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Energy Master Planning Towards Net-Zero Energy Communities/Campuses

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ABSTRACT

The influence of increasing oil prices, the effects of climate change, and the desire to become independent of fossil fuel imports have stimulated many countries and their communities to set ambitious goals to reduce energy use and to increase the relative amount of energy derived from renewable energy sources. The most ambitious goal is to become net-zero relative to fossil fuels or to employ the concept of the energy neutral community/campus. Essentially, both terms denote an energy configuration in which the amount of fossil fuel-based energy used over the course of a year is equal to the amount of energy derived from renewable energy sources that is exported from the community/campus to a power or thermal grid for external users' consumption. Under ideal circumstances, the community consumes no fossil fuel-based energy, only energy generated from renewable sources; this would require the availability of long-term thermal and power storage systems. The achievement of such energy goals in economical and physically realistic ways would require new, unconventional approaches with respect to organization, implementation, funding, and technical decisions. The technical approach involves the emphasis on energy conservation, implementation of energy efficiency measures, use of waste energy streams, reduction of fossil fuel-based energy (if needed), and/or complementation or replacement of fossil fuel-based energy with energy derived from renewable sources. This paper explores approaches used by some of the most innovative International Energy Agency (IEA) countries to develop an ideal road map and transition process to reach net-zero or near net-zero energy targets; analyzes best practices in different countries to provide the best examples of net-zero applications across the globe; and, based on an analysis of solutions using front-running methods and technologies, makes recommendations for energy master planning towards net-zero communities and campuses.

INTRODUCTION

In recognition of the fact that 40% of end-energy consumption is caused by the built environment, many countries around the world are setting increasingly stringent energy targets for new construction and building renovation projects to combat climate change, reduce energy-related costs, and improve energy security. In Europe, the main legislative instrument for improving energy performance is the Energy Performance of Buildings Directive (EPBD), which was introduced in 2002 and recast in 2010 (Directive 2010/31/Eu). Overall EU policy and goals include reduction in carbon dioxide emissions by 20%, generation of 20% of end-use energy from renewables, and a 20% drop in primary energy use by 2020. By that time, all new buildings constructed in Europe will be nearly zero energy buildings. During the same time period, the existing building stock will also have received continuous attention. New energy standards for new construction and major renovation projects have been introduced and applied to thousands of projects around the world (e.g., the Passiv Haus in Germany or the Swiss Minergie). Many countries have successfully demonstrated net-zero energy buildings.

In the United States, federal government agencies are required by law to eliminate fossil fuel use in new and renovated facilities by 2030 and to reduce overall facility energy usage by 30% by 2015 (EISA 2007). New buildings and buildings undergoing major renovations are required to reduce consumption of fossil-fuel-generated energy, both off- and

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on-site by 55% in 2010, 80% by 2020, and 100% by 2030. These reductions are relative to energy consumption by similar buildings in fiscal year 2003, as measured by Commercial Buildings Energy Consumption Survey (CBECS) or Residential Energy Consumption Survey (RECS) data from the Energy Information Agency.

The 2005 Energy Policy Act (EPAct 2005) requires that federal facilities be built to achieve at least a 30% energy savings over the 2004 International Energy Code or ASHRAE Standard 90.1-2004, as appropriate, and that energy efficient designs must be life-cycle cost effective. The U.S. Army has a policy goal to achieve nine net-zero energy installations by 2020 and 25 by 2030.

Currently, most international research and policy energy-related efforts in the built environment focus on renewable energy sources and energy efficiency in single buildings. Organizations that have made first efforts to evaluate and analyze international experiences on planning and implementation of low-energy communities include the IEA ECBCS Annex 51 (Jank 2012); the German funded project EnEff Stadt (a comprehensive approach to urban areas with local and district heating networks) (Jank 2010); the World Bank Energy Sector Management Assistance Program (ESMAP 2012), Energy efficient cities initiative (ESMAP 2012); and the Clinton Climate Initiative C40 program (C40CITIES 2011). The U.S. Army is pioneering a Net-Zero Installations program, for selected installations, which goes beyond zero energy and includes zero waste and zero water initiatives (ASA [IE&E] 2012).

First experiences in the development of net-zero energy communities have revealed not only challenges, but also significant opportunities supporting net-zero energy community concepts including increased budgets for investments derived from energy savings, increased comfort and quality of life, and local production that boosts local economies. Experience with the first energy-neutral town in the world (Güssing, Austria) showed that a transition to a 100% renewable energy supply (Güssing 2011) can triple tax incomes and thus boost the local economy within 15 years.

In community-wide energy planning, it is important to consider the integration of supply and demand, which leads to optimized solutions. The objective is to apply principles of a holistic approach to community energy planning and to provide the necessary methods and instruments to master planners, decision makers, and stakeholders.

According to the approach of transition-management (Loorbach 2007; Roorda et al. 2011; Rotmans and Loorbach 2009a; Rotmans and Loorbach 2009b; Drift 2010), it is important to set and define a realistic long-term target and to develop a road map to achieve it (Figure 1). As soon as the ideal road map based on the experiences of the early innovators is developed, one can analyze the bottlenecks that must be overcome. This bottleneck analysis with the relevant stakeholders forms a solid basis for the optimal way to exchange knowledge and learning experiences. Once bottlenecks are identified, one can begin to find possible solutions from the database of the best practices. Instead of "reinventing the wheel" or using inefficient guidebooks, stakeholders will be open to learn possible solutions from relevant case studies. Stakeholders may also be more willing to accept the feasibility of solutions that have worked elsewhere or at least to adapt the solutions to their own boundary conditions.

Transition to a net-zero community requires that a wide range of technical, economical, architectural, financial, legal, and behavioral requirements be met. Although these requirements are interconnected, efforts to meet apparently competing requirements may lead to contradictory measures, unless they are considered holistically. Therefore, it is critical to make a coordinated, interdisciplinary effort in the transition to a net-zero energy community. This effort, which requires the support and commitment of all stakeholders, should be based on a vision of a future state of the community.

One of the best examples of transition-management was shown in the process of putting a man on the moon. The political vision was first communicated by President Kennedy. That commitment was made without knowing what was necessary to achieve the goal. Many technical and organizational problems had to be overcome, and the process had to be carefully guided and coordinated over time. The process to reach net-zero energy communities requires a similar approach. The City of Stockholm's (2010) *Vision 2030*, which projects how it will achieve sustainability, focuses on development and management of the unique regional assets (e.g., land use, housing, environment, conservation of natural resources, energy generation and distribution in sparsely populated areas and archipelagos, social perspective). A similar vision has been developed for the province of Limburg in the Netherlands for 2050 (RiBuilt 2011).

Energy master planning is a complex process that includes cultural, organizational, technical, legal, and financial aspects. This paper explores approaches used by some of the most innovative IEA countries to develop an ideal road map and transition process to reach net-zero or near net-zero energy

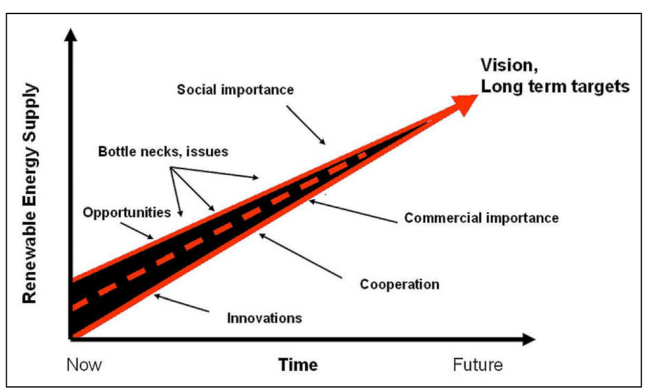

Figure 1 *Transition-management designing a road map towards a vision.*

targets for communities; it also analyzes best practices in different countries to provide examples of net-zero applications across the globe and also to show how different boundary conditions in different countries influence the results of net-zero energy communities/campuses' energy master planning processes. (Underwood, et al. 2010; Zhivov et al. 2010; Annex 51 – Subtask A 2011; Annex 51 – Subtask B 2012; Church and Webster 2011; Boutaud et al. 2012; Rosa 2011; Strasser 2011; Eicker and Herrmann 2010; Zinko 2011; Broers 2010).

