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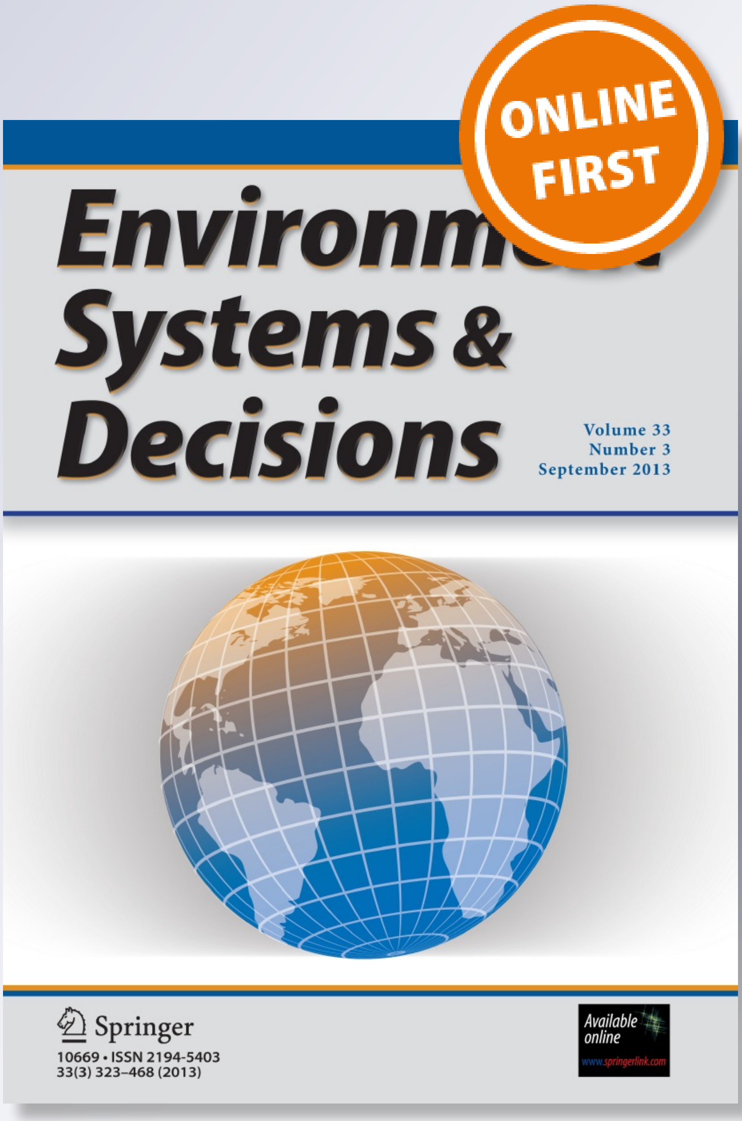

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PERSPECTIVES

Perspective on multi-scale assets for clean energy technologies in buildings

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Abstract Optimizing high-value energy efficiency and renewable energy in multi-scale systems that include buildings provides energy savings, energy reliability, indoor health and power quality, among other benefits. These benefits are not easily accounted for in traditional energy budget analysis, and their monetization is not included in typical cost-benefit calculations. Popular belief is that higher use of energy efficiency reduces return on investment (ROI) and that inclusion of renewable energy further reduces ROI. In fact, optimization of higher degrees of energy efficiency with on-site renewable has significantly greater positive economics. This is due to several factors including the aging electric grid—statistically having more and longer electric outages—and extremely poor electric power quality (electric surges, sags and transients) that wreaks havoc on digital equipment. Additionally, weather patterns are becoming more intense, stressing the wired electric system and fuel pipelines. As costs for energy efficiency and renewable energy are reduced and as these systems become more standardized and modular, it is more practical to begin utilizing these advances to increase operational resilience and make energy costs more predictable over longer periods.

