Friendly Fusion: Integrating Energy Efficiency with Renewable Technologies

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In the future, renewable resources will be required to move the United States and the world toward a more sustainable society. It will be up to the political structures of all countries to make sure that such a transition of energy sources occurs in a steady, not politically unstable manner. It will be important to plan today's systems for tomorrow's renewable energy resources, to look past merely achieving energy efficiency goals. Politically, renewable energy is on the subject to the "tragedy of the commons" trap; building a sustainability infrastructure will benefit the environment, the economy, and human life. This paper describes and discusses existing demonstration programs designed to promote the use of renewable resources and reduce building energy use, and the direct and indirect contributions of renewable technologies to such efforts.

Introduction

"Barring some major breakthrough in fusion or fission energy, we will in the future have to live largely on the current flow of solar energy rather than on the accumulated sunshine of Paleolithic summers" (Daly and Cobb 1989).

Under at least one energy future scenario, renewable resources will be required to play a major role in moving our nation and the world toward a more sustainable society. Given the magnitude of the societal changes that such a shift would require, it is incumbent upon our political systems to smoothly incorporate changes to minimize the inevitable potential political and economic disruption. While at the present time, most environmental advocacy appears to focus primary attention on achieving energy efficiency goals, failure to capture economically-available renewable energy sources, or to plan today's systems to take advantage of renewable resources in the future, may be just a particularly insidious form of "cream skimming."

One of the more promising opportunities to demonstrate and implement this mutually reinforcing approach to fusing energy efficiency and renewable technologies is manifested in the recently signed Presidential Executive Order 12902, which requires federal agencies to significantly increase their use of solar and other renewable resources to help meet the 30% energy reduction goal by the year 2005 (compared to 1985 building practices). In this "Government By Good Example" initiative, wise implementation of renewable energy resources by the federal purchasing system can provide a market for building the sustainability infrastructure of the nation and have synergistic benefits in terms of the environment, jobs and the economy, health, and human productivity.

Synergies Between Renewable and Other Societal Benefits

For the utility, military bases, and large federal complexes, renewable resources can be used in one of three ways: (1) as a supply-side technology, (2) for distributed generation that serves remote loads and reduces transmission and distribution costs or, (3) similar to energy efficiency technologies, for demand side management (DSM). Renewable resources provide a way to manage demand by substituting on-site power generation for conventional power generation and distribution, or in the case of passive cooling technologies, provide load avoidance strategies to reduce the need for conventional energy. Renewable may serve as a peak clipping strategy, or if storage is provided, they may serve as a strategic conservation strategy. The use of renewable resources increases the overall efficiency of the conventional electric supply system.

Renewable resources are capable of providing heating, cooling, daylighting, and electrical power on the customer side of the meter. Yet in the United States, renewable' potential to reduce the need for conventional energy use has been largely untapped. The availability of renewable technologies in the marketplace is growing, the products are reliable, the technologies are cost-effective in niche markets, and a number of progressive federal agencies, state, local agencies, and utilities are using or testing renewable for consideration in their buildings. What may prove to be even more important, however, is that people are becoming aware of the many synergistic benefits of renewable and becoming more receptive to their use.

The Passive Solar Industries Council and the American Solar Energy Society in their Buildings for Sustainable America Campaign (ASES/PSIC 1993) have identified five connections between renewable and other positive societal benefits as follows:

- Energy savings
- Affordability
- Jobs and the Economy
- Health and Productivity
- The Environment.

There is ample data in the literature to support each of these connections.

Meeting Customer Needs: Niche Markets

Renewable for buildings encompass a broad range of technologies including passive solar design, daylighting, evaporative cooling, solar water heating, ventilation air preheat, and photovoltaics. Many renewable technologies are design strategies while other renewable systems are pieces of hardware that can directly replace less efficient systems. In both cases, design strategies and hardware, the performance of renewable technologies will vary based on climate; for instance, solar would be more effective in Denver than in Seattle. However, in locations where the climate is poor for solar, the renewable alternative might still make economic sense if the cost of conventional energy is excessively high.