GOALS, BOUNDARIES, AND ROAD MAPS

Transition requires a disciplined planning and implementation process. This section discusses the definitions of goals and objectives, the identification of system boundaries, and the creation of a road map for implementation.

Goals and Boundaries

First, it is important to clearly define long- and short-term energy goals, project boundaries, as well as important limitations and other priorities, e.g., energy security requirements, water availability and conservation goals. Long-term energy goals can be expressed as the reduction by a desired percentage of site or source energy against a baseline in a given year or the achievement of a net-zero site/source energy community within a given time frame. There is often confusion between site and source energy in the definition of net-zero energy community, and this difference defines technical approaches used to achieve this status.

When the goal is to minimize community site energy, the emphasis is made on energy efficiency of systems located inside community boundaries; the amount of thermal or electrical energy supplied to the community is treated equally without any consideration of inefficiency of electricity generation or distribution losses in thermal and power networks. Such an approach may result in preferences for such technologies that consume electricity for heating and cooling, such as electrical heating, electrical cooling, or ground-coupled heat pumps. Given the inefficiency of power generation, such an approach will result in increased fossil fuel usage and greenhouse gas (GHG) emissions.

When the source energy or fossil fuel-based energy is considered as a minimization parameter, energy efficiency of the community systems may become of less importance. Communities connected to hydropower stations or to nuclear reactors will become fossil fuel neutral without any effort given to improvement of community energy systems. However, when electricity provided to the community is primarily based on fossil fuel, which is the case for most communities connected to large power grids, the goal of net-zero fossil fuel is more challenging in that it requires improvements in the efficiency of the community energy system and reduced energy waste in the power generation and distribution systems.

The scope of energy minimization effort can include residential, commercial, and public buildings; community-based infrastructure; industrial energy users; community-owned and transit transportation; agriculture and other energy-consuming users; or any combination of those. When defining the scope, it is important to understand which energy users the community can control. The most common net-zero definition of energy target includes source-based energy targets, community building stock, industrial processes, and community-based infrastructure; such targets sometimes extend to community-owned private and public vehicles.

The terms *net-zero fossil fuel* or *energy neutral community/campus* describe energy configurations in which the amount of fossil fuel-based energy used within community boundaries over the course of a year is equal to the amount of energy from renewable energy sources that is exported from the community to a power or thermal grid for external users' consumption. Under ideal circumstances, the community consumes no fossil fuel-based energy, only energy from renewable sources. Such a configuration would require the availability of long-term thermal and power storage systems.

A community can have fixed boundaries defined either by physical limitations (e.g., an island-based community) or political or administrative boundaries. For example, a military installation or university campus may be a contiguous area or may be comprised of separate areas. Such community boundaries define its real estate, but may also suggest the possibility for interface with other communities via electrical or thermal (district heating/cooling) networks. An analysis of community boundaries may also reveal how communities can best meet their energy needs (e.g., by purchasing power, hot water, steam, chilled water, or other utilities from networks, and/or by capturing waste heat from processes). The same analysis can determine the feasibility of exporting power, heat, and cooling energy from cogeneration to other buildings within the community.

After defining the community energy goal, it is important to connect that goal to the existing community's core values, which may include enhancing energy security and reliability, improving social cohesion, creating a healthy environment, and promoting local employment. Community leaders, decision makers, and local residents/end users and businesses can help to define these core area values and connect them with the planned community development.

Long-term goals should be transitioned into medium-term goals (milestones) and short-term projects, which must have tangible results. It is important to recognize that many decision makers (e.g., university presidents, military installation commanders, elected officials) have limited-term assignments or duties and will more likely commit to projects that can be realized during their tenure. Furthermore, short-term projects satisfy the short-term interest of the private sector. It is important to get commitment from both decision makers and the private sector since they play key roles in achieving the long-term goal. The main restriction is that 100% of the short-term projects fit on the road map towards the long-term goals.

In the case of the city of Tilburg, the coordinating party, which included all stakeholders, has defined the city's long term goal as becoming climate neutral by 2045 with the following phased GHG reduction: 5% by 2012, 30% by 2030, 50% by 2030, and 100% by 2045. Three scenarios with different levels of ambition (Figure 2) have been developed. All anticipated efforts with respect to energy savings and the implementation of renewable energy were added as a function of time. As soon the curves of energy use and renewable energy production cross, one reaches energy neutrality. With the current projects described in the climate program, Tillburg will be able to achieve energy savings of 8% in the built environment and small and medium enterprises and contribute 2.7% to the sustainable energy production. In the most ambitious scenario, this point will be reached in 2040 on a city level (Scupad Congress 2008) or by 2030 without accounting for transportation.

Backcasting and Forecasting

The transition process is described in terms of the definition and implementation of a road map to net-zero energy communities. As soon as the long-term goal is set, one can apply backcasting and forecasting techniques to define the process leading towards energy neutrality (Figure 3). Backcasting denotes the process of defining milestones and determining the necessary steps to reach the final goal. Forecasting refers to planning projects to meet milestones defined through the backcasting process: setting project requirements and optimizing and designing projects and sets of projects in a holistic way that is geared to meeting each milestone. The feasibility of the projects can be learned from the best practices and the frontrunners.

Backcasting starts with defining desirable future goals and then works backwards to identify policies and programs that will connect the future to the present. Backcasting answers the fundamental question: "If we want to attain a certain goal, what actions must be taken to get there?" Back-

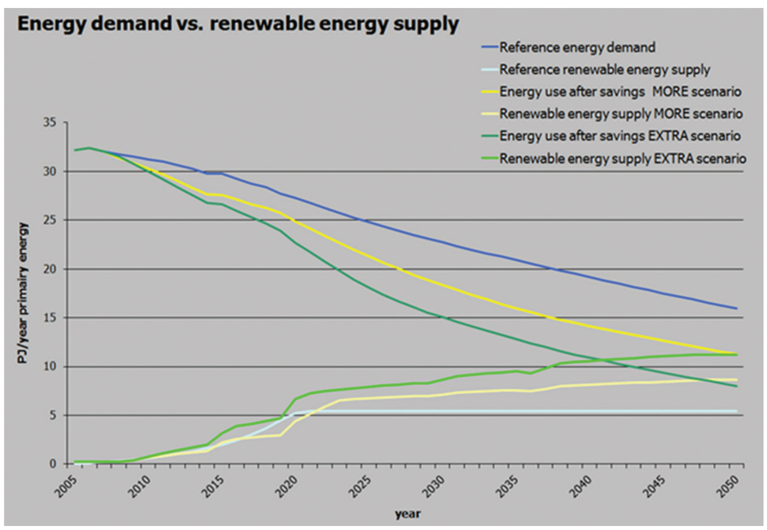

Figure 2 *Several scenarios of different ambition for the city of Tilburg to reach energy neutrality. (Scupad Congress 2008).*

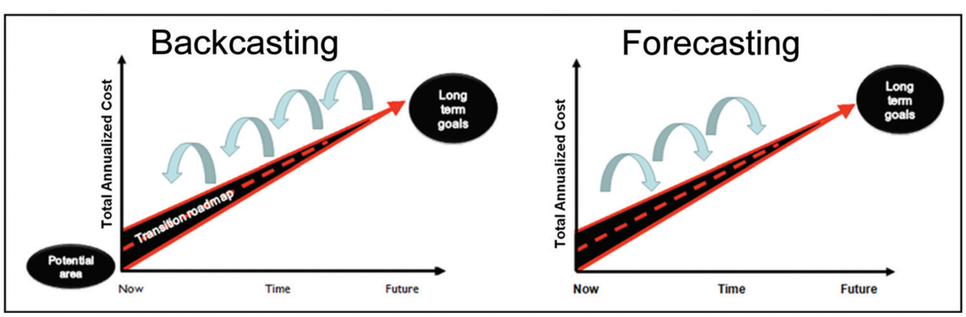

Figure 3 *Forecasting: formulate concrete actions from core area values and test them with the long-term values. Backcasting: formulate concrete actions from the long-term goals.*

casting and forecasting approach the challenge of discussing the future from opposite directions. Using backcasting, concrete actions in the short term can be formulated from the long-term goals. For instance, a goal of an energy neutral built environment in 2050 could be supported by requiring that all new houses built after 2015 (for instance) be energy neutral.

