Introduction

A Real Time Energy Management (RTEM) system combines the capability to supervise and dispatch on-site generation resources with the monitoring of various building automation systems responsible for mechanical plants and other energy-consuming equipment. RTEM, with its cloud-based integration capabilities, is uniquely suited to provide the coordination and optimization required to maximize the economic value of on-site generation. An RTEM system helps with “value stacking" (i.e., leveraging the same equipment, system, or plant to deliver multiple benefits that maximize economic impact).

RTEM’s capabilities in integrating a wide range of data sources not limited by physical boundaries is a key differentiator compared to a building automation system (BAS) that resides within the four walls of a building.

RTEM and Planning and Sizing of On-site Generation

Today, readily available on-site generation technologies allow for the dynamic mixing and matching of energy sources to meet a building’s need. Usually, cost avoidance is a primary consideration for selecting energy resources best suited to meet real-time and forecasted demand; however, start-up time, availability, reliability, suitability for emergency power, and reducing the carbon footprint are also factors building operators must consider to select the optimum on-site generation resources.

Companies can benefit from the insights gained by an RTEM system to meet their on-site generation goals—whether to reduce energy costs, enable demand management, build a reserve against outages, hedge against future cost fluctuations, or support the organization’s environmental objectives by using the least carbon-intensive fuel.

Significant time, effort, and investment are required to adopt on-site generation resources. For large commercial properties such as hospitals, shopping malls, or office parks, on-site generation requires a capital investment that can be in the range of seven figures and competes with other projects for funding. Consequently, it is prudent that financial and energy impacts be evaluated through a systematic approach that considers each site’s unique characteristics. An investment-grade engineering study is often employed to collect site data (including multiple years of energy consumption data) and site operational information, evaluate the scheduling of major electric and thermal energy consuming equipment and forecast future site consumption patterns and trends.

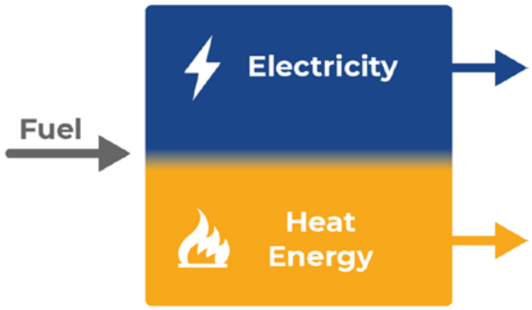
RTEM is one of the most highly refined data sources available to support an investment-grade study, providing key data: .

- Building electricity and thermal usage profiles for multiple years
- Actual operating schedules for key building equipment and plants
- Efficiencies of major equipment and plants over actual loading profiles
- Predicted load growth including weather forecasts
- Integration of on-site energy generation into building operations

RTEM is also a useful tool to provide evidence of the building operator's performance in managing building equipment and plants.

RTEM + Combined Heat and Power

An on-site combined heat and power (CHP) plant provides electricity and heat energy to the building. The economy of the total energy supplied by the CHP plant depends on operating the CHP plant at its highest efficiency, converting fuel to electricity and heat for as long as possible.



Usually, this requires the energy produced by the waste heat of the CHP plant to be consumed completely in support of building functions. A CHP plant's overall efficiency when its waste heat offsets another fuel usage can be in the range of 80% to 85%.[1]

When the CHP plant's heat energy output is radiated into the atmosphere, the total efficiency of the CHP plant drops quickly. A CHP plant's overall efficiency, when all of its waste heat is vented without offsetting another fuel, can be as low as 30% to 35%.[2]

Additionally, if the waste heat of the CHP plant is not consumed or removed, the plant's electricity production has to be reduced to allow the plant to operate continuously without shutdown or equipment damage.

The ability to absorb the CHP plant's heat energy output for useful building functions is often the limiting factor for sizing a CHP plant.

[1] Midwest CHP Application Center
[2] Ibid

Cloud-based RTEM readily integrates the monitoring of the CHP plant by connecting the plant control system to the building RTEM system. A separate gateway can also be installed to deliver the CHP plant performance data to the RTEM cloud if local integration is impractical. In either instance, the data from the CHP plant is incorporated into a common platform, allowing for the integration of analytics, cloud-based control sequencing, alarming, visualization, and reporting capabilities of the RTEM system.

When a CHP plant is operated independent of the building systems, the CHP plant’s built-in controller is only able to optimize the plant as an isolated entity. Optimization opportunities to extract the maximum value from the CHP plant is only possible through integration with the building it serves.