To better understand the contribution of one renewable technology, passive solar design in different climates, Balcomb (1992) developed a supply curve methodology to identify the contribution to energy needs in new residential building construction among three different measures:

- Shell Measures:
  insulation strategies to impede heat transfer from inside a house to the outside.

- Passive Solar Heating:
  suntempering (adding south window area up to the limit when mass must be added), direct gain (south windows with added mass), sunspaces (an unconditioned room than can be thermally separated from the house), and thermal storage walls (a massive wall located directly behind south windows).

- Furnace Efficiency:
  includes adding high efficiency furnaces.

In Balcomb's supply curve methodology, each of these strategies has an associated cost which was calculated. The cost curves for the passive solar measures are non-linear. The starting point in the model is an area of windows on each of the four building facades. The first strategy is to increase the window area on the south side up to 7% of the home's floor area. This is called suntempering. No additional mass is required to store the heat in the solar gain of one day. The assumption is made that windows are added to the south rather than moving them from the other facades. This is because some windows are required on all facades for light, air, and emergency exits. If the 7% limit is exceeded, the incremental cost increases because mass should be added for thermal storage, otherwise comfort criteria will be violated.

The computer model develops an "expansion path" which represents the minimum cost path for reducing building energy use. The objective is to develop the most cost-effective measure to use at each point along the path. The upper limit for selection of measures is when the marginal capital cost equals $448 per annual million BTUs of energy saved. This process can be followed for representative cities in different climate regions.

Using the supply curve methodology, heating energy use for a home in Denver, Colorado is reduced 92% over the base case. The reduction can be broken down as follows:

- 37% due to passive solar
- 30% due to shell efficiency
- 25% due to furnace efficiency.

In Hartford, Connecticut, energy use is reduced 85%. The percentage breakdown would differ 5% due to solar, 38% due to improved furnace efficiency, and 41% due to shell efficiency. See Figure 1 for comparisons. This example illustrates that in certain climates, heating energy can be reduced substantially more through an integrated design approach that considers renewable as well as energy conservation whereas in other climates, the added contribution from renewable may be less significant from an energy point of view.

There are some environmental and political factors which make all renewable more competitive regardless of climate. They include:

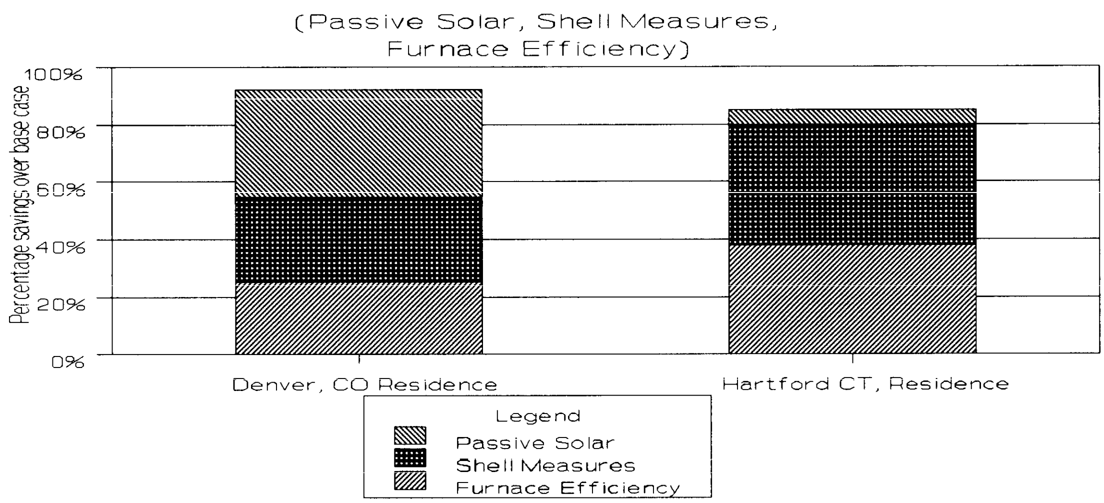

Figure 1. Residential Savings Comparison by Measure

- Environmental externalities:
  air pollution regulations are increasingly affecting utility and governmental activities. The issues may be local (air quality), national (Clean Air Act), or international (agreements on acid rain and atmospheric warming).

