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NET ZERO COMMUNITIES: ONE BUILDING AT A TIME

Issue Brief

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INTRODUCTION

Net zero energy communities are the next frontier in energy efficiency and sustainability. Community planners, investors, building owners and occupants increasingly recognize the potential for net zero energy buildings to help achieve sustainability goals. Achieving net zero at the community scale presents unique challenges as well as opportunities. A key challenge is the scope of the effort, requiring energy efficiency optimization of not one but all existing buildings within the community. However, achieving net zero can be more cost-effective at a community scale than for a single building because it opens up opportunities for both cost-effective renewable energy and economies of scale in technology procurement and deployment. Also, different buildings (commercial and residential) with different occupancy patterns can be balanced to flatten load profiles across a community, because time of use is different for each.

Communities that move to net zero energy often do so both because they want to be green and because of the potential for increased real estate asset values, improved building comfort, more energy self-reliance, and lower energy and maintenance costs. In addition, the energy savings from a net zero energy building can result in a lower life-cycle cost for the building. Initial studies show that energy efficient green buildings have greater market value, including rental rates 2 to 17 percent higher and occupancy rates 2 to 18 percent higher (IBE 2011a). Initial studies also show that improving the energy efficiency of a building can lead to gains in worker productivity due to increased occupant comfort from improved heating and cooling controls and daylit workspaces (IBE 2011b). In addition, many owners today cite the communication of a "winner" image as the primary benefit of having a net zero energy building (Mayer & Ghiran 2012).

A net zero energy building or community maximizes all energy efficiency opportunities and then uses renewable energy to meet remaining energy needs (Torcellini et al. 2006). This paper discusses only operational energy usage, although embodied energy may also be important to some net zero energy communities. For purposes of this paper, a community is defined as:

1. All buildings in a given geographic area, including commercial and residential buildings (multi-family and single-family housing), or

2. A portfolio of buildings dispersed across various geographies but linked by a single owner or set of occupants.

Changing energy decisions and usage in a community with many decision-makers, (those with multiple building owners and occupants) is inherently more challenging than those where decision-making authority, ownership and occupancy are more concentrated.

Government agencies the United States and Europe are driving net zero adoption and standardization through ambitious goals, paving the way for additional net zero buildings and communities (BD&C 2011).

The U.S. General Services Administration (GSA) Net Zero Energy Renovation Challenge will use 30-35 GSA buildings across the country as demonstration projects for achieving deep energy savings and net zero energy. The US Army is piloting eight net zero energy installations within its Vision for Net Zero initiative (DOD 2011). An Army installation often has tens of thousands of residents who both work and live within its borders, so these installations will be among the first net zero communities. The 2030 Challenge, started by the non-profit group Architecture 2030, sets a goal that all new buildings, developments and major renovations shall be designed to be carbon-neutral in 2030. The 2030 Challenge has been adopted and supported by many government entities, universities, businesses, professional offices, and organizations nationwide, including some of the nation's most influential architecture and design firms.

In the European Union, the recast Directive on the Energy Performance of Buildings (EPBD) stipulates that by 2020, all new buildings constructed within the EU after 2020 should reach nearly zero energy levels. Further, EU nations have adopted similar initiatives for commercial development around the Passivhaus standard for the energy efficiency of buildings.[1]

[1] Passivhaus is a design standard that cuts the heating energy consumption of buildings by 90%.

THE OPPORTUNITY AT THE COMMUNITY SCALE

Transforming a community to be net zero energy inherently involves transforming the existing building stock. The average age of commercial buildings in the United States, for example, is more than 40 years (SMR 2009). It is technically feasible to achieve net zero energy in many existing buildings: The National Renewable Energy Laboratory (NREL) has estimated that 62 percent of commercial buildings could reach net zero by 2025 (Griffith et al. 2007). Community-scale renewable energy projects may enable many commercial and residential buildings that lack sufficient on-site renewable energy resources to still reach net zero energy. Yet, despite the technical feasibility, the vast majority of buildings and communities are not on the pathway to net zero energy.