Examples of RTEM benefits enabled through tight integration include:

- Balancing between the CHP plant’s heat output and the building’s own heat-producing boiler, furnace, and hot-water equipment, to always use the lowest cost fuel overall
- Incorporating the CHP plant’s thermal storage to smooth out the production starts and stops of the building’s own heat energy-producing equipment
- Intelligent sequencing of multiple CHP units within the plant to meet the thermal and electric loads of the building
- Applying forecasting to the scheduling and sequencing of the CHP plant
- Incorporating the CHP plant into the building’s maintenance rotation, allowing for mutual support of the building’s heat energy-producing equipment and the CHP plant
- Providing performance monitoring of the CHP plant as part of the overall energy performance of the building, not as standalone equipment

Often the CHP plant is operated as a “start and forget” resource, butproper maintenance and ongoing commissioning are critical to maximize the return on investment of the CHP plant.

The CHP plant’s performance metrics may be visualized in real-time, or accumulated over a prescribed duration, such as monthly or annually, and distributed in charts, tables, and summary reports. Deviations of the CHP plant’s expected operating and economic metrics could trigger alerts, notifying operators for immediate remediation as necessary.

RTEM + Solar PV Generation

A solar photovoltaic (solar PV) generation system is eminently reliable as an on-site generation resource, and is cost effective throughout New York State. A wide variety of installation options are available, including rooftop, ground-based and canopy/awning structures to match the available spaces, façade, and architecture of the building.

Solar PV-generating power, when sufficient solar irradiance is available, produces energy on an intermittent basis. Production planning using forecasting is necessary to maximize the economics of the energy generated.

It is insufficient to monitor a solar PV system using only one energy (kWh) meter connected to measure the system's accumulated production. Understanding the production time profile of the solar PV system is necessary to identify and eliminate deviations between the theoretical performance, as designed, and the actual performance of the system.

For example, the ambient temperature surrounding the solar panels and whether the panels are operating at their maximum power point are data critical to characterize the economic performance of a solar PV system. An RTEM system is capable of acquiring a rich set of time-series data associated with a solar PV system, and to integrate local weather data for the actual solar irradiance level, allowing building operators to verify the availability and production of the solar PV system. Excess degradation in the efficiency when converting solar irradiance to electrical power, after factoring in the effect of ambient temperature, can signal the operator to perform routine maintenance such as cleaning the panel.

Other benefits available when an RTEM system manages solar PV on-site generation include:

- Forecasting (e.g., day ahead) of availability and estimation of production
- Availability and production status in real-time
- Real-time status of the produced power, whether it is consumed or exported
- Accounting for avoided purchased power and energy from the grid
- Adjustments in renewable production levels according to the lowest energy cost
- Shifts in loads to match the availability of solar PV power

RTEM + Electric Energy Storage

On-site electric energy storage is an essential technology to expand the use of solar PV generation. Solar PV generation is an intermittent energy producer and is not dispatchable, (e.g., called upon to generate power to match load demand), such as when solar irradiance is lacking (e.g., at night) or when the power is not needed (e.g., unoccupied weekend hours).

Consequently, the electric storage system is necessary to store solar PV-produced energy for use during times when solar PV is not producing.

Battery storage is well known for its high-energy density and flexible application. The stored energy can be converted to satisfy a variety of uses, lowering demand or supplying on-site consumption. A wide range of battery-based systems is available, commercially pre-integrated with renewable energy resources and CHP plants, or as a stand-alone system.

Battery storage can be a high-cost option requiring investment-level analysis and justification. As previously mentioned, an RTEM system offers a highly refined source of data to support the investment-level analysis. Once installed, battery storage immediately becomes a high-value asset. An RTEM system provides the necessary data to support the measurement and verification (M&V) phase of the project. Battery storage has a finite capacity that has to be managed between charging and utilization. RTEM provides the insight and analytics necessary to monitor the state of the battery and integrate battery systems as an on-site energy resource to ensure the economic benefits of the resource are maximized.

RTEM + Thermal Energy Storage

Although most businesses only consider battery storage for energy storage, other options are available. Some of these options leverage existing capabilities and can be used to shift or reduce demand or lower consumption during on-peak hours with little to no incremental cost.

Thermal energy storage does not store or generate electricity, but accumulates heat or cold energy for later use. Storage using existing thermal mass offers a low-grade form of energy. While less flexible than dedicated energy storage plants, thermal mass storage still may capture sufficient energy to avoid demand charges and provide cost savings.

Using the existing building thermal mass for short-term storage is free or costs very little. An RTEM system is very useful to identify the capacity of these types of energy storage, the capacity of which changes dynamically depending on weather, level of occupancy or building activity.