- Transmission and distribution:
  decentralized resources can lead to reduced utility transmission and distribution system requirements.

- Customer Value Benefits:
  renewable energy programs are in demand with the public for reasons other than commodity pricing.

There are some necessary conditions for most solar systems, one being an unshaded south location for collectors or windows. Key niche markets for several renewable systems are as follows:

Passive solar design:

- cold, sunny climates where the alternative is electric heating

- daylighting in schools and libraries where life cycle costing works

Solar water heating:

- sunny climates where the alternative is electric or other high cost fuel

Photovoltaics:

- remote locations where the alternative is extending utility lines or using diesel generator for power

In all cases, a systems or whole buildings approach must be taken when considering renewable. As the earlier example points out, achieving low heating requirements in buildings requires a combination of techniques. Other examples of a systems approach include a daylighting strategy. This requires not only windows designed and sized properly for the desired amount of diffused light, but also incorporates overhangs to block direct sun, an electric lighting control system, and energy efficient electric lights. Solar water heating is most cost-effective if done in combination with low-water use fixtures. Photovoltaics makes the most sense if energy-efficient and lower cost renewable measures are put into place first.

This type of a design approach is different than a conventional design approach. The successful integration of passive solar design, natural cooling and daylighting into a building requires a systematic approach that starts in predesign and continues through the design process (Balcomb 1994). There is no general prescription for design integration. The most appropriate design solution will vary based on climate and building type. There are some lessons that have been learned through past demonstration programs. They are as follows:

- Consider the use of renewable early in the design process. The building "footprint" on the site, orientation and form are integral to the successful integration of renewable.

- Expect that the design process will take somewhat longer than for a conventional building, at least at first.

- Begin by analyzing a base-case building, a building that responds to the architectural program but does not include renewable or energy-efficiency features. This will provide an understanding of how energy will be used in the proposed building.

- Support all design decisions with a thorough analysis that address building energy efficiency in its broadest sense.

- Consider renewable as an architectural, mechanical, and electrical integration issue, not as an add-on exercise.

Throughout the world, there are thousands of examples of passive solar homes that use only a fraction of the energy of conventional homes. A recent report by the Energy, Mines and Minerals, CANMET in Ottawa, Canada, documents that over 200 “advanced” house projects demonstrate reduced energy consumption is attainable with available technology at reasonable cost. Two of the houses described in this report are two prototype energy-efficient/ passive solar homes for employees at National Parks in the United States. The prototypes were designed for employees at both Yosemite and the Grand Canyon. Because the climates at these sites are so different, the sites offered engineers and architects very different challenges, but the same opportunity to demonstrate the practicality and cost-effectiveness of using energy-efficient and passive solar design. The houses are currently under construction. Based on simulated results, total energy consumption at the Grand Canyon housing is projected to be 78% less than conventional housing and the Yosemite housing is projected to use 73% less energy than conventional construction. The winter space heating load at the Grand Canyon housing is reduced by 91% over conventional housing and water heating is reduced by 63%. Cooling loads are nearly eliminated at the Yosemite site.

Using solar design in combination with energy conservation in new construction reduces energy bills, making monthly combined mortgage and utility payments more affordable. Developers in Dallas, Texas and Chicago, Illinois have been widely publicized for offering low income affordable solar energy and energy efficient housing with annual energy bills 50% lower than conventional housing. The Texas developer estimates the added first cost of the energy efficiency/solar package at $150 (Thayer 1994). The Chicago developer estimates his added first cost for solar/energy efficiency features over conventional construction at $500 to $700 and guarantees his winter heating bill at less than $200/year with most of his homes using less than $100/year for heating (Andrews 1994).