The timing of energy efficiency improvements can ease the transition to net zero energy. It is rarely cost-effective to upgrade all buildings and equipment at once to get to net zero energy. However, decisions that directly affect energy supply and demand are made every day in communities: Tenant spaces are built out, information technology (IT) infrastructure is embedded, HVAC systems reach the end of their useful life, windows and roofs are replaced. In addition, buildings are periodically upgraded either to keep up with the market or to reposition the property to increase rents. The challenge and opportunity lie in changing decision-making in order to manage a community toward the goal of net zero energy.

The transition to net zero energy can also be made easier by analyzing how different clean energy technologies work better at different scales, and in particular the potential to use community-scale renewable energy options. For example:

- Renewable energy in individual buildings, such as solar panels, building-integrated solar panels, or small-scale wind can be combined with community-wide renewable energy and central plant options.
- Cogeneration plants that run on biomass or waste can meet both the electricity and heating needs of buildings across the community.

- Larger-scale and higher-efficiency solar options become more feasible to implement on unbuildable brownfield sites or community greenfield sites, leveraging open plots of lands that are commercially undevelopable.
- Similarly, the opportunity to implement geothermal heating capacity lends itself well to developments within the vicinity of a community owned park.

Net zero energy buildings and communities will sometimes have additional up-front costs, although in some cases the life-cycle cost of a net zero energy building or community may be lower than for a standard code-compliant building. Financing models that can help with the additional up-front cost of creating a net zero energy building or community will be discussed in the final section of this paper.

EXPERIENCES AND LESSONS FROM EARLY ADOPTERS

To find out the main barriers to net zero energy, the Institute for Building Efficiency conducted a series of interviews with owners and architects of existing net zero buildings (Mayer & Ghiran 2012). These decision-makers commonly cited three main challenges to achieving net zero energy: process and transaction costs, the lack of technology awareness among owners, vendors and suppliers, and the engagement of building occupants. It is essential to address each of these challenges in order to put a community on the pathway to net zero energy. Each of these challenges in a single-building project has implications for net zero adoption at a community scale.

Early adopters of net zero energy buildings suggested that process and transaction costs can best be overcome by starting early, seeking advice, and staying engaged. All projects surveyed used some form of an integrative design process (explained in full in subsequent sections). Many noted that although the integrative design process may appear more time-consuming at first sight, greater effort at the initial planning stages seems to reduce overall project time. At the community level, integrative design may appear even more complicated, but communities should bear in mind that the know-how shared between diverse actors during integrative design can enable innovative thinking and ease the pathway to net zero energy.

Early net zero adopters also suggested that challenges around the suppliers and vendors' technology awareness can be met by mapping available technology and service suppliers. The implications at the community level could be significant since, service providers could be mapped and sourced for multiple projects and buildings in one process. In addition, early adopters pointed out that local and regional building codes and ordinances may actually prevent certain components of net zero projects. A net zero energy community would need to resolve these legal and political barriers.

Finally, early adopters suggested that the challenge of engaging building occupants can be overcome by creating a common vision and long-term value. Across an entire community, this principle is even more important, as not only building occupants, but all stakeholders in the community need to share the same vision. Many interviewees noted that communicating the life quality and non-tangible benefits of the net zero project is compelling for occupants. People often have strong feelings about their communities, and having them "fall in love" with their net zero community can help them stay engaged. Interviewees also noted the importance of balancing the up-front costs of achieving net zero energy with the energy savings over time. The following sections will explore how a community could approach finding a minimum-cost pathway to net zero energy.

THE PATHWAY TO NET ZERO ENERGY COMMUNITIES

Cost-effective, community-scale net zero projects require a master plan co-developed and agreed upon by all community stakeholders. The community must agree on the point where feasibility and the cost-effectiveness of investments in energy efficiency balance with the feasibility and cost-effectiveness of installing renewable energy. By examining the interplay of these two investments, the community as a whole creates its vision of net zero energy.

