



Definition of a "Zero Net Energy" Community

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Technical Report
NREL/TP-7A2-46065
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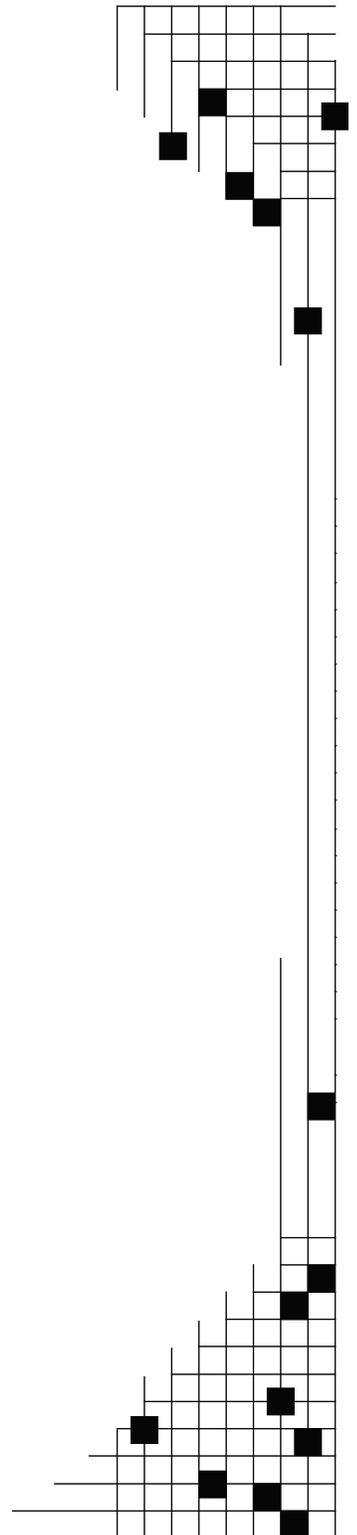
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Executive Summary

A net zero-energy community (ZEC) is one that has greatly reduced energy needs through efficiency gains such that the balance of energy for vehicles, thermal, and electrical energy within the community is met by renewable energy. Past work resulted in a common zero-energy building (ZEB) definition system of “zero energy” and a classification system for ZEBs based on the renewable energy sources used by a building. This paper begins with a focus solely on buildings and expands the concept to define a zero-energy community, applying the ZEB hierarchical renewable classification system to the concept of community. A community that offsets all of its energy use from renewables available within the community’s built environment and unusable brownfield sites is at the top of the ZEC classification system at a ZEC of A. (A brownfield site is where the redevelopment or reuse may be complicated by the presence or potential presence of a hazardous substance, pollutant or contaminant.) A community that achieves a ZEC definition primarily through the purchase of new off-site, Renewable Energy Certificates (RECs) is placed at the lowest end of the ZEC classification but is still considered a good achievement .

The hierarchical approach emphasizes using all possible cost-effective, energy-efficiency and demand-avoidance strategies first and then using renewable energy sources and technologies that are located in three places:

- First, on space within the built environment or unusable brownfield sites within the community
- Second, on either green space within the community or located outside the community boundary but within the region and brought into the community
- Third, through the purchase of new RECs.

Table 3 provides examples of each of these options.

In addition, we set up a series of intermediate milestones so a community can begin to plan toward the aspiration of net zero over time. The goal of this type of classification is to encourage developers and campus and community planners to develop a comprehensive multi-year plan to both understand the magnitude of change needed in community energy patterns to move toward the concept of a net-zero community and to lay out a multi-year scenario with defined milestones to drive the transition.

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1 Background

There are many ways to define net-zero energy in the context of a building. There are also many terms that have similar meanings to the term *net zero* or *near net-zero energy communities* including *carbon neutral*, *climate neutral*, *carbon advantage*¹ or *sustainable communities*. We use the term *net zero* because it is a more narrow focus than some of the other terms and one can measure and determine if the goal has been achieved. Torcellini et al. (2009) have developed four well-documented definitions of Zero-Energy Buildings (ZEB) including:

1. Net-zero site energy
2. Net-zero source energy
3. Net-zero energy costs
4. Net-zero energy emissions.

In a follow-on paper, Pless et al. (2009) go one step farther by proposing a classification grading system for ZEBs that establishes and ranks the renewable energy sources used by a building. For example, in the building-ranking system, building integrated photovoltaics (PV) rank higher than the burning of wood even though both are considered renewable energy. Generating renewable energy within a building's footprint is defined as superior from an overall energy perspective to the importation of wood chips from a remote location to burn on-site for fuel. Pless et al. (2009) classify ZEBs based on the location of the renewable energy hardware with respect to the building. The goal of the building classification system is to encourage building owners and designers to first utilize all possible energy-efficient strategies and then use renewable energy sources and technologies located on the building.