Forecasting is the process of predicting the future based on current trend analysis. For example, using forecasting, one learns from the frontrunners about how to achieve energy neutral houses and how to determine what measures are needed to achieve energy neutral houses. Backcasting and forecasting processes are both necessary to determine the transition path and to make the road map as concrete as possible. Backcasting and forecasting can also be used for monitoring the transition process to the long-term goals.

Complementary Goals (Spin-Offs, Co-Benefits)

Different innovative net-zero energy projects around the world have shown that energy efficient projects will be more successful if they can be linked to other key issues, which are of economic, social (quality of life), health and environmental character. In the United States, one can profit from regional credits. These “spin-off” effects are usually not taken into account when making a business case for an energy efficient urban development. When the spin-off effects are taken into account and valued, the whole effort will become more feasible and easier to motivate. However, a complication often arises from the fact that co-benefits arise from different departments and/or disciplines.

For military campuses in particular, but also in the future for local communities, energy security becomes an increasingly important spin-off (Army Senior Energy Council 2009). In a business case, it is hard to quantify the value of this spin-off; however, if one begins to consider the effects of black-outs (e.g., losing data, losing defense shields), the cost advantages of becoming net-zero become more apparent.

Driving Factors for Innovation

Essentially, the reduction of energy use is not as much the problem as it is the solution for making the net-zero project/program financially feasible. However, too often one only considers conventional figures of energy use. Energy efficient buildings need smaller and less expensive mechanical and energy systems. Since these systems were already in the budget, reducing their size and cost makes more money available to invest in building energy efficiency measures and renewable energy sources. This process works best when energy efficiency is seen as a challenge and not as just a difficult requirement. In developing requests for proposals one should not prescribe exact solutions, but leave room for contractors to innovate and create their own solutions. They can use innovation and energy efficiency as their selling point.

Innovative market leaders can influence other market parties to become more innovative as well. Different market players working together in new coalitions learn from each other and from market leaders about different technologies and how to organize the process. Community leaders can make progress by organizing competition between innovative businesses, and/or by awarding bonuses for every energy efficient project they complete. While innovation seems expensive at first, an approach that integrates insulation, multi-functional systems, and low energy appliances can dramatically reduce investments in the conventional infrastructure.

ROAD MAPS

As in the example of Tilburg (Figure 2), many innovators use different road map scenarios with different levels of ambition. Road maps predict possible energy savings and describe energy generation measures that can bring community to an energy neutral state in a certain year. When all the strategic decisions are made and backcasting and forecasting have been applied, one can then start to design road maps. However, before beginning to implement the road map, one must consider the bottlenecks that must be overcome and how to steer the process to overcome them.

DEALING WITH BOTTLENECKS

An analysis of Annex 51 case studies has identified ten categories of bottlenecks, all of which are related to key issues that should be addressed to make the transition to energy efficient communities possible:

1. Vision and targets
2. Process and organization
3. Support and involvement
4. Skills and know-how
5. Technical concepts
6. Monitoring
7. Tools and methods
8. Financing
9. Legal issues
10. Spin-offs, co-benefits.

Bottlenecks most commonly occur in the areas of finance, design, procurement, quality control, and collaboration between different trades; they are often characterized by short-term thinking, separation of implementation and operation, lack of incentives to achieve energy goals (including a lack of negative consequences for energy inefficiency), segmentation of organizations and working methods by sectors, lack of coordination between different projects executed within the same community, etc. Figure 4 shows the results of analysis of typical bottlenecks conducted by members of the IEA ECBCS Annex 51 based on their practical experiences and case studies using the “logical framework approach” (Europeaid 2004).

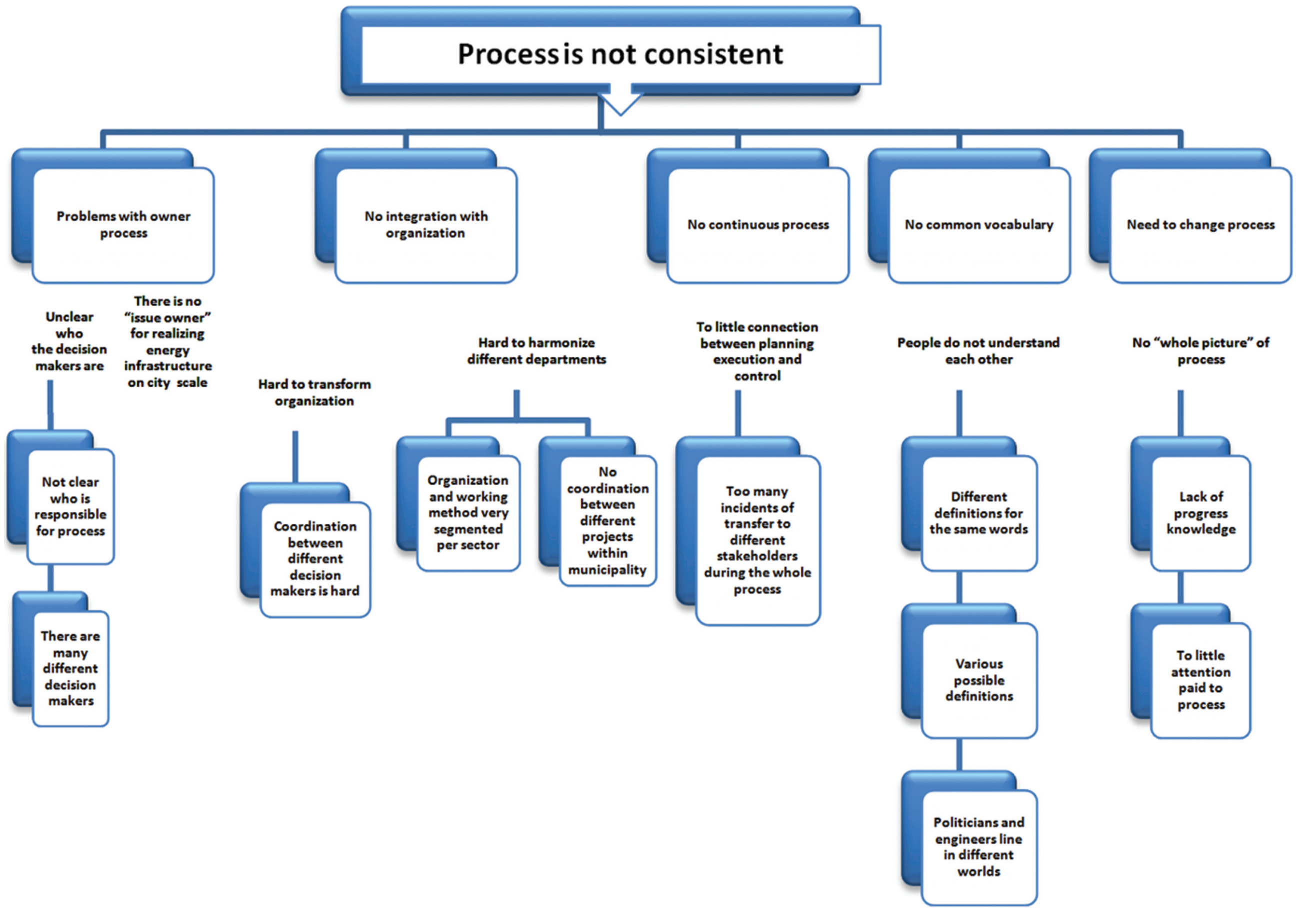

Figure 4 *Bottleneck analysis of transition processes. This problem tree must be read from the bottom to the top: The bottlenecks at the bottom lead to the bottlenecks above.*