Energy Savings – Existing Buildings

The first step is finding each building's optimal energy efficiency. This requires completing a detailed whole-building analysis and audit of potential energy savings for each building, and aggregating this analysis at the community level. Energy efficiency measures should be planned using integrative design principles, analyzing not just the efficiency gains from each individual measure, but also interactions between building systems and any prerequisites for implementing each source of energy savings.

Detailed plans for opportunities in each building enable improved decision making when there is a structural or system failure. Then, when an event occurs, the analysis can be used to complete the repair such that it is consistent with the net zero pathway. In addition to managing structural or system failures, a net zero integrated design can help manage investments that affect energy efficiency over the lifespan of the building.

Integrative design

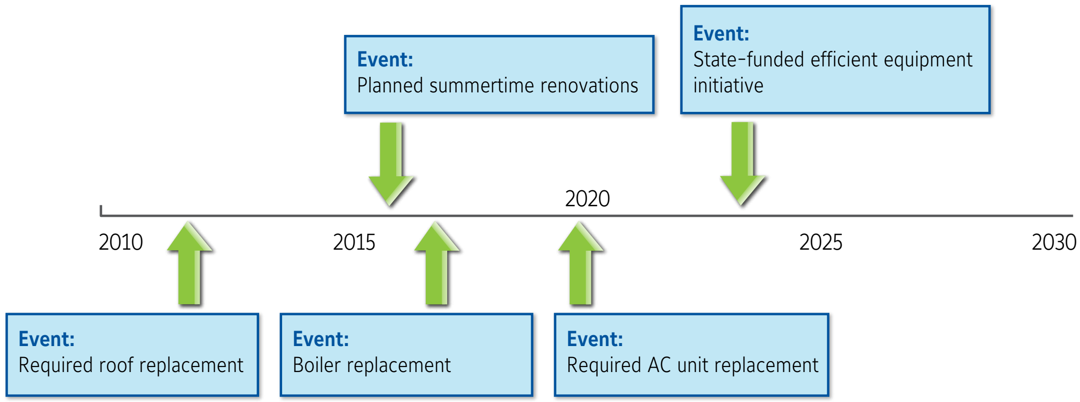
Integrative design is a collaborative process among all teams that participate in the design and construction to maximize the efficiency of a building. (AIA 2007) This involves reducing energy and power demand as far as possible before selecting HVAC and renewable energy generation systems. A well insulated building with efficient windows will have a smaller heating and cooling load and will therefore require a smaller HVAC system, reducing overall energy use. If electricity demands from lighting and plug loads are as low as possible, then less renewable generation capacity will be needed to meet those electricity demands.

Compelling Events

It is usually not cost-effective or physically practical to achieve net zero energy in an existing building all at once. An existing building is generally occupied, making it impractical to undertake measures that significantly disturb the occupant's space (such as adding daylighting and radiant floor heating) until a tenant turns over. Also, an existing building has systems and structures in place (such as the HVAC system and roof) that likely have not reached the end of their useful life.

Compelling events are points where an investment is being made in a building that could be leveraged to achieve improvements in energy efficiency. During these events, the cost-effectiveness and physical practicality of net zero energy measures are significantly increased. For example, when there is a turnover in a tenant space, there is a short time when the space is unoccupied, making energy efficiency improvements far less disruptive. In addition, coupling retrofits with the fit-out of the new tenant space may make it possible to improve energy efficiency at little or no additional incremental cost. Other compelling events include the end of service life of the HVAC system or the time when the roof needs replacing. Additionally, certain occupancy-related events specific to a building's primary activity offer time windows in which improvements can be planned. Examples include a K-12 school or college campus that goes dormant over the summer months, a sporting venue that stands vacant during the off-season, or convention hall whose activity is tightly scheduled months in advance. All events that can be anticipated in the building's life can be mapped out on a timeline, as in Figure 1.

