Guide to Driving Sustainable Power Across Industrial Sites

Sustainable Power Challenges

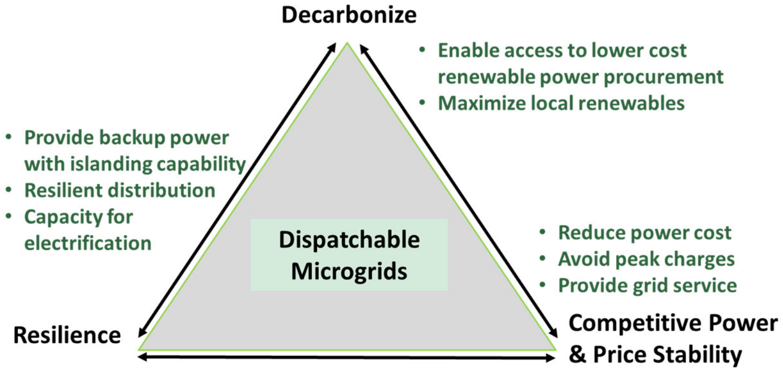
This guide provides concrete steps for achieving sustainable power by addressing the following challenges and sometimes-competing objectives inherent in sustainable energy planning.

1. **Reliability and Resiliency** – Electricity users are experiencing increased frequency and duration of power outages and rolling brownouts. For example, California utilities can cut off facility power for a week or more during certain weather conditions. Facilities should seek strategies to establish resilient site infrastructure and islanding capability while leveraging these assets to reduce costs.
2. **Cost Optimization and Operational Efficiency** – The worldwide drive to decarbonize combined with extreme weather are driving up utility costs and increasing price volatility. For example, Illinois is effectively banning fossil fueled power generation with net zero requirements which will artificially drive-up power and capacity prices. Facility owners can mitigate price increases and volatility by a), installing site generation to reduce peak power costs, b) continuous monitoring and improving efficiency of energy performance and c) implementing strategies for price hedging, creating energy models to simulate and evaluate future conditions to support the financial case for investment.
3. **Carbon Reduction and Efficient Power** – Users may be in a location with predominantly coal fired generation or only high carbon sources. In these situations, site generation, cogeneration, and trigeneration are key to reducing carbon while also providing resiliency during utility outages. In states with restructured power markets, users can pursue competitive contracts for existing renewable power and build new renewable power leveraging power purchase agreements.
4. **Fuel Switching, Economic Dispatch and Grid Service** – Electric power users face extreme price volatility. A few examples include extreme weather events and causing peak hourly power prices in Texas to increase to $2,000/MWh during extreme weather events. Facility owners could leverage dispatchable onsite power generation, demand response and alternate fuels to reduce grid power demand during peak power pricing events. These investments provide quick response to grid supply issues and minimize or offset carbon emissions, lower costs, improve reliability, and generate revenue (e.g., demand response).

We provide below the objectives and implementation guide to address the above Sustainable Power Challenges.

Introduction of Objectives

With the rising cost of power, more frequent and longer power outages, and environmental pressures, commercial and industrial companies are turning to electrification for their buildings and campuses. While electrification helps companies achieve their net-zero carbon goals, it strains power distribution systems and increases power costs. This guide provides the all-encompassing objectives and planned steps for addressing the sustainable power triangle shown in the adjacent figure.



Sustainable energy experts developed four all-encompassing objectives that form the foundation for companies to achieve their sustainable power goals for their facilities:

1. *Secure sponsorship* of the corporate executive team, form a knowledgeable team, communicate benefits to stakeholders, and develop a corporate strategy.
2. *Install site generation, demand response, and fuel switching* to protect the facility from price escalation, price spikes, and power outages or disruptions.
3. *Upgrade the site's electric infrastructure* to enable and support a) resiliency, b) increases in electricity demand, c) integration of renewable power, d) maintain and improve reliability, and e) dramatic daily swings in power demand.
4. *Monitor and improve key performance indicators and perform continuous evaluation* to ensure the project is on track and site activity is improving to meet the organization's goals and objectives.