By using this method, the real underlying problems can be identified. The bottleneck analysis gives insight into the causal relationships between the main problem and sub-problems. By using the reverse value of the bottlenecks in the problem tree, a solution tree is designed to reach the ideal situation. The problem tree is used to build up the solution tree. Every clustered bottleneck can be transformed into a solution if you know the underlying problem. Also the solutions mentioned in the case studies are used to make the solution tree. Solutions for bottlenecks that hinder the path to net-zero communities can be summarized as:

- Develop goals and ambitions and describe them in a policy document(s). Use benchmarking where possible to ensure feasibility of goals.
- Design the road map/transition-management plan: define and visualize the net-zero community, its space and area; define milestones (backcasting) and specific steps/projects (forecasting based on best practices). Organize a strong team to coordinate the road map.
- Bundle economic results/develop business model and spin-offs. Develop business plans. Select contracts based on price and quality for the whole life of the system. Obtain strong commitment from stakeholders by showing spin-offs.
- Develop different scenarios—consider "out of the box" solutions. Analyze these scenarios technically and economically.
- Select the best energy concept. Determine the energy use and energy use reduction with this scenario. Analyze the impact of the implementation selected scenario on the achievement of energy goals by the whole community. Select the right energy system/technical solution for the concept implementation.
- Plan the implementation, meter and monitor the results, and apply a steering mechanism that allows for appropriate iteration(s) based on quantified results.
- Ensure implementation. Develop a strong implementation/execution program with well-defined technical specifications and a contractual framework that allows for achieving ambitious goals.
- Involve users and encourage their participation and behavior, resulting in quick successes.

STEERING THE TRANSITION PROCESS

Many projects succeed or fail on the basis of whether they have included the right stakeholders and whether they can adjust to changing conditions. Over the course of a long transition, the stakeholders, priorities, energy costs, technology, and many other factors are likely to change. In an ideal collective process, all stakeholders will be represented in a transition arena. The goal of this arena is to realize an innovative and ambitious perspective for the future. Each stakeholder brings the perspective of their own organization, including goals and existing short-term initiatives. They should be empowered to speak for their organizations, make decisions, and to bring vision, strategy, and action together. The participants form a small and deep support group that fully understands the transitional strategy and that can steer it in later stages.

Although some believe that the transition arena approach is ideal, analysis of front-runner projects has shown that this is difficult to realize in practice. It may be the case that different steering models will be most effective in different phases of the transition process. Analysis of front-runner projects has identified six steering procedures:

- Government driven
- Private sector driven
- End users driven
- Public private partnership
- Participation model
- Transition model

A steering model shows the stakeholders that are involved and identifies the mutual relations between the stakeholders. Identification of the steering procedure that is most suitable for a project or for a situation depends on many factors, like the position of involved parties, the phase of the development, and the diversity of interests. It is important for a municipality to identify its degree of influence with respect to the other stakeholders. In many cases, the municipality is not the primary development party, but rather sets the direction and the conditions of the development. The steering procedures can be used to introduce the other stakeholders to this direction and conditions.

To give more insight into smart steering, six steering models have been identified (Figure 5). At some points, the steering procedures partly overlap because in some situations more than one steering procedure can be used. Also, in reality, mixtures of these steering procedures will occur.

Since energy efficient development projects will run for a longer time, the situation will change during the project and other stakeholders will be involved. It is probable that, with these changes, steering procedures also will change. Organizations can use the steering procedures to reflect on their current organization and use them smartly while realizing their targets.

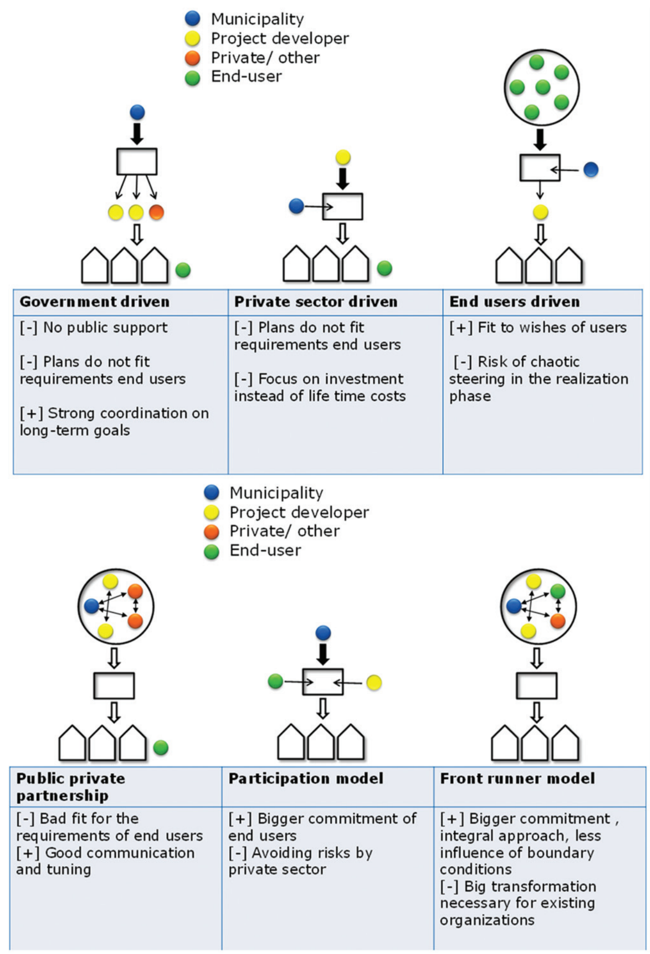

Figure 5 *Steering models.*

THE INTEGRATED ENERGY PLANNING PROCESS

Development of the transition process to low-energy or net-zero energy community requires close attention. Drawing from the experience of many studies conducted by the Engineer Research and Development Center (ERDC) and the IEA, a best practices process can be extracted for creating integrated energy plans. Figure 6 shows this process.

Decision makers can develop a standardized process for application to the future development of other energy efficient communities. This standardized process should include:

- Steps to follow throughout all phases: Determine the steps and the route that should be followed to actually realize an energy efficient community. Make a clear definition of ambitions and determine what should be translated into policy documents, what should be monitored, etc. These steps should be documented as a part of the policy.
- A definition of roles, tasks, and responsibilities of organization(s) and the people involved in the process: Who is responsible for what?