Figure 1: Timeline of Anticipated Events at a Secondary School



Sequencing

All possible energy efficiency improvements from the preliminary integrated design should be mapped onto anticipated events, such that the minimum-cost timing option is identified for each improvement measure. The necessary sequencing of events should be considered. For example, an appropriately sized HVAC system cannot be installed until all the heating and cooling load reduction measures have been implemented. Thus even if certain tenant spaces will not see a tenant turnover before the end of the HVAC system's useful life, it may be necessary to implement some heating and cooling load measures in that tenant space during evenings and weekends, or by rotating the tenant through other office spaces, so that the smaller, more energy efficient HVAC system can be installed when the old system's life ends. In Figure 2, the 'planned summertime renovations' had to be moved to precede the 'boiler replacement' so that the boiler could be properly sized for the highly efficient school.

When there are gaps in the integrated design that do not have a place on the timeline, the pathway planners can consider how and whether they want to add those design elements to the timeline. For example, rapid-payback, low-disturbance features can be implemented immediately, such as energy efficient lighting, plug load management and a smarter controls system that engages occupants in the net zero process. In Figure 2, the events shown in red were added to the timeline to accommodate additional efficiency measures.

Finally, the energy savings generated from the measures completed at each event, and the cost effectiveness of each measure, must be calculated. Figure 3 adds in the energy savings and information about the payback threshold for the measures implemented.

