impact on the installation of SMG, which are as follows:

- **Must-Have:** Must-have parameters are 'make-or-break' criteria. These parameters are the most critical for the successful functioning of the SMG. Such parameters are - Energy Accounting in Last 12 months; Average Monthly Bill Amount; Availability of Space
- **Good-to-Have:** These are other important parameters with varying weightage based on their dependency level in the functioning of SMG. All the remaining parameters than the three 'must-have' parameters are good-to-have parameters.

Weights for 'good-to-have' parameters:

Category	Parameter	Weight
Demand Profile	Average Daily Load	10
	Critical vs. Non-critical Load	8
	Steady vs. Variable Load	7
	Industrial/Machine vs. Lighting/HVAC	5
	Currently Installed Renewable Capacity	8
	Demand Growth (3 Years)	5
Energy Efficiency	Efficiency Improvement Projects	6
Past Experience	Energy Storage	6
	Net Metering	6
	AMI	6
	SCADA	6
	Usage Dashboards	4
Billing	ToD Tariff Availability	7
Social	Social Impact	6
Other Factors	Availability of Data	8
	Prior Experience in Similar Initiatives	6
	Leadership / Management Commitment	10
	Readiness of Local DISCOMS	10
	Structure Changes at Site	6
	Scope for Additional Capacity	7
	Willingness of Consumer	10
	Availability of Water for O&M	3
Total		**150**

Formula:

Site Selection Score = (Product of Must-Have parameters) × *(Σ (Weight*$_i$ × *Score*$_i$*))*

where,
'i' = Good-to-Have Parameters

How to Use the Scorecard:

- If any must-have parameter receives a score of 0, the overall site selection score automatically becomes 0, since the score of must-have parameters is intended to be multiplied with the combined weighted score of the good-to-have parameters.
- If the calculated site-selection score **exceeds 75% (i.e., 113 points)**, the site may be considered **highly suitable** for the development of a smart microgrid.
- If the score is **between 65-75%**, the site may become suitable for constructing a SMG but with some **necessary modifications**.
- Once the minimum required score is achieved, the user may consult subject-matter experts for detailed planning and implementation.

6. Conclusion and Summary:

The transition to a modern, resilient, and sustainable energy future is not just a goal but a necessity. Smart Microgrids (SMGs) stand at the forefront of this transformation, offering a decentralized, intelligent, and adaptive solution to the challenges of rising demand, grid instability, and the integration of renewable energy. This guide has established a comprehensive framework for selecting the optimal site for an SMG installation, recognizing that its success is profoundly dependent on this critical first step.

The site selection process is multifaceted, moving beyond mere technical feasibility. As detailed, it requires a holistic assessment across six key areas:

1. **Demand Profile:**
   Understanding the energy appetite, its volume, type, and pattern is fundamental to right-sizing the microgrid's generation and storage capacity.
2. **Energy Efficiency:**
   A site already engaged in efficiency measures demonstrates a culture of energy consciousness, providing a stronger foundation for the advanced optimization an SMG offers.
3. **Past Experience:**
   Existing infrastructure like renewable capacity, energy storage, AMI, or SCADA systems significantly de-risks the project and accelerates implementation.
4. **Billing Structure:**
   Analyzing cost patterns and Time-of-Day tariffs reveals immediate financial incentives and opportunities for cost savings and revenue generation.
5. **Social Impact:**
   The true value of an SMG extends beyond kilowatts, offering profound benefits in job creation, energy access, and community resilience.
6. **Other Factors:**
   Critical enablers like data availability, land, stakeholder cooperation, and strong leadership commitment are the bedrock upon which successful projects are built.

However, for Smart Microgrids to transition from a promising technology to a widely adopted solution, economic viability and a demonstrably strong Return on Investment (ROI) are paramount. The business case must be clear and compelling. This necessitates:

- **Strategic Site Selection:**
  Choosing sites with high energy costs (e.g., high monthly bills) and favourable conditions (e.g., existing infrastructure, ToD tariffs) directly enhances financial returns by maximizing cost avoidance and potential revenue.
- **Value Stacking:**
  An SMG's value is not just in energy savings. It is a stack that includes enhanced

reliability (avoiding outage costs), sustainability benefits, grid services revenue, and deferred infrastructure upgrades. Project planning must quantify this full value stack to present a robust economic picture.

- **Innovative Business Models:**
  Adoption can be accelerated through models like Energy-as-a-Service (EaaS), which reduce or eliminate upfront capital expenditure for the end-user, making the benefits of an SMG immediately accessible.
- **Supportive Policy Frameworks:**
  Continued and streamlined government subsidies, like those from the NSGM, and clear regulations for grid interconnection and energy sales are crucial to improving project economics and attracting investment.

In conclusion, a meticulous, parameter-driven site selection process, as outlined in this framework, is the essential first link in the chain of developing a successful Smart Microgrid. By carefully evaluating a site's readiness across technical, economic, and social dimensions, developers can de-risk projects, optimize design, and, most importantly, ensure that the microgrid is not only technologically advanced but also economically sustainable. Ultimately, it is this compelling economic proposition, a strong and clear ROI, which will fuel the rapid and widespread adoption of Smart Microgrids, paving the way for a secure, efficient, and decarbonized energy ecosystem.

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