This building's classification scheme provides a good starting point for a definition of a zero-energy community (ZEC). The United States and many other parts of the world have set aggressive goals for energy savings in many communities and states. Some of these goals can be realized best by looking at energy use in a community as an integrated system rather than looking at strategies for buildings, transportation, and industry as discrete problems with discrete solutions. For example, community scenarios could link transportation, homes, and the electric grid as well as enable large quantities of renewable power onto the grid. Preliminary analyses show that the homeowner would gain a net cost advantage on a life-cycle cost basis by integrating a near-zero energy home with a plug-in hybrid vehicle (PHEV). By defining a zero-energy community and offering a set of metrics to measure progress toward the aspiration of net zero, we aid in moving the dialog from building only zero-energy solutions to solutions that consider all uses of energy within a community for buildings, transportation, community infrastructure, industry, and others. A definition for a zero-energy community is different and more complex than that of a ZEB because a community uses energy not only for buildings but also for industry, vehicles, and community-based infrastructure, so the achievement of "zero energy" needs to include all applications. A definition of this nature is also more complex because of all of the factors discussed in this report.

¹ Term used in T. Friedman (2008), *Hot, Flat and Crowded*, is a better option to Carbon-Neutral because this term helps position these communities as models for new leadership in terms of attracting green businesses (jobs) and new ways of doing business as leaders, and "neutral" just doesn't imply leadership.

2 Assumptions

The hierarchical definition for a zero-energy community includes both energy-demand reduction options and renewable energy supply-side options. It places emphasis on energy efficiency or energy-use avoidance as the highest priority strategy. The definition requires that a community energy-basecase (or carbon inventory) be calculated (for a new development) or measured (for an existing community) to determine if the net-zero goal is met.

This definition assumes that in order to establish the basecase, the developer, community, campus, or military base official needs to decide on both a community boundary and what uses of energy are included. Except in the case of an island, the boundary is arbitrary. The boundary can be geographically or politically defined or, as in the case of the U.S. Forest Service, defined as the boundary of an eco-system (Kandt and Mann 2009). The other assumption that needs to be made is what energy uses are included in the basecase. One assumption might be to include energy used for buildings, community infrastructure, industry, and transportation (both within the community and to and from work). For the Department of Defense (DOD) net-zero base pilot project at the Miramar Naval Air Station, the definition included the minimization of energy demand through conservation and efficiency. This includes all energy required for the functioning of the installation (regardless of what organization controls it) and transport fuel – including fleet, commuting, business travel, and flying mission (Barnett 2009).

In the University Presidents Climate Change Commitment, (Dautremont-Smith 2009) “what to count” is defined as scope 1, 2, or 3. These are defined in terms of greenhouse gases (GHG) but could be defined in terms of energy instead. Scope 1 refers to direct GHG emissions occurring from sources that are owned or controlled by the institution, including on-campus stationary combustion of fossil fuels, mobile combustion of fossil fuels by institution-owned/controlled vehicles, and “fugitive” emissions. Fugitive emissions result from intentional or unintentional releases of GHGs, including the leakage of HFCs from refrigeration and air-conditioning equipment as well as the release of CH₄ from institution-owned farm animals. Scope 2 refers to indirect emissions generated in the production of electricity consumed by the institution. Scope 3 refers to all other indirect emissions—those that are a consequence of the activities of the institution, but occur from sources not owned or controlled by the institution. The signatories to this agreement need to account only for scope 1 and 2. EPA greenhouse gas accounting procedures also require only scopes 1 and 2.

