Community and Multi-building Development's Key Role in a Net-zero Energy Future

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ABSTRACT

It is typically assumed that the renewable energy required by net-zero energy buildings is produced by photovoltaic (PV) panels located on individual rooftops. However, this paradigm may produce unintended consequences by inducing sprawl and the development of low-density, low-rise buildings with large roof areas to support PV arrays. Furthermore, if other building energy systems, such as heating and cooling, are constrained to the needs of individual net-zero buildings, the benefits of diverse multi-building load profiles will fail to be realized.

Instead, a more sustainable approach could be achieved through multi-building systems which share renewable energy production and other energy systems, obviating the need for individual buildings to develop separate, small-scale solutions, and placing net-zero goals in reach of higher-density urban areas. Further, a multi-building approach to development may have other added benefits, such as reducing strain on transportation infrastructure and promoting community-oriented development.

In a recent report developed by the zero energy Commercial Buildings Consortium (CBC), industry stakeholders underscored the opportunity and multiple benefits of multi-building systems, including the ability to aggregate and balance electrical and thermal loads, efficiencies in shared energy management and equipment maintenance, sharing of other resources, and elimination of redundant equipment.

However, a number of technical as well as market-oriented challenges persist in making the important shift from individual building design and construction to multi-building configurations and community develop-

ment. These barriers include multiple ownership and incentive structures, technical hurdles in applying multi-building systems to existing buildings, and the need for improved waste heat technologies. This article will discuss these challenges in detail, as well as explore practical, near-term actions that can be taken at the state, regional, and national levels to move the commercial building sector along this path.

THE CBC

The CBC is a public-private, broad-based stakeholder group whose objective is to assist the commercial buildings sector in achieving greater efficiencies in buildings in the short-term, and ultimately net-zero energy buildings in the long-term. Members include building owners and operators, architects and engineers, manufacturers, financial institutions, policy makers, research institutions, and non-governmental organizations. In 2009, the CBC was tasked by the U.S. Department of Energy (DOE) to assess the current status of net-zero technologies, systems, and practices, and to identify barriers and solutions to market-wide adoption. The CBC convened its volunteer members in a variety of working groups, including one addressing multi-building issues. This article will summarize and outline the key findings of this group. The complete report of CBC findings can be found in its report [1].

MULTI-BUILDING SYSTEMS

The concept of multi-building systems as they relate to net-zero energy buildings is very broad, and the CBC Multi-Building Working Group explored a variety of topics such as shared building control systems, continuous commissioning systems, virtual distributed energy and controls networks, enterprise reporting, and utility and regulatory structures. This article will focus primarily on topics related to groups of nearby buildings such as communities, campuses, or districts that are connected via physical, electrical, or thermal energy systems.

Optimizing the net-zero energy attributes of groups of buildings over individual buildings has some inherent advantages. For example, it is typically assumed that the renewable energy required by net-zero energy buildings is produced by photovoltaic panels located on individual rooftops. This approach favors the development of low-density, low-rise buildings with large roof areas. A more sustainable, high-density approach could be achieved through multi-building systems that share renewable energy production resources, such as centralized biomass heating plants.

Centralized renewable energy systems at the community, campus, or district scale could be sited where most advantageous, without requiring individual buildings to develop separate, small-scale solutions. This approach is key to making net-zero energy more feasible and desirable in high-density urban settings, where individual net-zero buildings may be difficult to achieve due to a high ratio of floor space to roof area, or may be objectionable in terms of encouraging low-density sprawl.

In addition to renewable energy systems, multi-building energy systems consist of shared thermal distribution loops for heating, cooling, or heat pumps; centralized heating and cooling plants; centralized combined heat and power plants (cogeneration); centralized combined heat, power, and cooling plants (trigeneration); district heat pump systems; and shared information systems for building energy management.

ADVANTAGES OF MULTI-BUILDING SYSTEMS

The primary advantages of multi-building systems include the following:

Source Fuel Diversity

In centralized systems, the source energy fuels used to produce electricity, heating, and cooling can be switched more readily than with individual building systems. This allows energy sources to change with availability, market conditions, and the need for renewable energy supply.