Create the Energy Sustainability Team and Plan Outline:

This brief guide provides the six (6) key steps needed to achieve sustainable power goals and building sustainable energy and electrification plans including alternate energy sources (district energy, geothermal, heat pumps, solar PV, wind, and thermal storage).

The team should consider the following steps as they proceed. Each facility should assess and prioritize these steps based upon their site-specific needs and constraints (e.g., regulatory, space). For example, facilities and campuses may have limited authority to procure power (**Step 3**).

Step 1: Develop a team and perform a power assessment to evaluate the regulatory structure, rates, power models, and identify limitations and/or opportunities associated with their specific locations. This includes determining if skilled resources are available in-house to assess, plan, design and execute a sustainable power plan. Engaging third party resources provides value for tasks associated with information gathering, assessment, prioritizing these steps, planning, and implementation.

Step 2: Establish electricity performance metrics, goals, and measurement/verification program.

Step 3: Change power supply to immediately reduce costs and/or lower carbon.

Step 4: Build a Microgrid.

> **Step 4a:** Upgrade site electrical distribution to increase capacity for electrification, provide resiliency, increase safety, improve power measurement, and reduce the cost for integration of local power sources.
>
> **Step 4b:** Install site generation capable of supporting economic dispatch and site operations in island mode when utility power is lost, for resiliency.

Step 5: Install site power control automation to optimize economic dispatch of power generation capability, thermal/electric storage, and controllable loads (e.g., demand response).

Step 6: Establish operational efficiency and risk assessment. As appropriate automate operations, implement preventive maintenance programs, grid service programs, fuel switching, and other strategies designed to improve efficiency, eliminate cost and waste. This includes implementing a risk mitigation program.

These steps are further defined in the following section.

Detailed Steps to Guide Energy Sustainability Team

Strategic Overview

Firms that initiate a carbon reduction or net zero carbon emissions goals recognize the significant commitment of capital and resources. Key strategic questions to consider include:

- Is it possible to install onsite generation and/or procure renewable power from the market?
- What options exist to replace fossil fueled power sources with non-carbon or at least lower carbon sources?
- What are the challenges or roadblocks? Are they permanent or will time provide new answers?
- How can the facilities develop a transition plan that includes all stakeholders?

Step 1: Develop Sustainable Energy Team and Perform an Assessment

To get started, identify an executive sponsor, appoint a team leader, and assign key employees to participate on the team. When considering team membership, keep in mind that operations, engineering, and finance are all stakeholders and contributors. However, the work may require subject matter experts from third-party partners to support the efforts. Each organization has employees with different skill sets and access to tools used in this work, however, few organizations have all the skills needed.

The team should identify, select, and budget for the subject matter experts or vendors that can deliver on those tasks that in-house resources cannot. A guide for selecting subject matter experts or vendors is provided in **Appendix A**. A flow chart of plan steps and checklist for plan tasks is in **Appendix B**.

Step 2: Improve Energy Delivery Performance Metrics, Goals, and Verification

The second step is to establish a comprehensive yet focused set of relevant performance metrics, risk factors, and goals. These metrics are necessary to assess performance, identify gaps, and quantify the savings potential. Monthly energy bills provide basic usage and cost information. However, electric power supplies pose a significant risk and threat to facility operation (extended outages, massive price spikes, and equipment damage). New industry standards, such as ISO-50001 and the Green Business Certification Inc.'s (GBCI) PEER program outline methods for defining metrics and processes for assessing electricity sustainability, performance, and risks.

The objective is to monitor key performance indicators, track performance, and identify new improvement strategies. Strategies include:

- Develop comprehensive set of performance metrics suitable for the location. Below in Step 2a are details on key metrics and measurable capabilities from PEER. You can learn about additional key performance metrics and resources at the GBCI website (see peer.gbci.org/resources).
- Establish a means to measure ongoing performance against the current baseline. The difference is the value of improvement by the organization.
- Establish goals or upper limits of performance, the potential savings or value is the difference between the current condition and the upper limit of performance.
- Install metering to increase measurement quality and scope needed to verify progress.
- Implement facility/campus wide SCADA system to gather, store, trend, and report performance measures.