Figure 2: Mapping of Efficiency Measures to Anticipated Events

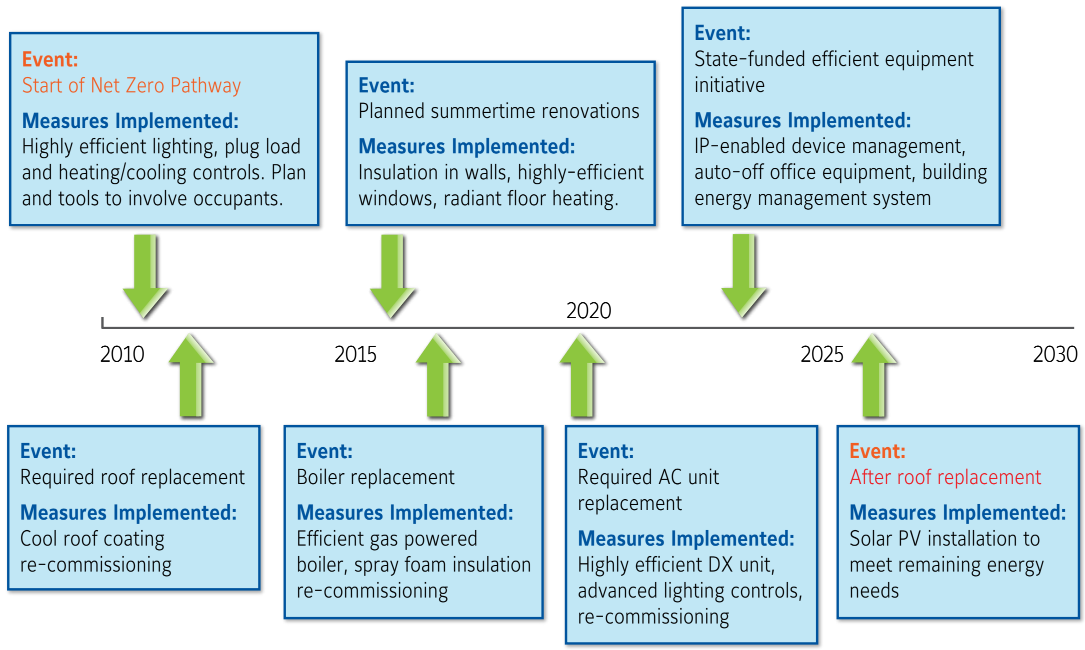
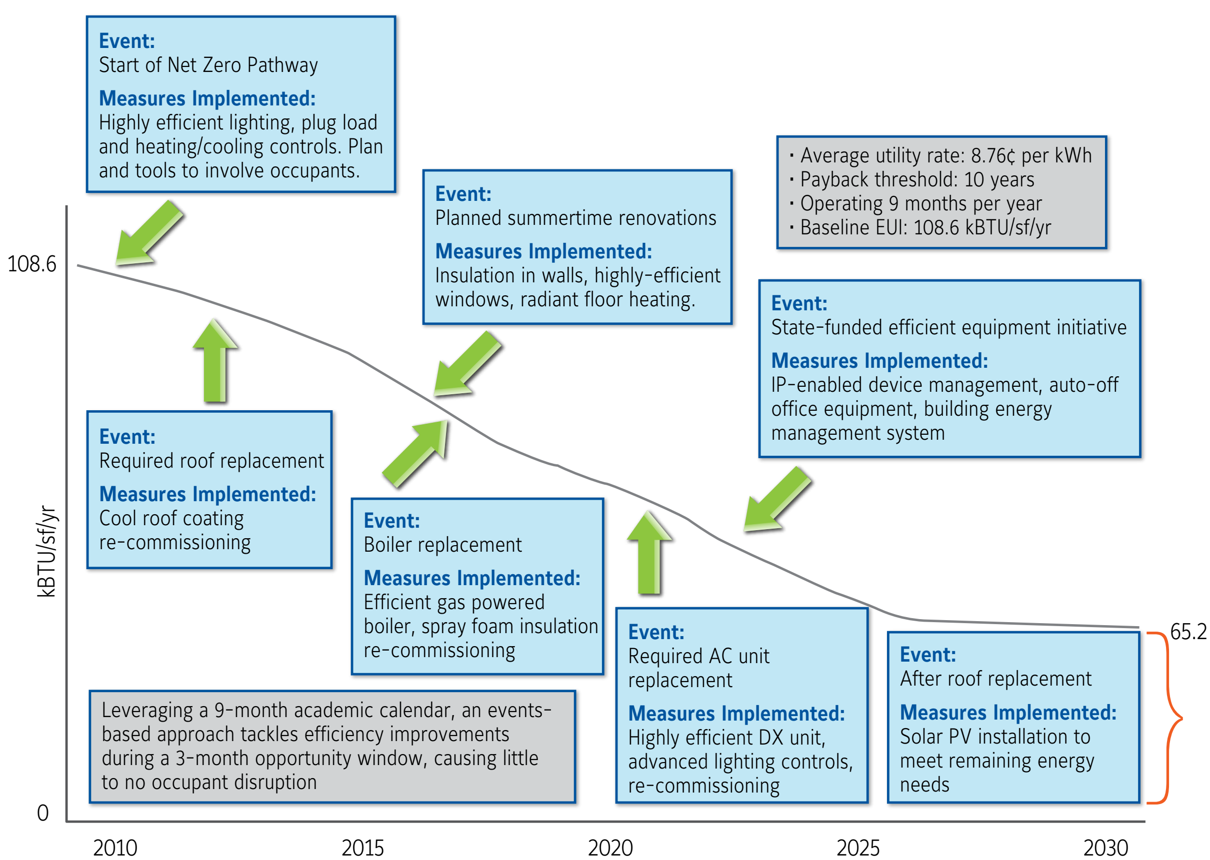


Figure 3: The Pathway for an Existing Secondary School to Net Zero Energy



A pathway to implementing all the energy efficiency measures needed to achieve net zero energy can be laid out for each building in a community, and all the timelines can be combined to make a master plan for maximizing the energy efficiency of the entire community.