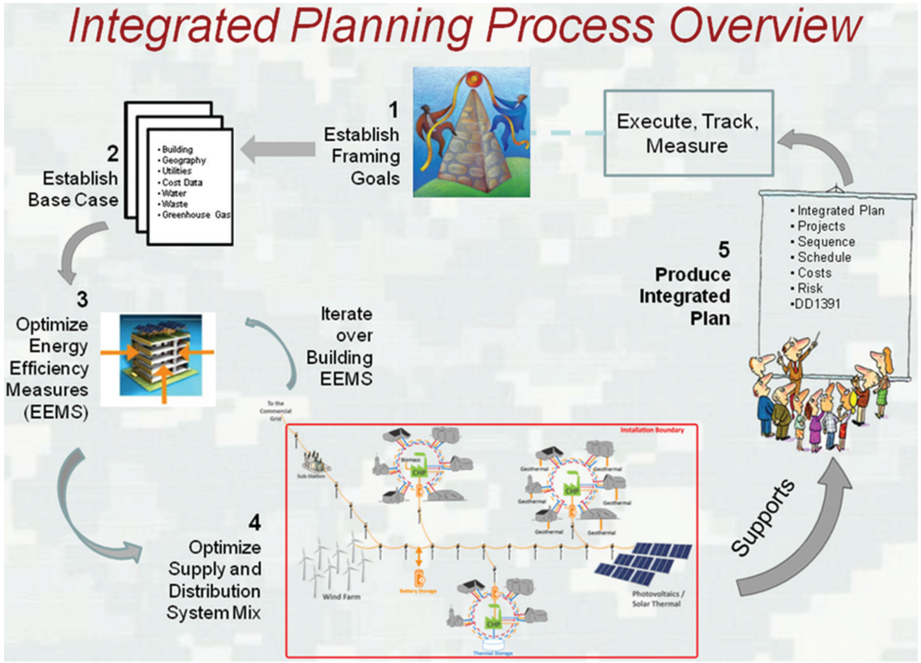

Figure 6 *Integrated planning process.*

- A definition of the "rules of the game": Net-zero community development is a kind of game. But often there are no clear rules. Define a standard set of rules.
- Begin the process by building a team/network of intrinsically motivated people. Creating a group of selected participants increases the chance of getting to a common ambition and will. However, there is still a good chance that some participants will need to be convinced to support the process. Be sure to follow the process of developing an energy efficient community. Assign a coordinator for the whole process. The coordinator is solely responsible for the realization of the integral and horizontal process. This person should be under the command of a high ranked official, with sufficient authority to organize this process. The coordinator must have certain competencies that enable him to organize the integral process. He must have insight in different areas of expertise and must be able to bring different trades together. He must be able to work on a broad, strategic basis and be capable to make decisions so that not everything need be passed to a higher board level. Note that the appointment of a single responsible person for the process does not mean that the appointee will know everything about the project. The knowledge about certain subjects and about the project should be widely shared. If a situation occurs in which this project leader will leave the organization, other people will have his knowledge and will be able to replace him. The responsibility should also be shared between different departments. Regular communication between these departments is vital to discuss ongoing projects, future plans, the role of energy efficiency and sustainability in these projects, etc. The core of energy efficient community development is to understand the energy efficient community in all its facets. To be able to create this, it is essential to involve all kinds of expertise and all kinds of perspectives. Co-workers of the organizations should be involved, as should all stakeholders, whose input and consultation is important from the first stages of the development.
- In a best case scenario, the process will establish a joint will, or commitment, that includes all involved stakeholders. This commitment will allow the community to accommodate new developments as they occur, and to jointly formulate integral goals, which must be attractive to all stakeholders.
- Development of an integral and widely supported community vision starts with a horizontal embedding in the organization. Simply put, all departments work together. This prevents fragmented planning and makes it possible, for example, to bring mobility plans and ecological plans together to answer questions such as: "Where do they fit well together, where are problems, and how should we solve them?" Another important advantage of this integral approach is that it anchors the organization. Working in this networked community starts with asking departments what they can contribute to the target projects. People should physically work together on themes or areas, but should learn to judge their contributions not on the results achieved by their own department, but on what their department contributes to joint objectives.

- A safe and open environment should be created to stimulate people to trust each other. Trust makes it possible for all participants to share their ideas and perspectives, and gives room to all participants to "score." It must be clear to the participants that the decisions made in common might not always fit in their individual views or interests. Where disagreements occur, the decision makers on opposite sides should clearly explain the reasons that influence their decisions. Focusing on the residents and users in the area favors an integrated approach and alignment with the demands of future users of the area.
- A safe and open environment creates room for new roles and new partnerships. New partnerships and new divisions of roles can invite creative collaborations between disciplines and actors. Parties work together and make each other stronger instead of reacting and maintaining conflicts. Fostering connections creates a strong group that can create and maintain strong ambitions and involve other persons in realizing community goals (example St. Johann, Austria [Strasser 2011] and Aarhus, Denmark [Rosa 2011]).
- Scope and Time Frame: Identify the elements and areas that are in-scope and out-of-scope for the study, as well as the planning horizon in years. Are all areas of the community being considered in energy calculations? Are there residents that the community does not have very much influence over? Will the study plan extend to the community boundary or beyond? What is the baseline year and are there data for it? What period will be covered? If the time period is too short, there will not be enough time to implement the plan; if it is too long, it may not be believable. Twenty-five years is a fairly common horizon for an integrated plan, although intermediate goals may be added.
- Framing Goals: It is very important to establish key goals before creating the base case or coming up with alternatives, For example: (1) decrease energy usage by 40%, (2) reduce fossil-based energy usage by 100% (i.e., net-zero), or (3) reduce water usage by 30%. The goals are used to compare the base case and alternatives.
- Baseline: A recent snapshot in time (e.g., for selected representative 12-month period) for which all utility costs and energy uses are documented. These energy data are critical to calibrate framing goals and progress in energy use throughout the study period.
- Base Case: Frequently, the most difficult part of doing an analysis, the importance of establishing the base case and projected energy usage over the study period, cannot be overemphasized. The base case includes current energy flows (electricity, fuels, hot water or steam, cold water, etc.) and projected changes already planned and funded. Alternatives considering portfolios of building energy efficiency measures (EEMs), distribution, and generation measures will be compared against the base case.
- Energy Efficiency Measures (EEMs: Improving efficiency is almost always less expensive than changes to distribution or supply systems. Thus we consider measures such as insulation, lighting, low flow fixtures, before adding expensive photovoltaics or other energy generation measures.
- Distribution and Supply: Many communities began with centralized electrical and (usually steam) heating plants, then slowly converted to hot (and sometimes cold) water distribution systems or completely decentralized systems that use natural gas or oil as a fuel and commercial power from the grid. Because of maintenance issues, steam systems are often not as economically viable as new or recapitalized systems, compared to modern cogeneration electrical power/heat/cooling plants or even as completely decentralized systems. However, a renewed emphasis on energy savings traced back to the source fuel may show that modern district systems are the preferred way to meet policy goals economically. (Typical electrical generation, transmission, and distribution systems waste up to 70% of the source fuel.)
- Renewable Energy: Supply solutions such as solar photovoltaics, solar thermal, wind energy, biomass (wood chips, etc.), biogas, or synthetic gas need to be considered as part of the mix during distribution and supply optimization. They are almost always more expensive than efficiency improvements or cogeneration using natural gas as a fuel, but there may be other policy goals driving their use (e.g., net-zero fossil fuel or energy security).
- Integrated Plan: The final integrated plan is produced by comparing the base case and alternatives using the metrics defined as part of the framing goals. A sensitivity analysis should be conducted using the alternatives and such risk factors as price volatility (What happens if natural gas prices double?), availability (Is there a domestic supply?), and maintenance costs (e.g., relative risks of decentralized versus centralized equipment). The integrated plan contains a phased implementation strategy over the study period that shows investment costs (public and/or private), predicted energy reductions, and return on investment.

FINANCING AND LEGISLATION

Solving the problems of financing should start by scanning the financial feasibility of the development as a whole. A change in thinking is necessary. Do not only focus on the initial investments, which will be quite high, but take the whole life cycle of the development into account, including such elements as distribution and storage of energy and the costs and benefits that result from consideration of the wide range of the "Triple P" (People, Planet, and Profit). Make clear what the costs and benefits (assurance of energy prices, energy security, more comfort, etc.) are for the different stakeholders involved in the development. Do this in an early stage of the development. Creating value will and should become an important starting point. These kinds of calculations demand long-term thinking in terms of longer recovery time investments, which might also attract other investors.