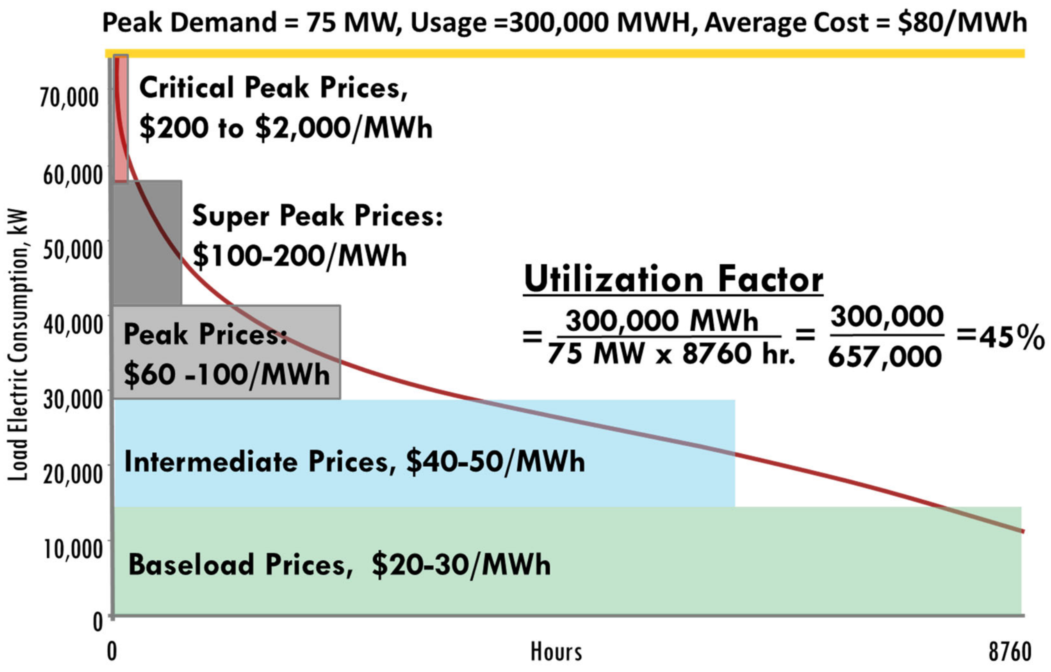
Step 2a: Performance Metrics and Capability Examples

Choosing the right metrics is key to success or achieving specific goals. The Table below provides several key metrics and capabilities from the PEER program. The Table shows how owners can establish a baseline performance for comparison to current performance and future performance targets. Users can calculate savings as the difference between baseline and current performance, as well as waste as the difference between future targets and current performance.

1. Primarily, users should track total cost of power in $/MWH for comparison to baseline conditions which change year over year due to market price changes. Wunderlich Malec created a power demand and cost simulator that estimates the baseline savings for each year based upon having no site generation.
2. Users should also track the number of outages and the average duration in minutes per year for the site and the utility supply feed. These can be compared to track improvement over utility performance.
3. Users can track islanding capability which is the total site power generation capable of islanding as a percentage of facility peak demand.
4. For resiliency WM created a set of measurable capabilities as a percentage. This includes main bus supply redundancy, distribution redundancy, switching automation percentage, and system hardening percentage, just to name a few.
5. Additional key metrics include carbon emissions in lbs./MWh compared to the regional average and renewable power percentage.
6. Another key metric is the facility utilization factor which is defined below.