In addition, there may be opportunities to achieve cost-effective upgrades across the community by achieving economies of scale for equipment or services. For example, it may be most cost-effective to replace roofs, HVAC systems or other items across a large portion of the portfolio all at once so as to secure the most favorable pricing from contractors. The potential for economies of scale should be taken into account when planning the timing of energy efficiency measures in a community.

Energy Generation – Renewable Energy Community Plan

Many renewable energy opportunities exist at the community scale. Each community has unique renewable energy potential depending on solar radiation at that geography, availability and accessibility of geothermal heat sources, availability of local biomass resources, and existence of nearby wind, wave or hydro resources. All potential renewable opportunities within a community can be analyzed, and the costs can be calculated and compared. A community may wish to benchmark the cost of producing renewable energy on site against the cost of purchasing renewable energy credits (RECs), and consider purchasing RECs during a transition period to full on-site renewable energy generation.[2]

Net zero energy buildings typically still depend on the electric grid to balance out renewable energy production with energy demand. Grid interoperability, through smart grid integration, allows two-way flow of electricity, enabling excess production to be sold back to utility providers when supply exceeds demand. The option also exists to install energy storage capabilities to make the building off-grid capable; this option could be factored into a renewable energy analysis when energy security is important.

The critically important factors to consider when analyzing renewable energy options are the cost per kWh, the potential installed capacity (kW), and any prerequisites for implementing the project. Some examples of the types of renewable energy available to communities are:

- Photovoltaic solar panels (mounted and building-integrated)
- Cogeneration plants that run on biomass or geothermal power to meet both the electricity and heating needs of buildings across the community
- Trigeneration (combined cooling, heat and power) plants, using solar energy
- Larger-scale and higher-efficiency solar options on unbuildable brownfield sites or community greenfield sites

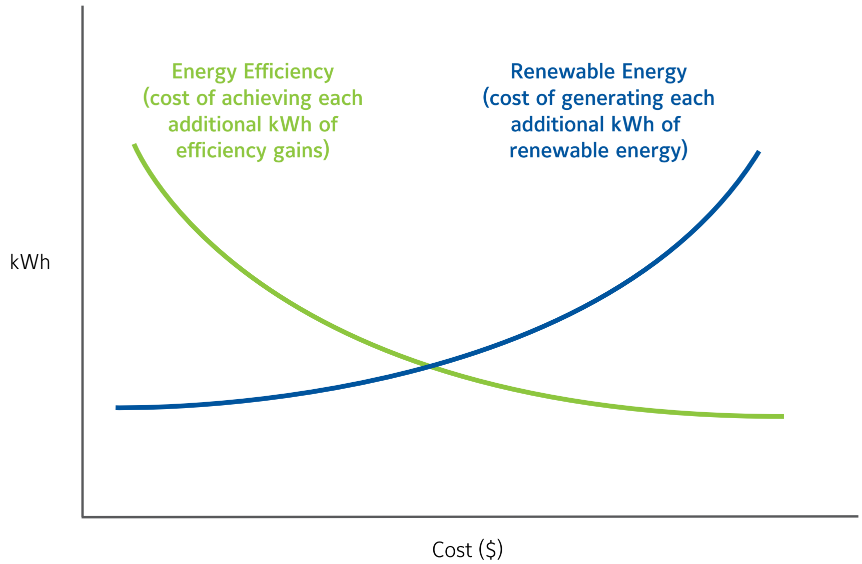
A pathway to implementing all the renewable energy installations needed to achieve net zero energy can be part of a community net zero energy master plan.

Efficiency and Renewable Energy Targets

Once the cost is estimated for each energy efficiency improvement measure, the cost curve for that building can be completed such that the cost per kWh of avoided demand can be graphed. This cost can be compared with the cost per kWh of renewable energy generation and utility procurement opportunities, and an optimal balance between energy efficiency and renewable energy can be identified. Each building will then have its own unique efficiency target that includes all efficiency measures that can be performed below the cost of renewable energy generation in the community. The timelines and cost estimates for all buildings can be aggregated to make a community master plan.