- The zero energy community definition assumes that the community has an electric grid. When on-site generation from renewable electrical energy is greater than the load, it can be sent to the grid. In a case where there is a large amount of renewable systems on the grid (called a high market-penetration scenario), the grid may not always need excess renewable energy generated at certain times of day. In this case, on-site energy storage may become necessary.
- By using the utility grid to account for the energy balance, excess production can offset later energy use. In accounting for net zero on the community scale, it is assumed that renewable electricity can be used to offset various fossil fuel energy use (such as natural gas or gasoline).
- The assumption is that over time the power grid will increasingly rely on renewable energy as more states implement renewable portfolio standards. This may reduce the total

amount of renewable energy generation needed by a community to achieve the designation of near or net zero. Today the gap between the renewable energy supplied by the utility and that needed by a community to become net-zero is so large that energy efficiency, energy conservation, and renewable energy installed at the community level is needed.

There are many guiding principles for the development of a sustainable community. Below is one recognized set. The aspiration of a net-zero energy community is intertwined throughout these principles. The goal of net zero provides a means to quantify and to track a community's progress toward sustainability by reducing its overall energy usage. Energy is the primary focus of this paper, but when developing a net-zero energy solution, one needs to be mindful that a successful solution must be one that works in terms of energy as well as other parameters of sustainability. For example, growing crops for energy within the boundary of the community would not be an acceptable solution if the water supply was not sustainable. Intentionally building low-density buildings to maximize roof area for PV, which results in increased traffic and limits access to community amenities for certain populations without access to cars, would not be in keeping with the principles of sustainability either. Sustainable and zero-energy design and planning are analogous to a three-legged stool: All legs need to be in balance for the system as a whole to function.

2.1 Sanborn Principles of Sustainability²

- Development is ecologically responsive and optimized for efficiency
- Residential and commercial buildings are efficient, healthy, and sensible and use renewable energy
- Schools and public buildings are a focal point for community education
- The community thermal-power grid and water and waste water infrastructure are efficient, planned, and installed.
- Some fraction of the heat and power source is distributed (on-buildings) and/or located within the community boundary and relies on renewable energy
- The transportation system is accessible and rich in alternative transportation options
- Water is sustainable
- The community minimizes waste
- The community is socially just
- The community promotes the growing and eating of local and sustainable food
- The community is culturally creative
- The community incorporates natural and man-made beauty
- The community is evolutionary.

² Adapted from the Sanborn principles (Harwood et al. 1994).

3 Definition

If we apply the most general definition of zero-energy to the concept of community, a net-zero energy community is “one that has greatly reduced energy needs through efficiency gains such that the balance of energy for vehicles, thermal, and electrical energy within the community is met by renewable energy.

The energy performance of a net-zero community can be accounted for in several ways. The definitions listed below are based on those by Torcellini (2006).

- **Net-Zero Site Energy:** As much renewable energy is produced in the community for buildings and infrastructure as is needed by buildings and infrastructure in a year when accounted for at the site. For transportation, site energy needs would be based on a calculated or measured vehicle miles traveled by community occupants regardless of whether they filled up their gas tank in the community or outside the boundary. As stated earlier, the definition allows for fuel switching so excess renewable electricity generation can offset various fossil fuel use.
- **Net-Zero Source Energy:** A source ZEB produces at least as much energy as it uses in a year when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building’s total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers based on the utility’s source energy type. For transportation fuel, source energy would include a multiplier to account for the energy required to transport the fuel to the fueling station.
- **Net-Zero Energy Costs:** In a cost ZEB, the amount of money the utility pays the building owners and the community (for renewable energy generated on all residential and community buildings and infrastructure) for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year. If you include transportation, the cost of the fossil-based fuels is offset by fuel generated from renewable sources.
- **Net-Zero Energy Emissions:** A net-zero emissions community produces and uses at least as much emissions-free renewable energy as it uses from emissions-producing energy sources annually. Carbon, NO_x, and SO_x are common emissions that ZEBs and transportation powered by renewable energy offset. To calculate a building’s and transportation (based on assumed or actual VMT) total emissions, imported and exported energy is multiplied by the appropriate emission multipliers based on the utility’s emissions and on-site generation emissions (if there are any).

A community may be designed or retrofitted to achieve one or more of the above definitions but may not achieve it in actual operations every year. If the community produces at least 75% of its required energy through the use of on-site renewable energy, it is considered a near-zero community. Off-grid communities are not considered in this paper.

Table 1 shows a hierarchy of options to move to zero-energy communities. The options are ranked in terms of desirable approaches to move toward the zero-energy definition. The goal of this type of classification scheme is to encourage community managers and developers to first utilize all possible cost-effective energy efficiency strategies and then evaluate options to move

to net zero. Table 2 includes two approaches both with pros and cons. The strategy chosen will vary with the circumstances.