Performing feasibility studies and making business cases will involve the participation of new market players who should be chosen through a formal offer, or "tender," in which project implementation and further operation and maintenance are taken into account. The tender shall be based on quality, not just on low pricing.

Creating new partnerships and ownerships opens the opportunities for new partners. Partners can be involved in schemes like energy performance contracting, power purchase agreements, and lease constructions.

In these kind of financing schemes, different approaches should be considered including phasing projects, sharing risks, and combining private and public funds.

Solutions to legislation and financial problems can come from unconventional parties being involved in funding projects, e.g., investment in building's energy efficiency can be transferred to tenants through increased rent. (Lower energy bills will make this transition to tenants cost neutral.)

The anxiety of market parties can be mitigated by making the risks and uncertainties explicit and by sharing risks. Bring in expertise to parties involved to minimize the perceived risks.

Monitoring Process Results

Monitoring the process is an essential step in the process (Figure 7). Monitoring starts with the willingness to learn, to share these learning moments, and to change. All participants should be aware that regular monitoring is essential to realize end goals. Without monitoring, the process devolves into wishful thinking such that no intermediate steering is possible. Monitoring should take place along every step of the process, from beginning till the end. Monitoring denotes not only an analysis of the numeric information, but also a careful documentation and review of the transition process itself to analyze what went well, and what problems or circumstances arose that indicated that improvements were needed. Monitoring includes watching the progress, but also (perhaps more importantly) learning from mistakes. The results of monitoring can then be used to make changes in current and future projects, or if necessary, to redefine the transition path. For example, in Freiburg, Germany, the city's objective is to move away from nuclear energy and towards the use of renewable energy sources. The data shown in Figure 8 show how monitoring short-term results can help to achieve long-term goals.

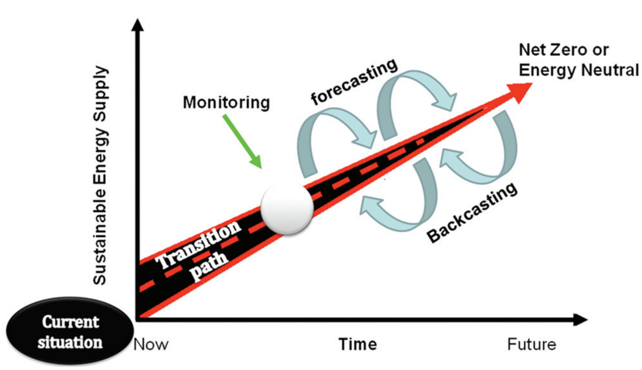

Figure 7 *The importance of monitoring: during the implementation, one must apply backcasting and forecasting to analyze whether it is still feasible to reach the long-term targets and/or whether additional measures are necessary.*

For example, the boundary conditions can change as a function of time. Storage systems become important at the stage of a 20% renewable energy supply. Distribution grids will be favorable with respect to flexibility and the implementation of storage systems in future. By using smart grids, energy management can be optimized and the exchange with the main grid can be minimized.

Knowledge Management (Training)

Attention to knowledge management is essential, on both internal and external levels. The involved persons (contractors or builders) should have the appropriate knowledge to do their job. One should organize workshops and training sessions for all relevant persons throughout the whole process to increase their knowledge. This process should use existing networks of several similar projects to foster knowledge exchange, to avoid "reinventing the wheel."

Cooperation and Rapid Changing Technologies

The problem with the involvement of multiple companies is not always easily resolved. One single product does not solve the integral problem and it is difficult to estimate its contribution to the whole. An integral approach is always preferable, but as discussed above, is not necessarily an easy route when the participants are historical competitors. An immediate solution would be to make one single company responsible for the result.

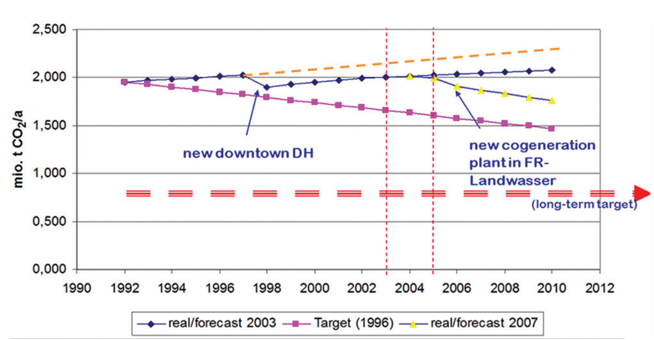

Figure 8 *CO_2 emissions in Freiburg, Germany (planning and reality) (IEA 2013).*

Since technology is changing at a rapid pace, it is likely that new concepts that are useful for the community will be developed during the lifespan of long-term projects. Therefore it is advisable to keep the possibility for new concepts open. Make the project's targets and vision clear, but also predetermine what techniques to use at project's outset.

Summary of Recommendations

The International Energy Agency common recommendations can be summarized as follows:

A. Smart Control:
   a. Utilize personal ambitions and effort.
   b. Appoint a process coordinator.
   c. Assemble a strong project team.
B. Inspiring Vision and Targets:
   a. Visualize the future energy efficient community.
   b. Set ambitious targets.
   c. Lay down targets in policy documents.
C. New Coalitions:
   a. Create new forms of cooperation.
   b. Involve end-users in the decision making process.
   c. Share knowledge.
D. Clear Analysis:
   a. Develop energy analysis of the area/community.
   b. Determine the energy demand after implementation of energy conservation measures.
   c. Analyze energy conservation potential.
   d. Select a suitable energy system.
E. Realistic Plans:
   a. Develop an integral business plan.
   b. Take the operation phase into account.
   c. Build powerful financial coalition.
F. Decisive Implementation, Execution, and Operation:
   a. Utilize innovation skills of companies.
   b. Assure quality of energy systems.
   c. Monitor progress and results.
   d. Encourage energy efficient behavior.

TECHNICAL CONCEPTS AND SCENARIOS OF ENERGY SYSTEMS FOR A NET-ZERO ENERGY COMMUNITY

Community energy planning and energy system optimization do not require new tools, just better integration of existing tools. In the past, central energy system designers used hydraulic and thermal optimization tools to design the components of the energy supply system for a combined heating and power plant using an optimization strategy. This strategy can be used for both heating and cooling systems. While these tools and this approach are rarely used by community energy planners, they illustrate an important feature necessary in community-wide energy planning to integrate supply and demand to achieve an optimized solution. The objective in applying the principles of such a holistic approach to community energy is to provide such necessary methods and instruments to master planners, decision makers, and stakeholders.

Thermal energy systems consist of three major elements: energy generation, energy distribution, and energy demand (Güssing 2011) (Figure 9). The goal is to find the optimum balance of these three elements for the entire energy system, where each element is considered in the calculation of the amount of energy delivered and lost, in various forms, by the energy systems (Loorbach 2007). The challenge is to assess the system's energy needs in terms of heating, cooling, and power generation, and then to estimate how those needs can be met by the various energy systems that are ultimately chosen.

Some communities have specific energy security requirements for the entire community or selected buildings (e.g., military installations, hospital campuses, childcare and senior citizens facilities, telecommunications and financial facilities, data centers, manufacturing enterprises with uninterruptible processes). An important element in energy security is energy surety, i.e., to prevent loss of access to power and fuel sources. This common term, used in the U.S. Department of Defense (DoD) and Department of Energy (DOE) communities, refers to the integration of safety, security, reliability, and performance aspects of energy systems. Future community growth and climate change present a challenge to energy sufficiency of the entire community, especially to its critical mission facilities.

Meeting these challenges requires consideration of boundary conditions and specific requirements for equipment and energy concepts for on-site energy generation and energy storage and distribution systems, which may include, but not be limited to uninterruptible power supply to mission critical facilities, and a supply of heating and cooling energy to prevent freezing and overheating of buildings (living quarters), steam for sterilization, and operation needs for critical processes, including smart power and thermal- and micro-grids.