Passive solar design in residences has amenity value which customers appreciate. “High efficiency heating equipment can account for significant energy savings, but won’t be as much fun on a winter morning as breakfast in a bright attractive sunny sunspace” (PSIC/NREL). In both the United States and Canada, developers are building and marketing homes that use passive solar design to meet customer desires to live in “green” or sustainable communities.

In terms of commercial buildings, the United States passive solar demonstration program (Burt, Hill, Kosar, and Rittleman 1987) resulted in the design and construction of 19 low-energy commercial and institutional buildings. The buildings were typically daylit, some were passively heated, and others relied heavily on solar load avoidance strategies to minimize cooling needs. After construction, 12 of these buildings were monitored for a period of one year or more. Actual energy use was 47% less than the “base case’’—defined as the same size building, serving the same function in the same climate, but built to conventional construction practices. Energy costs were reduced 51%. Heating, cooling and lighting loads were all substantially reduced by simple changes in design such as window type and orientation. The construction cost of two of the buildings was less than the range of estimates for a typical building of the same size, in the same location, and serving the same function. The construction cost of three of the buildings was greater than the range of estimates, and the construction cost of seven of the buildings fell within the range of estimates. Thus, based on this program, there is no evidence that the passive buildings need to cost more than buildings of typical construction.

In the United States passive solar demonstration program, the owners of passive solar buildings, especially those with substantial daylighting, report increased satisfaction levels among employees. While difficult to measure directly, there are strong indications that higher satisfaction levels have translated to increased productivity in these buildings. This conclusion is substantiated by data presented in this panel by Romm and Browning (1994).

The Process of Change and the Role of Demonstration Programs

Given all the positive reasons to consider renewable, utilities and governments appear reluctant to aggressively incorporate renewable into their programs. Diffusion theory, the process by which an innovation is communicated through certain channels over time among members of a social system, offers some perspective on the process of change. In his book, Havelock (1969) describes the steps that one needs to move a technology into the marketplace. These are described as follows:

"Decision-making begins when an individual (or organization in the case of a government program or utility programs) is exposed to the innovation's existence (in this case, renewable resources) and gains some understanding of how it functions. The predispositions of individuals influence their behavior toward communication messages and the effect such messages are likely to have. Generally, individuals tend to expose themselves to those ideas that are in accord with their interests, needs, or existing attitudes and to consciously or unconsciously avoid messages that conflict with their predispositions. In this problem solving perspective, it is a need or problem that provides the motivation for some kind of search behavior on the part of the individual."

The recently signed Presidential Executive Order will require federal building managers to increase their familiarity with and use of solar and other renewable resources to help meet the 30% energy reduction goal by the year 2005 (compared to 1985 building practices). In this "Government By Good Example" initiative, wise implementation of renewable energy resources by the federal purchasing system can provide a market for building a sustainability infrastructure. According to a recent editorial by the Department of Energy's Assistant Secretary for Energy Efficiency and Renewable Energy, Christine Ervin, "A time of enormous opportunity is dawning again for renewable energy . . . [renewable energy and energy efficiency] are at the cutting edge of the President's budget to plant the seeds for new American jobs, new levels of American productivity, and American leadership in the international marketplace" (Ervin 1994).

To respond to this order and the 1992 EPACT legislation, many federal agencies are designing and building buildings to demonstrate their commitment to the use of renewable resources or developing guidelines to requiring that renewable resources be included in the design of new facilities.

- The Department of the Interior has been very proactive in their use of renewable. The Fish and Wildlife Service has developed an energy management manual which requires the use of passive solar design strategies in new building design.

- The National Park Service has initiated an energy efficient design guide for all National Park Service Housing and considers sustainability as a key criteria in the design for new park facilities.

- The Federal Energy Management Program (FEMP) is actively promoting the use of passive solar design in new building construction through workshops on passive solar design for residential and nonresidential buildings and their auditing capability.

- The General Service Administration (GSA) is currently working with NREL to demonstrate three renewable retrofit systems in their buildings at the Denver Federal Center. The objective of the demonstration projects, which will be fully monitored, is to provide GSA with hands-on experience in designing and procuring renewable systems for use in their buildings.