Performance Criteria or Outcomes	Current/ Baseline	Dispatchable Microgrid	Target or Upper Limit
Energy Costs, $/MWh	**$100**	**$58**	**$43**
Site Utilization Factor, %	**45%**	**50%**	**55%**
Sustained Outage (min)/ (#/yr.)	**140 / 0.9**	**0 /.02**	**0 / 0**
Site Generation/Islanding %	**20%**	**100%**	**100%**
Electric Resiliency Capability, %	**10%**	**50%**	**100%**
• % Redundant main bus supply • % Redundant distribution to loads	• % Automated switching • % Hardening (underground, storm, seismic)		
CO2 Emissions, lb./MWh	**820**	**190**	**50**
Zero Carbon Power, %	**15%**	**60%**	**90%**

To understand how to reduce costs users need to understand what a load duration curve is and how it impacts your electricity costs. The figure below shows the annual power utilization curve for a large industrial/manufacturing facility. This curve plots the hourly total system demand in MW for every hour of the year from highest to lowest. Users can calculate your utilization factor by dividing your annual usage by the peak demand times 8760 hours. For the example below the utilization is about 45%. This is a low utilization factor and results in a higher average power cost. Users can make investments in peak demand reduction, fuel switching, and site generation to improve their utilization factor and lower average power costs.



Step 3: Improve Power Supply Cost, Efficiency, and Carbon

This step can have the most significant impact on cost, carbon, and efficiency. Strategies include:

- Competitive bid for a new electric power supplier with a lower carbon footprint and more efficient supply (e.g., wind, combined cycle)
- Contract for a Power Purchase Agreement for remote renewable power for a portion of the facility annual usage.
- Contract for a Power Purchase Agreement for local renewable power generation.
- Install cogeneration or tri-generation.
- Install generation that can be dispatched to reduce peak power costs, increase resiliency, and enable your facilities to purchase retail or wholesale real-time power from the System Operator power pool leveraging site generation to hedge volatile power prices.
    - Leverage proven software solutions to maximize savings and minimize carbon emissions.
    - Purchase merchant wind and solar from the wholesale real-time power pool leveraging renewable energy credits.
    - Transition cogeneration systems from baseload to real-time price dispatch.

Step 4a: Upgrade the Site Electrical Distribution System

This step is critical to achieving power resiliency and net zero as the existing site distribution will not support integration of the technologies and new loads (e.g., electrification) stemming from the pursuit of net zero. Strategies include:

- Improve electrical system safety by providing actual real-time current and voltage data that can be utilized to improve the accuracy of arc-flash and power flow studies.
- Increase electrical system resiliency and reliability - Focus on the main power sources including the main buses from the utility and any current site generation capacity. Walk down all systems and focus on the key feeder systems to the facility. Inspect the main distribution and any emergency panel backed up by site generation to ensure they support the key life safety loads most critical production systems at the site. Consider the severity of system failure to key production systems.
- Reduce electricity system losses by installing higher efficiency transformers, increasing the voltage for distribution, and other innovative means.
- Increase electrical system capacity to accommodate switching from fossil fuels to electricity. This includes developing load models for projected future loads.
- Build islanding capability – changes to electrical system to enable installation of site power generation to provide reliable islanding using local generation. Be aware that just adding site generation is typically not sufficient to enable islanding. An expert assessment of the site loads and the control system should be included as well.
- Improve power measurement and quality.
    - Install metering capable of measuring and recording all key power quality metrics.
    - Install variable frequency drives on motors.
    - Install power conditioning equipment.
    - Analyze the utility's main medium voltage feeder(s) for power quality during peak usage periods, including voltage sags, current imbalance, and other power quality issues. Site generation can be dispatched to stabilize site power quality.

Step 4b: Build Site Generation for Resiliency

Integrate sufficient site generation to enable a facility to operate during a utility outage. Islanding capability can be developed in phases, with initial emphasis on site generation and load response assets that provide a clear return on investment. Over time, islanding capability can expand to include more loads.

Islanding capability requires the deployment of a system controller to control load and balance demand and generation. Electrical system upgrades may be needed to ensure "black start" capability and to address power quality issues when in island mode.

Strategies to integrate generation to operate a facility as an island during a utility outage include:

- Modify site electrical systems to support integration of site generation islanding capability.
- Onsite generation is typically installed to provide backup of the main bus serving the facility critical production loads.
- Evaluate site generation with advanced hourly modeling to estimate the savings from various site generation options. Site generation can be used to avoid RSO coincident peak capacity charges and reduce host utility distribution charges. It can be deployed to improve facility power quality and provide full backup of the main bus serving the facility critical production loads.