Load Aggregation

When the thermal and electric needs of multiple buildings are summed, there are often complementary attributes, such as the flattening of electric profiles and the distribution and sharing of excess thermal energy. Net-zero energy buildings can benefit enormously from the well-designed collection, distribution, and utilization of waste heat among multiple buildings.

Shared Energy Management

It is often more economical to install energy management systems in multi-building systems than in individual building systems. This improves performance and energy efficiency.

Centralized Equipment Maintenance

It is less expensive to service larger equipment located in a centralized area than numerous smaller distributed systems. Central systems typically receive better and more frequent maintenance, improving energy efficiency.

Centralized Equipment Quality

Multi-building equipment is usually larger, of higher-quality, and more reliable. Larger equipment is often more energy-efficient.

Peak Thermal Load Diversity

The coincident peak heating or cooling load of multiple buildings together is less than the sum of all the individual building peak loads. Therefore, the total installed capacity of the shared heating and cooling systems is smaller, and often costs less.

Resilience and Redundancy

In centralized systems, electricity, heating, and cooling are typically produced by multiple generation units (e.g., generators, chillers, boilers). If one unit should fail, there are more available to carry the load. Individual building systems usually rely on single units and have no capacity for back-up in the event of equipment failure.

BARRIERS TO MULTI-BUILDING SYSTEMS

The majority of barriers to multi-building systems tend to involve societal, economic, or private ownership issues. Technology barriers are somewhat secondary, although there is ample room for innovation.

Multiple Building Development

Generally speaking, buildings are designed and constructed individually. Outside of zoning law requirements, there is little regard for the attributes, needs, or beneficial resources of nearby buildings.

Developing buildings individually is *suboptimal,* and there is lost opportunity for the benefit of shared resources and economies of scale. If groups of buildings were planned and designed on a larger scale, the energy solutions would likely be more effective than those of individual buildings.

Multiple Ownerships

It is difficult and complicated to share energy systems across multiple buildings with multiple owners. Physical systems have to be installed on private property, legal contracts have to be agreed upon, and complex energy flows must be measured and assigned value. Managing multiple ownerships is complex, yet aggregating thermal and electrical loads over multiple buildings leads to more optimal systems. At present, the greatest promise for multi-building energy systems lies with single-owner campuses.

Obscurity

Multi-building systems tend to be overlooked. There is a fairly limited application and history of these systems in the U.S., particularly with regard to commercial buildings. Multi-building solutions tend to get lost between the divisions of building research and hence are studied less than individual buildings solutions. Multi-building solutions are frequently absent from energy advocacy efforts, utility and public benefits programs, and green building rating systems. Traditional building design processes often do not consider multi-building energy solutions and lack powerful and flexible analysis tools to evaluate their potential within an integrated design process.

Existing Building Challenges

Applying multi-building systems to existing buildings can be difficult. It is usually not economical to connect existing buildings to multi-building systems until the individual building systems are at the end of their useful life. This moment of opportunity occurs every 10-20 years. Individual building owners must be convinced of the benefits of a retrofit, and they must believe in the long-term economic viability of the entity owning and operating the multi-building system. Creating a new multi-building system is capital intensive, involves considerable business risk, and must occur at sites where there is a high energy demand density. When new systems are established within existing neighborhoods, there can be conflicts over site emissions, fuel delivery, and aesthetics. Also, installing underground distribution systems in existing urban environments is challenging, as traffic disruption and damage to existing underground utilities must be minimized.

New Technology Development

Some multi-building systems, such as district steam, have changed little in over a century. While these are well-known and reliable systems, there is a need to develop new technologies. The ability to gather, distribute, and utilize waste heat is of particular importance to net-zero energy buildings. Most buildings contain many sources of excess heat that is rejected to the atmosphere, rather than being re-used or converted into other forms of useful energy. The energy entering a building needs to be squeezed for every drop of useful work before it is rejected. Promising systems to assist with that process include water-source heat pump loops, geothermal heat pump loops, energy recovery systems, thermal dehumidification, novel energy cycles, and others.