Solar Energy Research Facility

The National Renewable Energy Laboratory (NREL) has completed the design of a new 115,000 square foot laboratory building (the Solar Energy Research Facility) to support research in photovoltaics, basic science, materials science, superconductivity, and photoconversion. The building will use 30 to 40% less energy than a comparable conventional building. At a cost to build of $170/g.s.f., the building cost less to build than a typical research facility. The daylighting strategy, a series of south-facing stepped clerestory windows, used in the building give it a distinctive appearance. Other less visible energy efficient features include direct and indirect evaporative cooling, high efficiency motors, variable frequency drives, and a passive solar Trombe wall.

The design process involved three-steps. First, the design team characterized building energy use and cost. This allowed them to isolate energy-design problems and to identify energy-savings technologies to address those problems. Second, the design team established an energy-cost budget for the building based on the conceptual design and the Energy Policy Act (EPACT) requirements. Third, the team followed an iterative life-cycle analysis and design process to determine which of the energy savings technologies to incorporate into the building, to establish the design-energy cost of the SERF, and to verify that the design-energy cost was in compliance with the previously established energy-cost budget.

The design team analyzed 15 alternative systems. Of these 9 are included in the building. The daylighting feature was not subjected to the evaluation process used for the other energy-saving technologies. It was integrated into the base design as a matter of good passive solar design principals.

Arizona Federal Correctional Institution

Eight percent of the national commercial and residential energy consumption is for hot water. While the majority of water is heated by natural gas, electric water heating represents a significant and growing market share. Currently 35% of American households use electricity to heat water and almost half of all new water heaters sold are electric. A new generation of solar water heaters, which are vastly improved over models introduced in the late 1970's, are commercially available. In another federal renewable initiative, the Federal Correctional Institution in Phoenix Arizona will soon have its hot water supplemented by a cost-effective solar thermal system, which will be installed through an agreement between the Department of Energy, NREL, the Federal Bureau of Prisons, and a private corporation. The project is a technology demonstration sponsored by FEMP. The private company will design and install the solar parabolic trough system to preheat water for laundry, kitchen, and showers in a 1,500 inmate facility. A parabolic trough uses collectors with reflective surfaces to focus the sun's rays onto a receiver where the solar energy warms a heat-transfer fluid to preheat the domestic hot water. This reduces the amount of conventional energy needed to heat the water. The solar troughs also rotate to track the sun.

The solar water heating project will also demonstrate the use of an energy savings performance contract. This is the first performance contract for renewable energy technology signed by a federal agency. The agreement calls for the private company to install and operate the solar system at no cost to the Bureau of Prisons. In return, the private company will share in the utility cost savings generated by the system. The Bureau will share in the energy costs with the company. The private company has installed a similar system for a prison in California under a performance contract.

In addition to federal agencies, NREL has been working jointly with the Solar Industries Association, the Edison Electric Institute, the American Public Power Administration, and private and public utilities to promote the use of solar water heating as a demand-side management strategy. The program, called the Utility Solar Water Heating initiative (USH20) is designed to facilitate the use of solar water heating in utility demand-side management programs. To date, solar water heating is part of over 40 utility demand side management programs. The Sacramento Municipal Utility District (SMUD) is one of the largest programs with over 3,000 systems installed. Their long term goal is to have 30,000 systems installed in 5 years. Their program objectives include energy savings, peak load reduction, and environmental improvements while promoting the development of the solar industry and improving cost effectiveness for customers.

The Big Picture

Renewable play a vital role in moving our nation to a more sustainable society. It is important to continue to undertake design, build, and monitor programs to gather more data on renewable systems. We have found that the two most important criteria for a successful renewable project include a "project champion" at the site and funding support. For federal buildings, cross-technology analysis of a range of renewable opportunities is important. In niche markets, renewable will offer an added opportunity for energy savings.

Currently the sustainable design movement is moving from a utopian philosophy to a challenging goal as designers, developers struggle with the complex issues associated with it. Through demonstration and retrofit programs, it will become more of a reality in years to come.

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