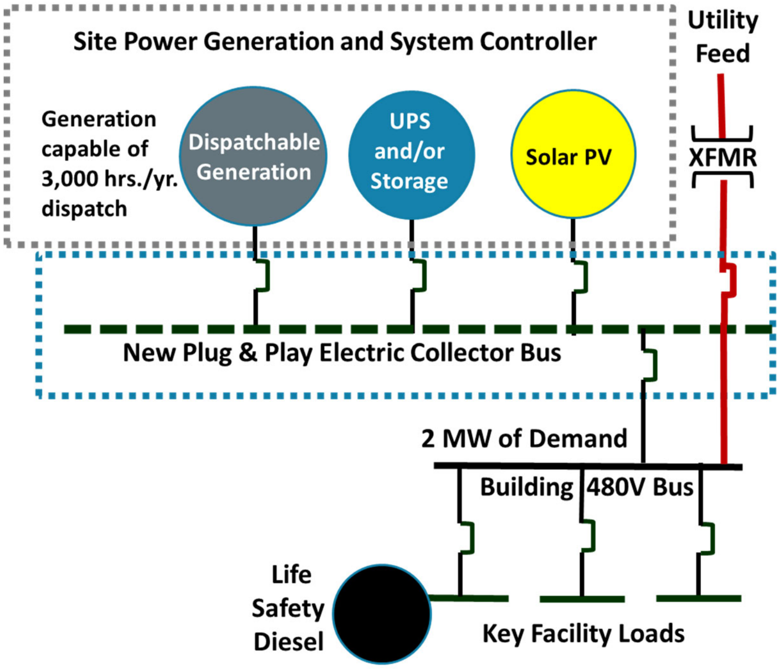
Step 4b: Build Site Generation for Resiliency (Cont'd)

- There may also be potential for added savings from generation heat recovery.
- Diesel backup is typically limited to only five hundred hours per year due to air permit limits on run hours. As a result, site diesel backup generation cannot be relied on for economic dispatch.
- Natural gas generation enables increased savings due to the ability to permit additional operating hours.
- Installing cogeneration or trigeneration which is the recovery of generation waste heat to produce heating and/or cooling.
- Install solar PV to improve carbon footprint.
- Consider biomass to leverage a renewable fuel.
- Install flywheels to stabilize power quality during grid connected and islanding modes.
- Be aware of other Distributed Energy Resources (DER) that may provide additional strategic or operational value.

Step 5: Add Economic Dispatch to Reduce Costs and Generate Revenue from Grid Service

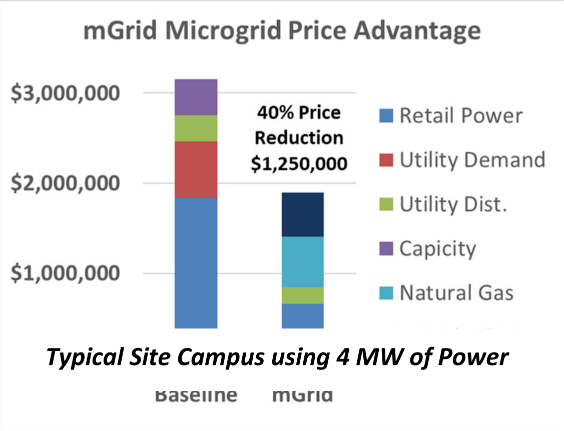
This step addresses managing costs, generating revenue, and improving the efficiency of peak power demand usage. Peak power costs can exceed $2,000/MWh during periods of extreme weather and grid supply constraints. In addition, several Regional System Operators (RSO) charge capacity charges based on a few hours of the highest peak use on the system in a year. Facilities can avoid RSO capacity and utility demand charges while also receiving payments for providing demand response services. Strategies include:

- Automated control of non-essential loads to reduce peak demand or respond to RSO and utility curtailment signals.
- Install dispatchable onsite generation (i.e., dispatchable microgrid) to reduce system operator and utility charges. Switching from diesel backup to natural gas fueled backup increases dispatchable hours and opportunity for cost reduction. This is critical during major heat or cold waves that can cause power prices to spike for days or weeks, causing end user power prices to quickly increase. See the adjacent figure for a simplified single line diagram of a dispatchable microgrid.