Table 1. Community Efficiency and Renewable Supply Hierarchy

Option Number	Option Name
0	Energy Efficiency and Energy Demand Reduction
1	Use Renewable Energy in the Built Environment & on Unusable Brownfield Sites
2a	Use Renewable Energy on Community Greenfield Sites (A Greenfield site is a site that has not been previously developed or built on, and which could support open space, habitat or agriculture)
2b	Use Renewable Energy Generated Off-site, On-site
3	Purchase New Off-site RECs ³

Table 2. Pros and Cons of Options 2a versus 2b

Option 2a Renewable Energy Supply in the Community Greenfield	Option 2b Renewable Energy Generated Off-site for use On-site
Pros	Pros
<ul style="list-style-type: none"> ▪ Lower transmission line losses ▪ The community is more independent and self-sufficient ▪ This might create a new business opportunity—developing the infrastructure for distributed renewable energy within a defined community ▪ Community members will become more aware of where their energy comes from, which will lead to more energy conservation ▪ If there is a good renewable resource located within the community boundary ▪ Community has more control for near- and long-term energy decisions 	<ul style="list-style-type: none"> ▪ A central source of renewable energy serving a regional need rather than a community need might be more cost-efficient ▪ If there is a good renewable resource located outside the community boundary but located within the region (landfill gas, wind) ▪ A utility partner might have a business interest in working with a community or communities in a region to develop a regional renewable strategy, which could be a win-win for multiple parties ▪ For liquid fuels, this is the most viable means to provide renewable energy ▪ Off-site central station power may have higher efficiencies of scale ▪ This may facilitate greater coordination among regional communities (i.e. enhance regional solutions for transportation, land-use planning, district systems, etc.)
Cons	Cons
<ul style="list-style-type: none"> ▪ Use of community green space for energy generation where there might be a higher value use of the land ▪ The resource for energy generation might not be optimal ▪ The land use might not be compatible with other desired land uses 	<ul style="list-style-type: none"> ▪ There is an efficiency trade-off as the distance from the site of generation to the source of use increases ▪ The community has less control over its energy supplies

³ RECs represent the attributes of electricity generated from renewable energy. These attributes can be unbundled from the electricity and bought and sold separately.

In Table 3, each of these options is defined more fully with examples provided in the categories of buildings, transportation, and community infrastructure. Option 0, energy efficiency and energy demand reduction, is considered a prerequisite to the renewable energy supply side options. Option 0 includes a fourth category, behavior. From a community point of view, energy demand reduction can occur in all four categories, and it is important to place behavior changes on par with technological changes. For example, behavior can impact energy use. One recent example is an environmental competition held among 13 buildings at Harvard University. The result was \$72,472 in energy dollar savings through changes in operations and maintenance practices (Bradt 2008).

From a developer or community leader’s point of view, there are only certain things that they can do to influence energy use directly in the design of a new community or to retrofit an existing community. In the case of human behavior, a developer can influence energy use indirectly, and a community leader can have influence through policy or financial incentives/disincentives. If a developer wants to build a new zero-energy community, he or she needs to make an assumption about human behavior to establish the basecase for the purpose of measurement and verification and then decide “what counts” for the claim to a be a net-zero community. For example, the developer could define and quantify that he or she has designed a net-zero community “for only the aspects of energy use that he or she can directly control within a defined life-cycle cost.” (See discussion of intermediate milestones below.)

The net-zero concept is shown graphically in Figure 1.