INDUSTRY RECOMMENDATIONS

Working Together

State, regional, and national building energy programs should coordinate efforts towards enhancing multi-building energy systems programs. Currently, efforts are often directed toward single-building solutions, while multi-building issues are generally overlooked. A coordinated effort would serve to enhance research, development, demonstration, and education efforts that specifically focus on multi-building technology and policy development. The following paragraphs include steps relevant to such an effort.

Evaluation of the Potential

Assess the potential for municipal and community-based shared energy systems. Gather models of existing community-based energy systems from state and local jurisdictions. Evaluate shared challenges such as siting issues, emissions requirements, fuel delivery, distribution system right-of-way, metering, and customer needs. Delineate barriers to the development of municipal, neighborhood, and private-sector small-scale energy systems. Investigate approaches to the effective integration of existing buildings into multi-building systems.

Complementary Building Types

Research and determine optimal aggregations of building types for shared energy systems. Develop optimal groupings of buildings that aggregate ideal thermal and electrical load shapes. Determine what building types are complementary to sharing waste heat or flattening electric demand profiles, and what type of communities these buildings would create. Evaluate the effect of climate on new building developments versus that on existing buildings. Assess the potential energy and economic savings. Determine methods for designing new developments that would allow for future adaptation to multi-building systems.

Research and Development

Enhance existing research and development in alternate thermal recovery, distribution, and utilization technologies. Determine common sources and uses for thermal energy recovery and exchange (with or without power generation) at the building and multi-building levels. Develop recovery devices that can be applied to the harvesting of all sources of waste thermal energy in a building. Develop energy conversion devices that can effectively utilize the waste thermal energy in new and innovative ways. Research and improve approaches to district geothermal heat pump systems.

Energy Storage

Determine the potential for active and passive energy storage and explore approaches for its application, both thermal and electrical, at the building and multi-building levels. Evaluate technology options, energy savings potential, and the feasibility of shared daily and seasonal storage systems.

Renewable Energy Systems

Determine the potential for shared renewable energy resources. Investigate the challenges to integrating on-site and grid-connected wind, solar, geothermal, and biomass resources at the building and multi-building levels. Evaluate complementary building types, renewable energy sources, and distribution systems. Assess the advantages of multi-building renewable energy systems over single-building renewable systems.

SUMMARY

Multi-building systems offer many advantages in attaining net-zero energy status: fuel diversity, load aggregation, improved equipment quality and maintenance, reduced capacity, and less redundancy. Expanding the application of these systems is hampered by a history of one-at-a-time, single-building development and ownership. Greater awareness of multi-building systems within energy programs, greater knowledge of multi-building benefits and applications, and improved technologies will aid in overcoming these barriers.

CONCLUSIONS

Multi-building energy systems offer a number of advantages over single-building solutions, yet significant barriers exist to widespread adoption. The recommendations presented here offer a starting point for overcoming these barriers.

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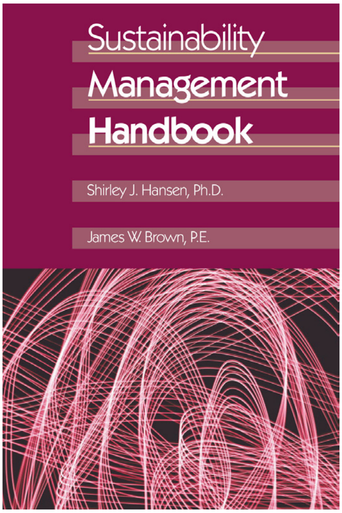

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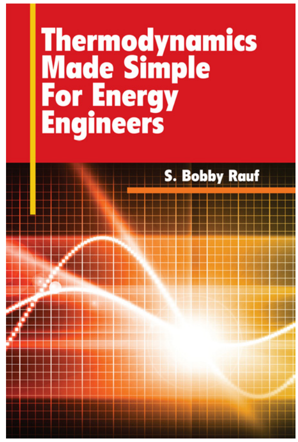

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