Step 5: Add Economic Dispatch to Reduce Costs and Generate Revenue from Grid Service (Cont'd)

- Install a system controller to:
    - Dispatch real-time generation to avoid utility, state, and system operator charges.
    - Dispatch real-time generation to avoid peak power cost and create revenue by responding to utility and system operator demand response requests (i.e., grid service).
    - Dispatch thermal or electric storage.



Typical Site Campus using 4 MW of Power

Step 6: Implement Operational Efficiency and Risk Management Program

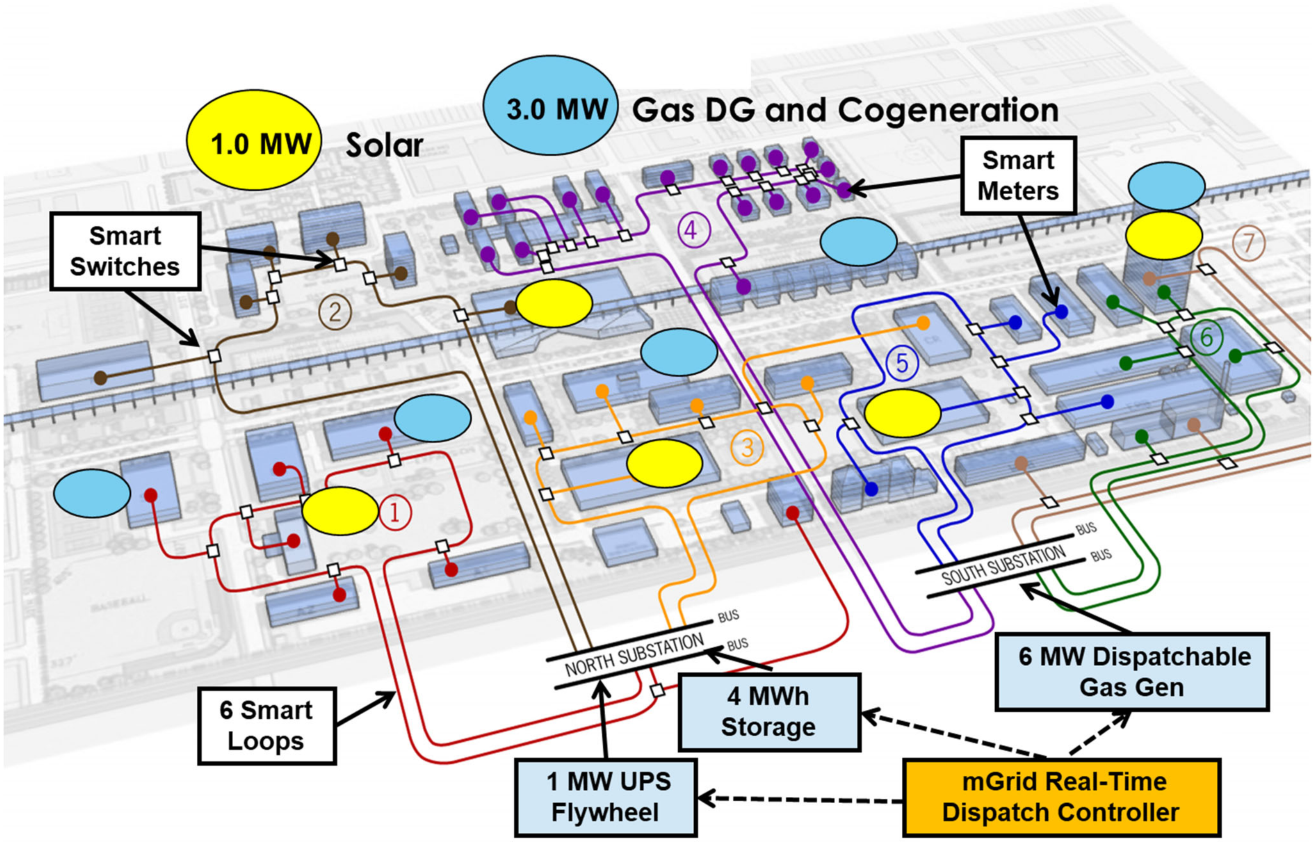
This step is designed to eliminate waste and risk. Strategies include:

- Establish failure analysis program to track corrective action from failure root cause analysis.
- Perform a risk assessment leveraging six sigma or similar methods. This includes identifying, evaluating, and addressing risks.
- Fuel switching from electric chillers to steam chillers, gas chillers, and/or thermal storage.
- Automate processes to reduce labor costs and errors.
- Review production processes to reduce the total energy consumed by measuring and trending power usage by area or process, to improve operational practices, or identify equipment degradation that may cause increased power usage.
- Use accurate measurement by submetering facility loads to evaluate electrical system capacity to accommodate new loads. Without this data, facility engineer's conservative assumptions will lead to higher capital costs for electric system upgrades to support new loads.
- Analyze previous sustained power outage events, as well as momentary outages, to assess the root cause and quantify the economic impact. Quantifying the economic impact of power interruptions will provide users with financial data needed to justify investment in power system upgrades.
- Track and review electrical equipment failures to determine root cause of failures and define corrective action. Poor power quality can damage electrical equipment and cause process system trips.

Putting it All Together: Microgrids

The steps above can be implemented in phases. Ultimately resulting in the building of a site microgrid that enables fulling islanding capability, provides for resiliency, and enables economic dispatch to minimize cost and carbon. The figure below depicts the Illinois Institute of Technology (IIT) microgrid designed by Wunderlich Malec and Dr. Shahidehpour from IIT. This microgrid includes:

1. Smart meters to enable real-time performance measurement.
2. 6,000 kW of dispatchable gaseous fuel generation with utility interconnect at the substations to reduce peak power costs and provide islanding capability.
3. An Uninterruptible power source to improve power quality and eliminate momentary interruptions.
4. Distributed solar generation to reduce cost and carbon.
5. Distributed dispatchable generation to increase savings and resiliency,
6. Electric distribution loops enabling two-way power flow and redundant feeds to each building to automatically reroute power if a feeder is damaged or overloaded.
7. Automated switching to instantly balance power flows and switch power sources (e.g., solar shortages and solar surpluses) and finally.
8. A Real-time system controller to:
    a. dispatch generation assets in real time to reduce peak power costs and provide a hedge for volatile but lower cost real-time power and
    b. control of facility loads to provide demand response and manage power flows in both utility connected and islanding modes.



This Guide to Competitive Sustainable Power Authored By:

- John Kelly, PE, BSME
  email: john.kelly@wmeng.com
    - Co-developer of the GBCI PEER program resources
    - registered six sigma green belt
    - Patent for mGrid®
    - Certificate in Environmental Engineering, Illinois Institute of Technology
    - Certificate in Electricity Restructuring, Illinois Institute of Technology
    - Chairperson of the Board for non-profit LEAN – Local Energy Aggregation Networks

- Greg Rouse, PE, MBA, BSME
  email: greg.rouse@wmeng.com
    - Co-developer of the GBCI PEER program resources
    - registered six sigma green belt
    - Holder of 5 Patents

- Tim Grigg, PE, MSME, MBA
  email: tim.grigg@wmeng.com

- Mark Cosentino, BSEE
  email: mark.cosentino@wmeng.com

APPENDIX A:

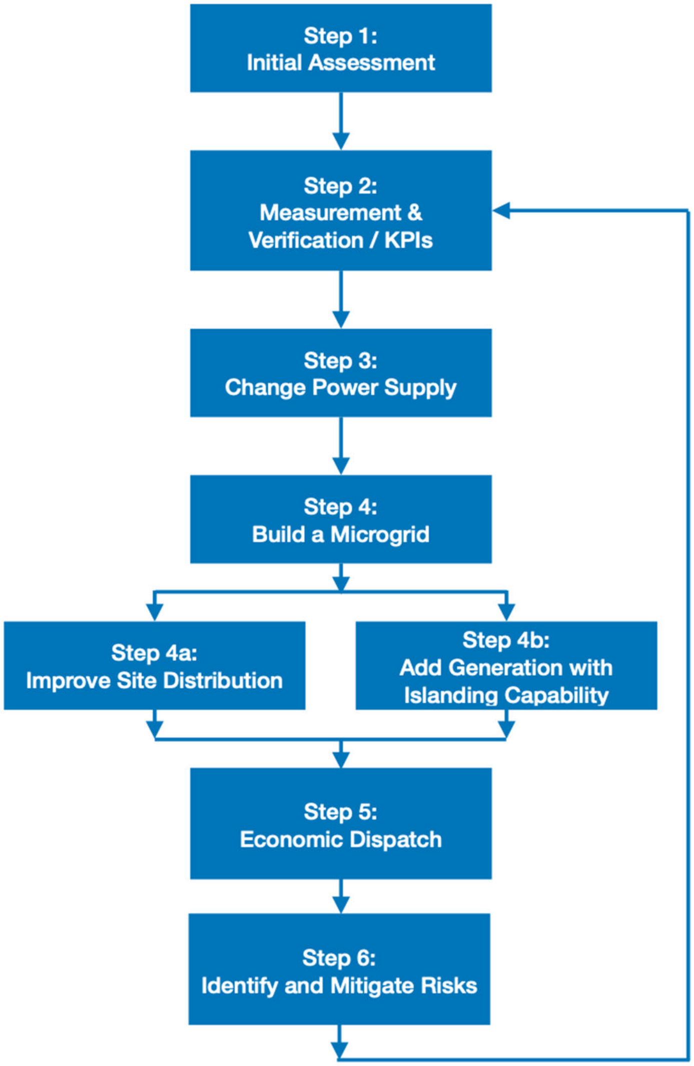
Resources Needed to Develop and Implement Sustainable Energy Plan

Your selected team members should have the following skill sets and where lacking select industry specialists as consultants to complement your in-house capabilities. The team with support consultants should include:

- Expert knowledge in power distribution, reliability and efficiency designs and benefits alternative energy solutions.
- Proven experience in the design and delivery of power generation systems.
- Access to software and tools that can provide analysis and performance of energy supplies and generation. Tools and knowledge to optimize your sustainable energy systems while maximizing savings to improve investment returns.
- Owner's engineer to optimize a design plan and assist with a competitive implementation process.
- They should be experienced in the application of the worldwide microgrid standard (PEER),https://peer.gbci.org/leading.

APPENDIX B:

Sustainability Guide Flow Chart & Checklist



Step 1: Energy Team Assessments;

- ☐ ISO market options
- ☐ Utility rate & procurement
- ☐ Space and fuel supply
- ☐ Interconnect
- ☐ Power models and simulations of curren and future state

Step 2: Establish Goals, Measure & Verify;

- ☐ Determine KPI
- ☐ Determine performance.
- ☐ Establish goals.
- ☐ Upgrade monitoring
- ☐ Establish verification/ERP

Step 3: Change Power Supply;

- ☐ Change supply contract
- ☐ Power purchase agreement
- ☐ Day-ahead
- ☐ Real-time + REC

Step 4: Build a Microgrid

4a; Improve Site Distribution

- ☐ Power Quality improvements
- ☐ Capacity upgrades
- ☐ Redundant feeds
- ☐ Auto restoration

4b; Add Generation with Islanding

- ☐ Solar PV + Electric storage
- ☐ Renewable fuels
- ☐ Backup power (< 500 hours, diesel fuel)
- ☐ Dispatchable power (>500 hours)

Step 5: Economic Dispatch;

- ☐ Economic dispatch of DER
- ☐ Master controller
- ☐ Capacity avoidance
- ☐ Demand response

Step 6: Identify and Mitigate Risks;

- ☐ Automate & Optimize operation
- ☐ Safety / FMEA
- ☐ External risks