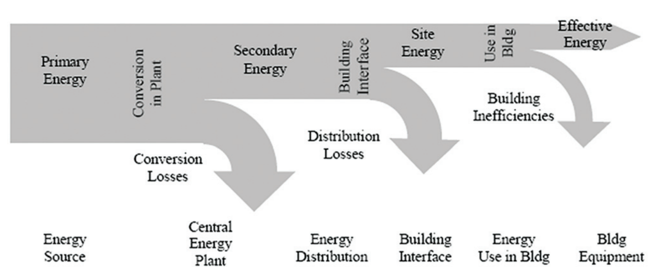

Figure 9 *Energy supply chain from primary energy to its use inside a building.*

Optimization of community energy systems to achieve both annual net-zero energy consumption goals and energy security requirements will define the spectrum of energy systems to be considered. A limitation on the type of energy system to be selected may be whether that community can be connected to external utility grids or whether it can import fossil fuel. A community's physical (isolated island location), political, or administrative boundaries, will limit its capability to export excess power and thermal energy produced from renewable sources, which could otherwise offset fossil fuel-based energy use. Utility grids servicing such communities that rely only on renewable energy sources will require long-term, large scale electrical and thermal storage. Figure 10 shows community energy supply on an installation level.

ESTABLISHING A BASELINE

An important step in community energy planning and energy system optimization is establishment of current site and source energy use and cost profiles and associated greenhouse gas emissions. The baseline data need to include information on different types of energy used, fuel mixes, and electricity sources. Figure 11 shows an example of primary energy use and cost for one military community.

Then, the total energy use in the community should be broken between consumption between different users, losses in generation, conversion, and transmission. This information will provide a good starting point for identification of energy wastes and inefficiencies along the chain between the energy sources and energy use. The best sources of such information

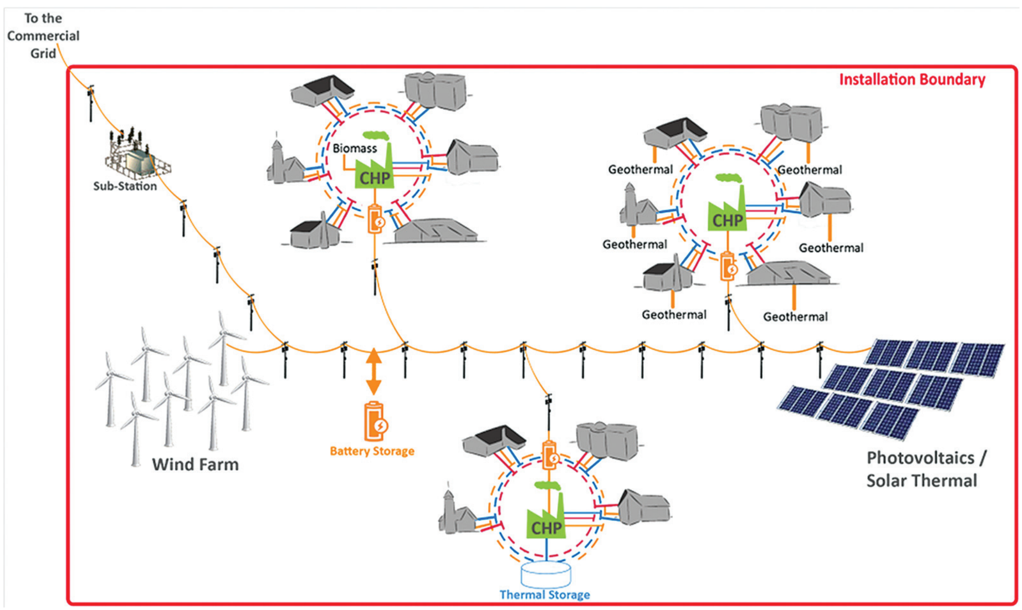

Figure 10 Community energy supply.

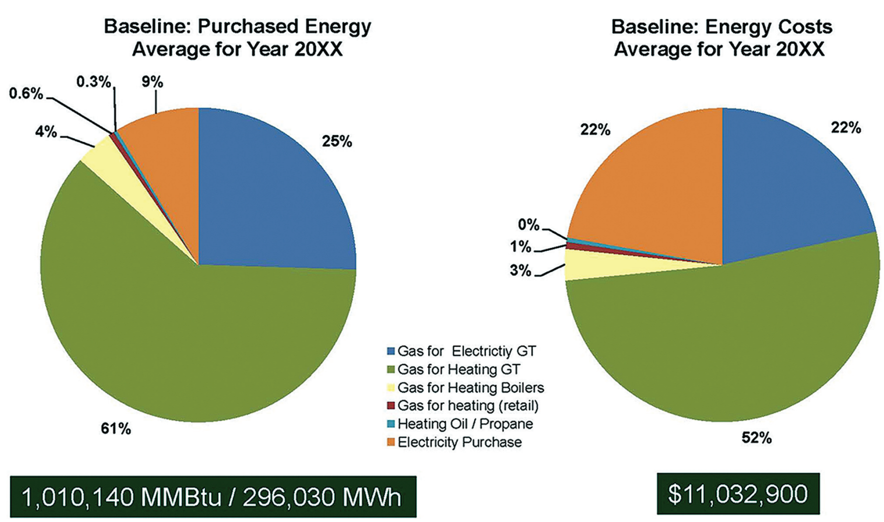

Figure 11 Example of primary energy use and cost for a military community.

are energy bills, metered energy logs, targeted measurements of energy losses in distribution systems and modeling results. The energy distribution profiles should be shown for groups of buildings and individual buildings as well. The baseline data described above can be used to project a base case scenario for energy use given the availability of information on an increase or decrease of energy use due to new construction, consolidation and demolishing processes, buildings repurposing and change of mission, use of new and existing utility contracts, and the dates when known contracts will expire, Any planned and programmed measures for energy use reduction through efficiency measures should be included in the base case scenario. Case et al. (2013) describe the data collection and analysis process for a base case using the U.S. Army's Net Zero Installations planning tool.

BUILDING LEVEL OPTIMIZATION

Communities can be comprised of either homogenous building stock (i.e., residential areas) or a variety of building types. Energy requirements in some of them (i.e., residential buildings, offices, child development centers, repair and maintenance facilities) are dominated by climate control (heating, cooling, and humidity), with smaller effects from plug-in loads. Other buildings (e.g., hospitals, data centers, dining facilities, laboratories) have high energy loads dominated by internal processes and/or high ventilation requirements.

Most of these facilities may be candidates for some similar, well understood energy use reduction methods (e.g., building envelope improvement, better lighting systems designs and technologies). In buildings with high internal loads, however, energy use can be reduced only by altering the way specific processes use energy efficient appliances and significant waste streams (Zhivov et al. 2006; IEA 2012; Deru et al. 2012); currently, this is rarely addressed.

Energy demand determines the amount of energy that the energy supply and distribution system must provide. Evaluation of a community or a cluster of buildings will reveal opportunities for energy savings and challenges for analysis and optimization. Addressing buildings as a cluster does not require a deep evaluation of each building, but does require that individual analyses be applied to the building cluster and that consideration be given to the possibility of integrated supply services.

The building optimization process starts with: (1) identifying typical buildings and energy systems in the community and existing energy wastes and inefficiencies related to these buildings and systems (IEA 2012); (2) developing load profiles for typical base-case buildings; and (3) analyzing suites of technologies for an ultra-low energy community to include waste recovery and energy conserving (ultra-low energy) and energy generation and storage technologies that could be applied to buildings and the energy systems that support those buildings to minimize traditional electrical and fossil energy use (Zhivov et al. 2009; Herron et al. 2009; Deru et al. 2009; Carpio and Soulek 2011; Liesen et al. 2012; Deru et al. 2012).