Examples of existing thermal mass that can be characterized and used as energy storage by RTEM are:

- Building envelops (as thermal storage of the internal environments through temporary heating and air conditioning setpoint changes, pre-cooling, and pre-heating during the off-peak period). As weather conditions permit, this strategy can be especially effective when combined with free cooling and heating.
- Temporarily lowering the setpoints of refrigeration equipment, such as walk-in coolers and freezers during off-peak periods, to allow for a reduction in demand and consumption during the on-peak period while maintaining the food preservation environment.
- Temporarily generating excess chilled or hot water during off-peak periods to store cooling and heating energy for on-peak use.

- Generating and storing compressed air during off-peak periods to store mechanical energy for later on-peak use.

Ideally, new buildings are purposely designed to maximize thermal storage capacities. Incorporating passive solar features and using ground temperature for its tempering effect year round adds to the options available to an RTEM system.

Adding thermal energy storage may also be a less costly option to shift demand or to reduce on-peak consumption. A number of strategies including adding insulated storage tanks for chilled or hot water to buffer chiller and boiler plants may offer shorter paybacks and can be more immediately implemented without the complexity of installing or replacing major equipment or plants. An RTEM system is critical for initially characterizing building consumption and usage patterns to identify thermal energy storage opportunities and in managing new storage resources to optimize usage under a dynamically changing building environment.

RTEM and Net Zero Energy Building

If your organization's objective is to operate your facility as a net zero energy building (NZEB), according to the definition[3] specified by the U.S. Department of Energy (DOE), RTEM is an invaluable tool for your organization's stakeholders. In particular, RTEM ensures energy savings within the building are maximized before relying on the renewable energy resources to supply the remaining energy requirements. Additionally, RTEM could automate the accounting to demonstrate a building's NZEB performance on an ongoing basis, simplifying what otherwise would be a manual reporting effort.

Figure 1 is a simplified diagram of the site boundary of energy transfer for zero energy accounting published by the DOE. RTEM integrates the monitoring of all the energy quantities delivered to the building and tracks the energy excess exported by the building.

Additionally, RTEM automates the net accounting, applying the appropriate source energy conversion factors[4] in real-time to provide visual confirmation of NZEB status through RTEM dashboards, and is a high-quality data source to verify compliance for NZEB certification.

This valuable data is gathered on a 15-minute or greater frequency and is stored in the cloud indefinitely.

[3] https://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

[4] Table 1 from A Common Definition for Zero Energy Buildings, USDOE, September 2015.