Keywords Zero energy buildings · Distributed generation · Renewable energy · Energy efficiency · Sustainable buildings · Multi-scale systems

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When cellular telecommunications were just entering the consumer market, traditional telecom leaders derided cellular as being five times more expensive and not likely practical. They were astoundingly wrong because they could not see the other values that customers would eventually monetize—including convenience, safety and higher reliability—and the potential of other services, which evolved to cameras, MP3s and ultimately Internet services.

This analogy applies to high-value energy efficiency and renewable energy in buildings. Outwardly, they can lower energy bills. Energy efficiency and dedicated on-site renewable energy can offset uniquely high electric utility rates expressed in a ledger as demand charges, peak and seasonal power rates and ratchet rates. These benefits are often tied with federal and state tax incentives, state renewable energy portfolio standards, state net metering rules, system benefit trust funds (energy), Clean Air Act implementation funds (SIPs) [and, in some cases renewable energy credits (RECs or SRECs)]—all the traditional drivers of most installation deals and economics.

But the other asset portfolios may be the real market drivers on multiple scales, similar to internet accessibility, GPS and cameras on smart phones. And those other drivers are important when integrating on-site high-value efficiency and renewable and distributed generation in buildings and infrastructure. Renewables have limited value unless building loads are reduced significantly. Most energy efficiency protocols reduce buildings loads from 15 to 22 %. This is cost-effective, but the energy loads are still so high that it is only practical to rely on electric grid support. By dramatically reducing energy loads, however, the consumer has more options.

Consider for example a residential home and two-story office building in Arlington, Virginia. Recent efforts of the author reduced the building energy loads by 65 % through a portfolio of energy efficiency applications. (The author applied a similar approach at various other sites around the world.) The energy efficiency achievements in reductions were met with already commercialized technologies starting with the building envelope:

- Insulation, sometime blending various materials and insulations, to obtain effective R-38 in walls and R-50 in ceilings or roofs.
- Utilization of white roofs and reflective paints on top and low-emissivity thermal barrier paints underneath the roofs, which reduces summer heat gain to nearly 30 %.
- Super-insulating and electrochromic glass to increase window *R* values above 7 and up to 9.5 (rather than the usual 3.5) and reduce summer heat gain.
- For lighting, transfer to solar daylighting bringing in full spectrum lights without the heat (and zero electricity in day time) and integrating LEDs and lighting controls to maintain candle power requirements when there are people actually on-site.

For heating and cooling, there are many options. One of the most efficient choices is ductless or radiant systems, fed either by geoexchange (geothermal) or by solar thermal or cogeneration. Ducts, even after they are re-insulated, still leak, and energy is required to move air through these ducts and filters. Experience is showing that duct air quality quickly declines within weeks to high levels of pathogens that are beyond most filters. COPD and sinusitis are plaguing industrialized countries, due significantly to the duct systems within our HVAC systems and building materials. Advanced natural gas furnaces are the next viable choices after geothermal heating and cooling systems. In all cases, energy systems using solar water heating, or conduct heat from existing geothermal (geoexchange) or cogeneration systems into super-insulated water tanks using radiant heat, provide the healthiest way to approach heating and cooling buildings.

An ancillary approach is to utilize solar attic vent fans to reduce top-of-building heat build-up, as well as ceiling fans to move winter time heat from the top of the room down to where occupants sleep, sit and stand. Similarly, ceiling fans are reversed during the summer to gently pull the cool air from the bottom of rooms to where occupants sleep, sit and stand. Both options, if used strategically, can save over 5 % of traditional HVAC costs.

Incorporation of the highest-efficiency (e.g., *Energy Star*) appliances and office machines is the final alternative to employ. This is where most buildings fall short. But including these units as part of the project forces the last largest load to be accommodated. In the experience of the author, it has been essential to require control over appliance and office machine choices to ensure appropriate load management and load profiles. Such a path changes paybacks for efficiency from 3 years or less to 5 years or less—and this allows on-site energy to have the maximum effect and better payback because of the dramatically reduced electric loads.