[2] NREL has developed definitions for zero energy communities and buildings depending on their source of renewable energy. For example, "A" classification for community means that all power is generated within the built environment. "D" classification for a community means that after maximizing all potential energy efficiency, the remainder of the load is met through RECs that add new grid generation capacity. (Carlisle, Van Geet, & Pless 2007)

Figure 4: Energy Efficiency/Renewable Energy Cost Comparison



By comparing the cost of energy efficiency gains with renewable energy generation, planners can dynamically optimize the costs of achieving net zero energy, so that the lowest cost pathway to net zero energy can be found. The cost assumptions can be reevaluated over time as new technologies become available. Once all the energy efficiency and renewable energy options from across the community are combined onto one timeline, the pathway to net zero energy can be compared to a baseline for business as usual. Progress toward net zero energy can be measured and verified over time so that everyone, from community planners to building occupants, can see how their piece of the community is advancing towards the goal, and how the entire community is progressing, as well.

Ft. Bliss: A Net-Zero Installation

Ft. Bliss, located outside of El Paso, Texas, is a pilot U.S. Army installation working to achieve net zero energy, water and waste. Key criteria for selecting the pathway to achieve net zero energy are energy security and independence for the base, as well as the affordability of the projects.

In designing the pathway to net zero energy, energy usage profiles are modeled and forecast into the future. Combining analysis of increased efficiency with distributed generation provides multiple paths forward that will lead to net zero. The challenge is identifying a path that is budget-neutral and addresses energy security. Some paths are fiscally viable but do not improve energy security. Others fully address energy security but are not affordable. This is the challenge and opportunity of the net zero efforts at Fort Bliss. The results will provide a template for other Army installations to follow when they move toward a net zero future.

For example, Ft. Bliss is considering implementing a waste-to-energy system using the waste from the city of El Paso. Alternately they are considering using geothermal resources to install a base-load plant, which would operate 24/7. Modeling of both these scenarios in conjunction with future energy efficiency projects and peak-load renewable solutions, such as solar photovoltaics, allows decisions to be made based on the base's security and cost criteria.

The macro-economic model allows all the possible paths forward to achieve net zero energy to be evaluated and filtered in an efficient manner, so that Fort Bliss can meet its aggressive timeline of 2015 for net zero energy. Net zero waste and water, which are on a 2018 timeline, are being addressed in similar fashion. (Reasoner 2012)

BUDGETING FOR NET ZERO

All measures completed along the pathway to a net zero energy community need to be paid for from either operating or capital budgets. Operating budgets pay for the maintenance and repair of facilities and infrastructure, energy bills, and other day-to-day expenses. Capital budgets include expenditures on any major new equipment, installations or facilities. Capital items typically require maintenance, care and operation after they are purchased. Life-cycle cost analysis is commonly used to account for all costs associated with capital items over their expected lives, including purchase, operation, maintenance and disposal or recycling. Often, energy efficiency and renewable energy projects have lower life-cycle costs than standard facility and community projects because the savings they generate pay back any additional up-front costs. The life-cycle cost of taking a building to net zero energy depends greatly on the type of building and the purpose for which it will be used. Even when the life-cycle cost is lower, it can be challenging to find resources in the capital or operating budget to pay for the additional incremental up-front cost of energy efficiency improvements or renewable energy installations.

Various financial mechanisms have been developed to deal with this challenge. Innovation in budgeting can be particularly important when net zero is being planned for a campus or portfolio of buildings with a single owner, given that all additional capital would have to come from one source. Here is a summary of useful financing approaches.

Shift Priorities

To stay within existing capital budgets while achieving net zero energy, members of a net zero community can explore shifting their priorities so that investments in energy efficiency take precedence over other investments. There may be "standard" components of facility and infrastructure that are not actually as important as achieving the net zero energy goal. Making standard components a lower priority and moving energy efficiency components higher may lead to innovative solutions from contractors that enable the community to meet an efficiency goal while staying within budget. In addition, integrative design can find ways to create multiple benefits from single expenditures.