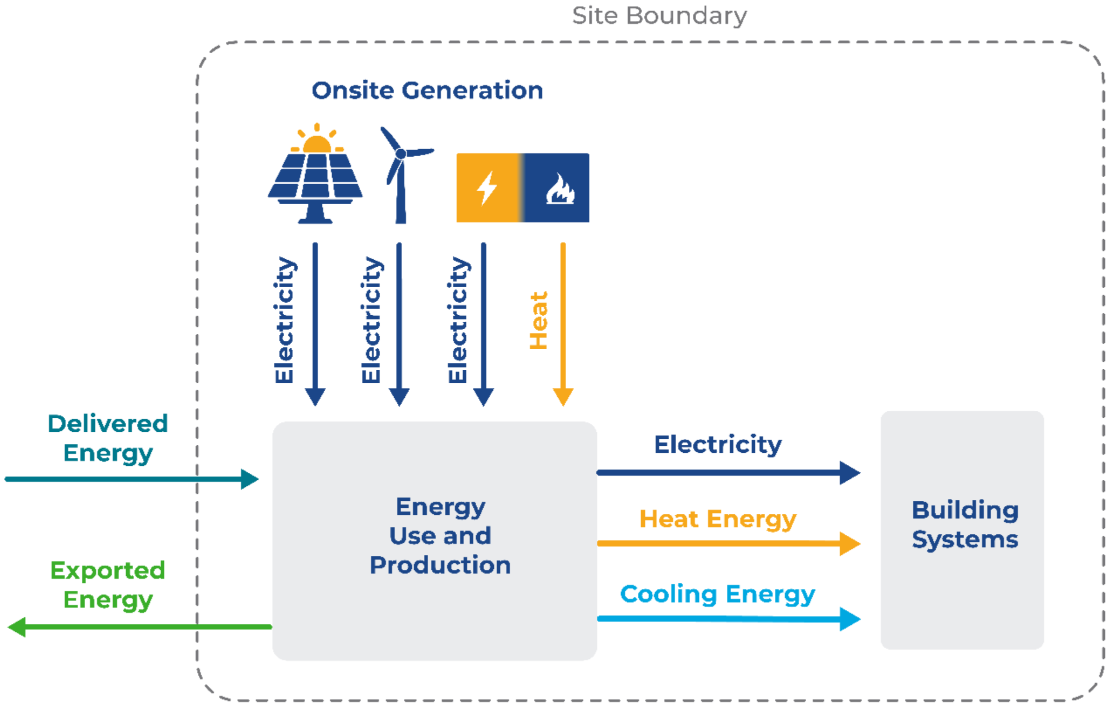


Figure 1: Site Boundary of Energy Transfer for Zero Energy Accounting

Control and System Integration

Beyond whole-building accounting, RTEM integrates the various control and automation systems, sub-meters, and sensors, enabling the continuous breakdown of the building's consumption to meet its various critical functions. RTEM is capable of monitoring all major building equipment ranging from comfort heating, cooling, and ventilation to lighting, plug loads, domestic hot water, and process loads (e.g., IT, healthcare, food preparation). This level of monitoring is essential to achieve the energy efficiency in building scheduling, operations, and maintenance necessary to support NZEB status.

The National Institute of Standards and Technology (NIST) has published the "Measurement Science Roadmap for Net Zero Energy Buildings[5]." The National Science and Technology Council also emphasized the need for improved monitoring techniques, metrics, and models to assess the energy performance of NZEB. A judicially selected and implemented RTEM system offers many of the attributes identified in the NIST roadmap.

[5] http://ws680.nist.gov/publication/get_pdf.cfm?pub_id=905024

According to NIST,[6] buildings could become "integrated generation units" in the future, using renewable energy technologies and CHP systems to enable active participation in utilities' energy management activities. Ultimately, buildings would become entirely self-sufficient entities with dedicated central power generation facilities providing a minimal amount of additional electricity.

In the following list,[7] NIST identified critical future attributes required in the control and integration of on-site power generation technologies to achieve NZEB:

- Software advances that enable accurate predictions of the energy production potential associated with various alternative energy sources
- Means for control and monitoring so consumers can regulate their own usage and induce long-term changes in behavior
- Feedback to stakeholders that verifies the actual power generation of renewable energy systems compared to predicted/perceived performance
- Advanced on-site power generation control systems
- PV, solar thermal, and energy storage systems that are fully integrated to optimize overall performance

RTEM would not only address the issues associated with the control and integration of on-site generation resources and the short-term challenges identified in the NIST report;[8] it would also provide a platform to address the medium and long-term challenges as solutions are identified.

Revenue Source

So far, most of the economic benefits presented for on-site generation resources are aimed at risk management or to reduce the purchase of grid-supplied power; however, leveraging on-site generation resources to participate in utility and ISO-administered demand management programs, such as demand response, provides an opportunity to generate revenue with these resources.

An RTEM system allows for the automated participation in demand response or other demand management programs. By monitoring and managing building loads and on-site generation resources on a single platform, the curtailment quantity available for participation may be derived from load

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[6] Measurement Science Roadmap for Net-Zero Energy Buildings, Workshop Summary Report, March 2010 (NIST Technical Note 1660_M0318420pm.doc)
[7] Ibid
[8] Ibid

reduction, power generation, or both. This level of flexibility and intelligence allows for maximized participation without risking critical building functions.

Value Stacking

An RTEM system can monitor the production of solar PV on-site generation while also helping to shift load to avoid peak time-of-use charges, and concurrently participate in demand response programs. The quantity of PV production and timing depends on real-time dynamic conditions such as cloud cover, ambient temperature, load requirements, and other real-time factors. Without an RTEM platform, this level of complex coordination could result in missed financial opportunities and negative impacts on equipment performance or operating life.

Value stacking is complicated. RTEM is capable of continually balancing multiple value streams simultaneously, factoring in competing considerations and constraints, while also monitoring the dynamic conditions of the building. Predicative analytics (such as modeling) and machine learning (such as determining optimal operating settings for major plants) are becoming available for the implementation of value stacking in commercial buildings.

In the past, on-site energy resources may have been difficult to justify economically, because analyses are based on a single-value or one-purpose scenario. Today, balancing time-varying energy rates based on dynamic market conditions between supply and demand, maintaining a comfortable and healthy building environment, and ensuring critical functions are supported in the event of emergencies—while participating in demand response programs—are all available options. An RTEM system is becoming a necessary and critical tool to monitor and manage all of the complex decisions requiring data from widely distributed data sources.