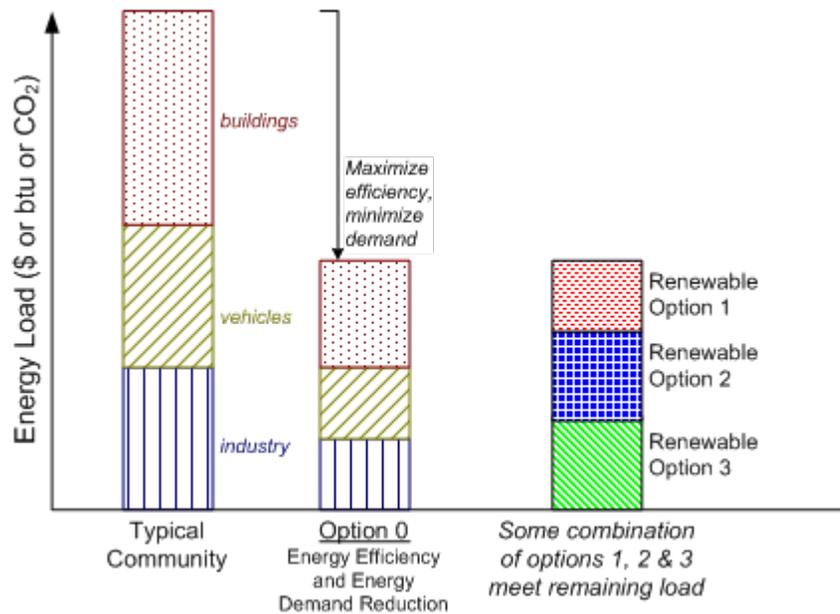


Figure 1. Net-zero concept

Table 3. ZEC Renewable Energy Supply Option Hierarchy (modified) (Pless, et al. 2009)

Option Name and Number	ZEC Supply-Side Options	Examples
<p>Option O Demand reduction (a prerequisite for the renewable supply side options)</p>	<p>Buildings Reduce site energy use through community design, setting targets for building energy efficiency and incorporating low-energy building technologies for new construction; for existing communities, making energy savings retrofits to buildings.</p> <p>Transportation Reduce vehicle miles traveled for gasoline-powered passenger vehicles within the community and to and from the community. Provide convenient bus and/or rail stops for destinations to locations of employment outside the community.</p> <p>Community Infrastructure Assess loads for all sectors to define the biggest opportunities for energy savings and use energy-efficient strategies to minimize these loads.</p> <p>Behavior Set community goals for energy and water use. Use policies, information and education, and incentives and disincentives within the community to achieve desired objectives.</p>	<p>Buildings Influence energy demand reduction through urban design and lot layout, setting energy-efficiency targets and density targets including both jobs and dwellings per acre.</p> <p>Buildings can incorporate aggressive energy efficiency and use daylighting, passive solar design, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, ground-source heat pumps, ocean water cooling, etc.</p> <p>Transportation Community design can include a diversity of land uses, densities, and a mix of housing and retail and enhance walkability and connectivity within a community to minimize need for personal vehicles. Design can also create destinations within the community and minimize the distance to public transit.</p> <p>Community residents and visitors can use alternatively fueled transportation, advanced vehicles and fuels; maintain and operate vehicles to maximize efficiency; form car sharing clubs and other community-based initiatives; and provide and plan for alternative transportation and access to mass transit within the community.</p> <p>Community Infrastructure LED traffic lights, high-efficiency pumps (for water pumping). Utilities are installing “smart grid” to provide user feedback regarding energy use and impact on their energy costs.</p> <p>Behavior Set aggressive energy-efficiency standards for all construction. Established policies and covenants can be used to incentivize building owners to use less energy and water.</p> <p>Through consumer education and feedback (metering, commissioning, retro-commissioning), consumers can be educated to turn lights and equipment off at night, metering, turn off vampire loads in buildings at night and when buildings are not occupied.</p>