NREL

The National Renewable Energy Laboratory was able to build its new facility within the standard budget for a building by giving contractors a clear set of rankings of importance of outcomes, and by giving points for all outcomes met in order of rank. For example, an energy demand goal of 25,000 Btu/ft^2 was No. 4 on the list of 50 desired outcomes. Even if a contractor met other outcomes that were lower on the list, that firm could not receive more than three of 50 points if unable to meet the energy demand goal. One contractor was able to meet all 50 desired outcomes within the standard budget (Torcellini 2011).

Portfolio Approach

Diversey Inc. improved its energy efficiency as part of a long-term strategy that balances the speed of financial return (simple payback), the volume of financial return (NPV) and the cost of the carbon investment ($/MT carbon) across an entire portfolio of projects, instead of evaluating each efficiency project solely as a discrete investment. The approach reduces uncertainty and risk through diversification, increases opportunity by looking beyond just the "low-hanging fruit," and allows for a predictable and reliable rate of return (Diversey 2011).

Energy Performance Contracting

An Energy Performance Contract (EPC) is an innovative financing technique that repays the cost of energy efficiency projects through the cost savings they produce (IBE 2010). In a typical EPC, a building owner contracts with an energy service company (ESCO) – the "performance contractor" – to install the energy improvements and guarantee the energy savings over the contract term. The ESCO is responsible for designing, implementing, and measuring the results of an EPC project. The ESCO also arranges for long-term project financing provided by a third-party financing company.

Solar Power Purchase Agreement (PPA)

A Solar PPA is a financial arrangement in which a third-party developer owns, operates, and maintains the photovoltaic (PV) system, and a host customer agrees to site the system on its roof or elsewhere on its property and purchases the system's electric output for a predetermined period. This financial arrangement allows the host customer to receive stable and sometimes lower-cost electricity from a renewable source that can be paid for out of the standard operating budget (EPA 2012).

Lease Equipment

Certain types of leases on equipment like efficient HVAC systems, lighting upgrades and building control and monitoring systems can qualify as operating leases that can be paid for out of operating expenses, where the lease payment can be offset by monthly energy savings. Often, the lease can be off the balance sheet and can therefore be paid through operating rather than capital budgets.

Green Leases

Building owners often pay the capital expenses for energy efficient upgrades to the base building, but tenants receive the financial benefits of energy savings through a reduction in their energy bill (the "split incentive" problem). A green lease (sometimes called an "energy aligned lease") enables both property owners and tenants to benefit from energy efficiency upgrades.[3]

[3] For an example see www.nyc.gov/planyc or http://www.greenleaselibrary.com/

CONCLUSION

Achieving net zero energy at the community scale requires maximizing the energy efficiency of all the buildings in that community, including many existing buildings, and then meeting the remaining energy demand with renewable energy supplied at scale to the community as a whole. Net zero energy in existing communities can be managed over time rather than completed as a single, all-encompassing project, thereby lowering the cost and the disruption to current occupants. By balancing the cost-effectiveness of energy efficiency with renewable energy options, communities can find a minimum-cost pathway to net zero energy. Various financial mechanisms exist to help communities pay for the pathway to net zero energy. Increased asset values, increased comfort, increased energy independence, lower maintenance and energy costs and the potential for lower life-cycle costs are just a few of the reasons that communities are considering the possibility of net zero energy.

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The Institute for Building Efficiency is an initiative of Johnson Controls providing information and analysis of technologies, policies, and practices for efficient, high performance buildings and smart energy systems around the world. The Institute leverages the company's 125 years of global experience providing energy efficient solutions for buildings to support and complement the efforts of nonprofit organizations and industry associations. The Institute focuses on practical solutions that are innovative, cost-effective and scalable.

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