Optimizing Distribution and Supply

After the life cycle cost efficiency measures have been applied to decrease load as much as possible, analysis continues with distribution and supply systems optimization. One of the supply scenarios may include a decentralized option for building heating and cooling. The engineer may also identify clusters of facilities to be supplied by a central plant or by several smaller plants. As the user includes or excludes facilities, cluster loads and load profiles must be updated to optimize supply system architecture, which may include reciprocal engine or gas turbine cogeneration, solar, wind, and biomass, as well as more traditional solutions such as gas-fired boilers and diesel engines. Different alternative distribution systems can be considered as well.

The supply system optimization process determines the lowest life cycle cost suite of equipment and ensures that the demands for heat, cooling, and electric energy are satisfied during each of the 8760 hours of the year, and that additional user-specified constraints are also satisfied.

Integrated versus Single Component Optimization

There is a debate over whether to conserve energy first or to simply generate energy with renewable alternatives. Figure 12 shows several theoretical paths that a designer or master energy planner can choose and the process for each individual building and building cluster optimization. Point 1 represents the base case building, which is either an existing building or a new building that must be built to local code requirements with a given total annual cost (the annual mortgage or financed first cost plus the annual energy operating costs). If renewables are added at this point, the total annual cost of the net-zero energy building will be as shown in Point 7, using a constant cost for a unit of photovoltaic system ($/sq ft [$\$/m^2$] of a photovoltaic [PV] panels or $/Btu [$/kWh] electricity produced). Point 8, which is created by adding expensive renewable technologies without reducing buildings demands first, has the largest annual cost.

Another alternative from Point 1 is to add energy efficiency technologies at the building level, which will require investing in these technologies (additional first cost). With this alternative, you eventually reach Point 2 with the lowest total annual cost. Typically you would not add renewables at Point 2 since adding many conventional energy efficiency technologies at this point may be more cost effective than adding renewable generation. When Point 3 is reached, you have achieved the same total annual cost as your existing building or a base case building built to code (Point1), but the building at Point 3 is now much more energy efficient and often much more comfortable. As one continues to add energy efficiency improvements, the building will eventually reach Point 4, where adding more EEMs will either result in diminishing returns, or will cost more than adding renewable generation.

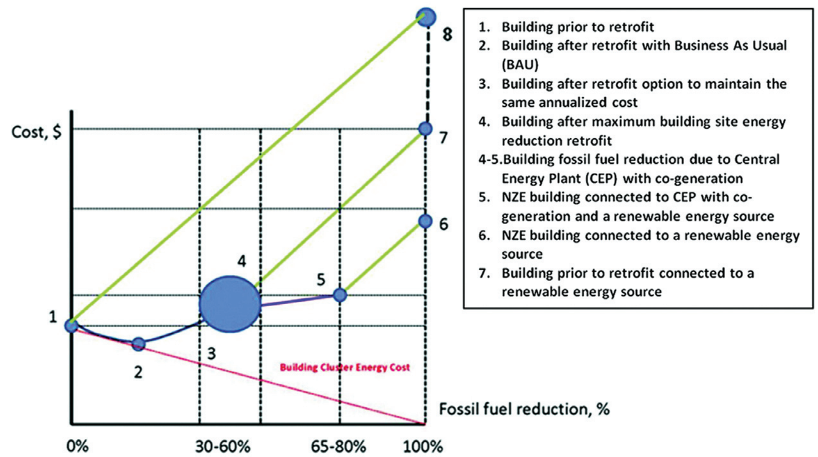

Figure 12 *Building fossil fuel reduction optimization process.*

For an individual building analysis, this building at Point 4 would be Net-Zero Ready. For different types of buildings and climate locations, fossil fuel-based energy reduction will vary (Church and Webster 2011). In buildings with low internal energy loads, reduction of fossil fuel can be significant (50% to 75%), but in buildings with high internal loads, lesser reductions (20% to 30%) may be achieved. This is true even for buildings built or retrofitted to passive house requirements and that use advanced low exergy systems to satisfy remaining heating and cooling needs. The remaining energy requirements will be dominated by electrical power needs for lighting, appliances, and internal processes and by domestic hot water needs e.g., for showers. Adding renewables from Point 4 will result in the total annual cost shown by Point 7. The process from Point 4 to 7 is approximately at the same slope, or cost, as the process from Point 1 to 7, but it is shown to be more cost effective to purchase less expensive renewable energy technology for a building with reduced energy demands.

Alternatively, the building characterized by Point 4 can be connected to a cogeneration plant serving either this individual building or a cluster of buildings. This will require a smaller investment compared to the cost of decentralized boilers and chillers for single buildings and the cost of larger renewable generation equipment (IEA 2011), but will result in a significant fossil fuel reduction due to use of waste heat in combination with the generation of electricity. This heat can be used either to satisfy the heating, cooling, and domestic hot water needs of the building cluster, or it may be exported to another building cluster. The use of cogeneration for individual buildings and building clusters affects the optimal location of Point 4 for each individual building. When the subject of interest is a single building, the waste heat produced by cogeneration process can be only used for heating, cooling, and domestic hot water needs of this building. The amount of waste heat generated will determine the optimal level of the building insulation and its loads. Typically, the level of insulation used in new construction and retrofit project results in small heating and cooling loads and the waste heat from cogeneration process will compete with the heat that can be generated using solar thermal systems. When the boundaries of the analysis go beyond a single building, the waste heat can be used for the building clusters under consideration, and the decision on the level of building insulation must be made based on a mix of buildings (new and old) and on other potential uses of waste heat.

Fossil fuel usage by the building cluster (Point 5) can be further reduced (another 20%–25%) by connecting to a combined heat and power (CHP) plant. When a CHP uses biomass or biogas as a fuel, the connected building(s) become net-zero fossil fuel. Typically, at Point 5, buildings do not require additional thermal energy from renewable energy source, but may require additional electrical power. After Point 5, adding solar- or wind-generated electrical power becomes a cost-effective supply option. At this point, by definition, the building cluster is net-zero ready. Path 1-2-3-4-5-6 is the lowest cost path for building improvement leading toward net-zero fossil fuel-based energy strategy.

When this process has been completed for each building, the results from all of the individual buildings are integrated and summed into annual load duration curves. The load duration curve shows the cumulative duration for different loads in the system over a full year. These curves are derived from hourly load data to show all possible variations to the system, and are generated from the hourly building energy simulation program. Due to the diversity of energy use in buildings comprising the cluster (community), the peak of the resulting load curve is much smaller than the sum of peaks of individual buildings so that the needed generation and back-up capacity is much smaller.

CONCLUSIONS

This paper has described how ambitious energy goals—to achieve low-energy or net-zero energy communities—can be successfully achieved in terms of transition management by using a combination of best practices in an integrated energy master planning process, based on a long-term vision. Important steps in achieving these goals include bringing all major stakeholders together, establishing framing goals, developing road maps, and managing the transition process play an important part. This paper also summarized a number of lessons learned from experience with front-running methods and technologies that can help to overcome many bottlenecks. For example, technical concepts should be established based on agreed upon framing goals and a baseline, followed by development of the base case and alternative scenarios. A successful approach must include smart steering, monitoring, knowledge management, new ways of financing, and cooperation among stakeholders. It is recommended that close attention be paid to knowledge management (training) issues in terms of exercising smart control; inspiring vision and targets; forming new coalitions; performing clear analyses; making realistic plans; and ensuring decisive implementation, execution, and operation.

Although the development of scenarios and optimizing those scenarios and testing them against framing goals can be a laborious effort that requires simulation and optimization on the building, supply, and distribution levels, integrated tools currently being developed can be used to reduce the level of effort and streamline the optimization process. In the final analysis, an integrated and holistic approach, if properly implemented, will show that energy efficiency is not a problem to be overcome, but a solution that will make community-level energy projects financially feasible.

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