Renewable Supply Options—Within Community		
<p>Option 1 Use renewable energy systems in the community or campus within the built environment and on unusable brownfield sites</p>	<p>Buildings and Community Infrastructure Use renewable energy sources on sites available within the built environment or on site that are unbuildable such as brownfield sites. This includes using solar on residential and commercial rooftops, parking structures, and along roadways.</p> <p>Transportation Provide transportation options powered by renewable energy available to all destinations within the community.</p>	<p>Buildings PV, solar hot water, ground-source heat pumps located on buildings, parking structures, along roadways and connected to building systems.</p> <p>For new construction, the design and layout of buildings should maximize rooftop area for renewable systems and the systems are either designed and installed on all new buildings or plumbed and wired to be added at a later date.</p> <p>For existing communities, maximize the amount of unshaded rooftop spaces with renewable systems that are determined to be cost-effective.</p> <p>This option would also include generating and using methane from a wastewater treatment plant or producing power from waste as long as the energy is generated from waste streams generated within the community and processed in the community.</p> <p>It would also include the use of PV, wind, solar located on a brownfield site within the community.</p> <p>Transportation This option includes the installation of electric plugs in homes, public parking so that people can plug in electric or electric/hybrid vehicles at home or in public parking and power vehicles from renewable sources on buildings.</p> <p>It includes using electric-powered buses and shuttles within the community powered by renewable energy generated in the community.</p> <p>Community Infrastructure Use renewable energy to power street lights, monitors, and meters.</p>
<p>Option 2a Renewable energy supply in the community Greenfield</p>	<p>Buildings and Community Infrastructure Build renewable energy sources on Greenfield sites located within the community boundaries. The renewable systems are connected to the electrical or distribution grid.</p> <p>Transportation Include the use of renewably generated electricity for cars, busses, and shuttles.</p>	<p>Buildings PV and wind located within the community boundary and connected to the grid. Central solar hot water connected to a distribution grid. Biofuel applications only if the fuel were grown in the community.</p> <p>Transportation Renewably generated electricity for cars, trucks, and busses. Ethanol or biofuels for transportation only in cases where the plants for the fuels are grown in the community.</p> <p>Community Infrastructure Community scale micro-grid connects distributed and community-scale renewable systems (electric and or thermal energy) to buildings and utility grid. Storage may be added to the grid to power peak needs, night-time loads, or seasonal loads.</p>

Off-Site Supply Options		
<p>2b Off-site renewable energy used to generate on-site</p>	<p>Buildings Use renewable energy sources available off-site to generate energy on a campus in a community or neighborhood.</p> <p>Transportation Use renewable-based fuels generated off-site for use on site.</p>	<p>Buildings/Community Infrastructure Biomass, wood pellets, ethanol, or biodiesel or landfill gas that can be imported from off site, which can be used on-site to generate electricity, heat or fuel.</p> <p>A community could also negotiate with its power provider to install dedicated wind turbines or PV or solar panels at a site with good solar/wind resources outside the community. In this approach, the community would own the hardware and receive credits for the power. The power company or a contractor would maintain the hardware.</p> <p>Transportation Ethanol and biodiesel fueling stations located on site are included in this option.</p>
<p>3 Purchase new RECs</p>	<p>Buildings/Transportation/Community Infrastructure Purchase new off-site RECs that result in additional generation added to the grid.</p>	<p>Buildings/Transportation/Community Infrastructure Utility-based wind, PV, emissions credits, or other “green” purchasing options. Hydroelectric is sometimes considered. All off-site purchases must be shown to add new generation capacity to the grid.</p> <p>RECs could be used as a strategy to meet a goal for an interim period of time or as a “top off” strategy to provide, for example, the last 10% of renewable energy. It is important that an REC purchase add new generation capacity to the grid.</p>

3.1 Applying a Classification System to Zero-Energy Communities

While all attempts to achieve a zero-energy community (ZEC) are valuable, we can classify a ZEC based on the renewable supply options used and definitions met. A community that meets the ZEC definition solely through the purchase of new off-site RECs is placed at the lowest end of the ZEC classification as shown in Table 4. A community that offsets all of its energy use from renewables available within the built environment is at the top of the ZEC classification system. (This also includes brownfield sites). In order to keep the nomenclature consistent between the zero energy buildings and community net zero definitions, the achievement of an “A” classification for community means that all power would need to be generated within the built environment (and assumes that energy efficiency is first maximized). From a community perspective, one would want to trade off building density versus available area within the built environment suitable for renewable production. As a community becomes denser, there is less rooftop and built-up areas suitable for renewable production. In a community, density allows for greater walk-ability and many other attributes desired in a sustainable community. In addition, today it would be very challenging for a community to generate 100% of its transportation fuels within its boundaries. For these reasons, the achievement of a ZEC “A” may be impossible in many locations. The ZEC “B” category includes renewable energy generation in both the built environment and within the community green space and/or with some aspect of renewable energy generated off-site and imported to the community for use or further refinement. It also allows a fraction of the renewable energy to come from new RECs. For a community,

Classifications A, B, and C are all considered excellent. A fourth option where the community purchases all of its renewable energy from new RECs is considered a good achievement.

Table 4. Classifying ZECs – Energy Supply Options

ZEC Classification		Renewable Energy Supply Option Number
	A	<p>Option 0: Energy efficiency opportunities maximized</p> <p>Option 1: 100% energy load met by renewables in the built environment and unbuildable brownfield sites within the community</p>
	B	<p>Option 0: Energy-efficiency opportunities maximized</p> <p>Option 1: A fraction of the energy load met by renewables in the built environment and unbuildable brownfield sites within the community</p> <p>Option 2: A fraction of the energy load met by renewable generation on community Greenfield sites or from off-site renewables used on site</p>
	C	<p>Option 0: Energy efficiency opportunities maximized</p> <p>Option 1: Fraction of the energy load met by renewables in the built environment and unbuildable brownfield sites within the community</p> <p>Option 2: Fraction of the energy load met by renewable generation on community resources or from off-site renewables used on site</p> <p>Option 3: Fraction of the energy load met through RECs that add new grid generation capacity</p>
	D	<p>Option 0: Energy efficiency opportunities maximized</p> <p>Option 3: The remainder of the load is met through RECs that add new grid generation capacity</p>

3.2 Intermediate Steps and Verification to Move to the Aspiration of Net Zero

Achieving the net-zero definition will need to be time-phased with intermediate goals. Time-phasing offers flexibility to develop an approach to a net-zero energy community, campus, or base that is very aggressive in terms of energy but yet recognizes that the energy solution needs to be balanced against budget. Time-phasing also extends to the annual cycle. For example, assuming the system is grid connected, net zero allows a community to go into a carbon electricity debt through the winter months and “break even” at the end of the summer season with excess PV generation. In addition, if a developer takes on a significant carbon debt during the construction phase, the process to achieve net zero could establish a target year for getting back to net zero through cumulative years of additional renewable energy generation in excess of the community needs.

In order to time-phase and set intermediate milestones, the most important task is to define and quantify the basecase. For a new development, the basecase represents what the development would have used in terms of energy if buildings were designed to code and if transportation systems were designed using conventional patterns. It is useful to break down the basecase by subcomponents such as: residential buildings, commercial buildings, public buildings, transportation within the community, transportation to and from the community, and infrastructure. Once the basecase is defined and quantified, intermediate targets can be set. The intermediate steps can be anything that community members can visualize and can be large or small. For example, “the community has verified that it has generated enough power from renewable sources to claim it is net-zero for the equivalent of the elementary school or all buildings in the community.”

One set of intermediate targets could include:

- The equivalent energy offset to accomplish all the “Option 0” strategy in the renewable energy supply hierarchy. The Option 0 case represents the amount of energy (or carbon) needed to power the community under a scenario where all energy-efficiency measures and design improvements are included to maximize cost-effective energy savings.
- The equivalent energy to offset the energy used by buildings in the community.
- The equivalent energy to offset the energy used by transportation in the community.
- The equivalent energy to offset all other uses of energy in the community.
- The equivalent energy to offset the added energy growth that will come over time as the community grows.

If the community wanted to become a ZEC “C” for example, it could use a combination of Options 0, 1, 2, and 3 (from Table 3) to meet each intermediate milestone. Once the equivalent energy was offset to meet the intermediate milestone, the community could claim, for example, that it has generated enough energy from renewable sources to be net zero for the “equivalent of all energy used in the community for buildings.” By breaking down the overall goal into a series of smaller sub-goals, communities can measure and demonstrate very significant intermediate milestones over time. The intermediate milestones break the daunting task of achieving net zero into a series of manageable pieces that are planned, budgeted for, and achieved over time. Breaking this goal into a series of smaller, manageable and financeable pieces over time, might be the key for communities to move towards the aspiration of net-zero energy.

One example set of intermediate milestone toward the aspiration of net zero is shown graphically in Figure 2.

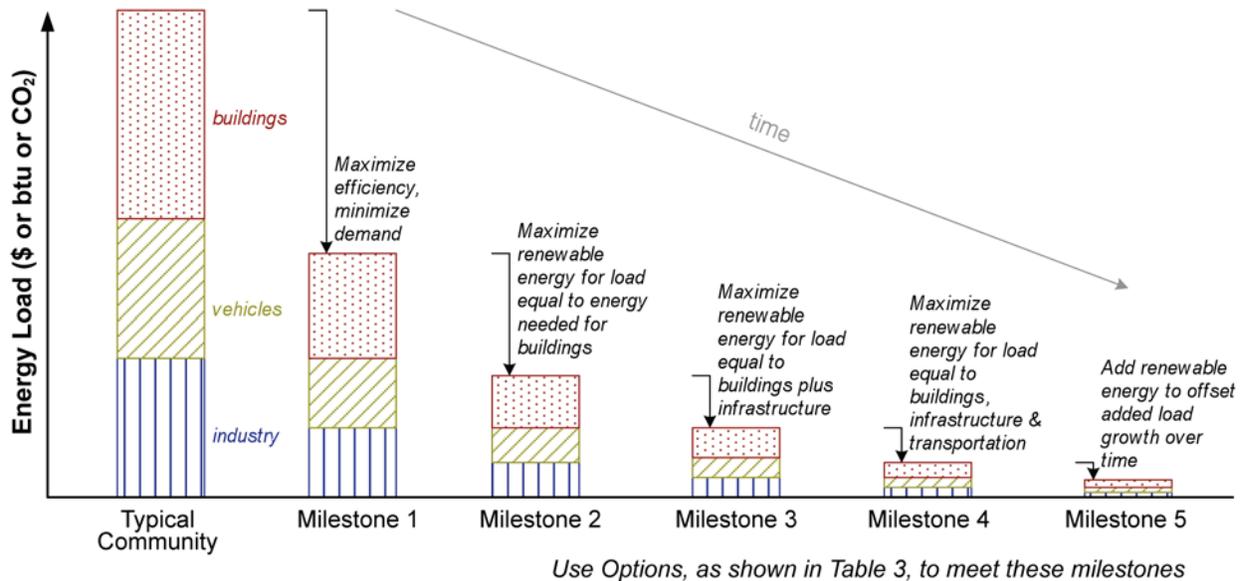


Figure 2. Intermediate milestones to Net Zero Communities

When the community has implemented all energy efficiency and conservation opportunities and quantified these energy savings, the community can claim it fully met the achievement of a net-zero community for milestone one. In this way, over time the community can show progress and claim success as it moves toward the “aspiration of net zero.”

Developers of a new community may decide that they cannot take the community to net zero because they do not control all aspects of energy use within the community. In that case, the suggestion is that they define the energy used in a typical community and then define the quantity of energy that represents their sphere of influence and control. When the developers can calculate and verify that they have reduced energy use in the community to the degree necessary to achieve the milestones they feel are within their control, then they can claim they have achieved net zero for “all measures within their control.” The measurement and verification would be important to substantiate the achievement of the goal.

The measurement and verification process is the key to defining and tracking the goal. The energy used by the community would be measured by comparing a baseline of energy needs for buildings, community infrastructure and transportation (as a minimum) to the energy supplied by Options 0-3 on an annual basis from renewable energy sources. Measuring can be done on a site or source energy basis, carbon basis, or energy cost basis in order to compare all renewable energy supplied (for electricity, thermal and transport fuels) to all loads to determine if the goal was achieved over a given time period. In this way, for example, excess renewable electricity production could be used to offset the use of conventional thermal energy or transportation fuels used.

4 Conclusions

In order to realize deep energy savings it is important to look at energy use in a community as an integrated system rather than discrete problems and solutions in each energy end-use sector. By defining a zero-energy community and offering a set of metrics to measure progress toward the aspiration of net zero, we aid in moving the dialog from buildings-only zero-energy solutions to solutions that consider all uses of energy within a community for buildings, transportation, community infrastructure, industry, and other.

A definition for a zero-energy community is different and more complex than that of a ZEB because a community uses energy not only for buildings but also for industry, vehicles, and community-based infrastructure. This paper builds on work done to develop a zero-energy buildings definition and expands the concept to define a zero-energy community. The ZEB hierarchical renewable classification system is then applied to the concept of community. This approach emphasizes using all possible cost-effective energy-efficiency and demand-avoidance strategies first and then using renewable energy sources and technologies that are located in three places: first, on space within the built environment or unusable brownfield sites within the community; second, on either green space within the community or located outside the community boundary but within the region and brought into the community; and third, through the purchase of new RECs.

In addition, we set up a series of intermediate milestones so a community can begin to plan toward the aspiration of net zero over time. The goal of this type of classification is to encourage developers and campus and community planners to develop a comprehensive multi-year plan to understand the magnitude of change needed in community energy patterns to move toward a net-zero community. Both the long-term understanding and multi-year implementation strategies with a series of intermediate milestones are essential to drive the transition towards greater emphasis on energy demand reduction and greater reliance on the use of renewable energy.

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