The most critical implementation approach is to isolate electric loads through sub-circuit breaker subpanels so on-site energy systems can be fitted as appropriate to each electric load. Under each electric subpanel is its own dedicated “smart” battery bank (a complete battery system with web-enabled diagnostics) that becomes the portal for any type of on-site electric power generation. Deep cycle batteries are sealed with 7–10 years warrantees. These batteries are becoming less expensive and longer lasting with nearly zero maintenance, due to advances in cellular, laptop and hybrid car batteries. The asset value is also that each set of circuits is protected from electric surges, sags and transients. The USA spends billions of dollars for electric power quality or surge protection equipment—much that does not work—and this lack of quality leads to equipment and microprocessor failures whose expenses usually are excluded from energy budgets and too easily assumed to be an unalterable cost of doing business. They can be huge and recurring, always leading to high operations and maintenance (O&M) costs.

Once loads are segregated with their own battery banks, it becomes a mix-and-match game with on-site renewable energy systems, including but not limited to: photovoltaics, small wind, chp/cogeneration, microturbines (natural gas/propane), modular biomass, microhydropower, and hybrids of the aforementioned. Experience of the author is that using more than one option provides better sizing, redundancy and cost than trying to upsize and contort to an overall building load profile.

So aside from reducing energy costs (efficiency) and offsetting uniquely high electric sub-rates, there are results of better in-building health and immensely greater electric power quality—all monetizable benefits to any business or institutional building operation. And of course, battery systems fed by on-site generation also obviate the need for backup diesel electric power systems that usually sit idle and are not guaranteed to work when the grid goes down. Additionally, such diesel systems need a minimum of monthly testing and change out of diesel fuel every 18 months, as well as O&M after the tests. This cost center is then reduced to zero, which is another asset of battery-based systems.

Many commercial and institutional users also receive faster permitting for new buildings or large building renovations because air quality (Clean Air Act compliance) is demonstrably better than any alternative. Liability for backup diesel oil spills is also reduced and shown in lower insurance rates, as are dedicated energy systems for sump pumps and building/operations security, which adds another positive monetary impact.

Along with energy retrofits, reducing water use dramatically through extreme low-flow toilets, waterless urinals, low-flow showerheads and faucet aerators (with timers as applicable) will significantly save water and water heating costs. Roof water catchment systems as well as downspout barrels allow water to be reused for primarily grounds watering. While reducing water saves money, reducing the gross amount of hot water saves more energy as well.

Net zero buildings and zero energy (self-powered) buildings are achievable and can be cost-effective if the entire assets of these integrated systems are valued and monetized. Worker/occupant productivity and health are critical factors in making these decisions, as are continuity operations.

As our electric grid ages and weather patterns intensify, there are more electric outages than ever before and of longer durations. This can hemorrhage business profits and interfere with organizational missions. According to a recent July 13, 2012, article, "America's power grid is falling down thanks to a lack of investment and… It's not just a feeling: Power outages have become normal in the United States…. In 2011, there were more than 3,000 outages affecting 41.8 million people." (www.psmag.com/…/electric-forecast-call-for-increasing-blackouts-43…)

While green buildings and LEED buildings are becoming more common, the US military is moving toward net zero energy buildings, with specific initiatives announced by the Army and Navy. *Net zero* means that over the year, the building produces all the energy it needs when "netted out." This means there are times when the building uses electric grid power, but there are times it produces more power than it needs. And when the year-end calculations are made, the building produced all its energy. Zero energy buildings do not have the luxury of using the grid to back up operations at certain times. Representative of experience of the author with over 125 zero energy buildings worldwide, predominantly for Fortune 500 companies and the US military, the Washington Navy Yard was commissioned in early 2013 and will be used as a teaching building for the Naval Facilities Command.

The trend has just begun, with experts believing that net zero energy buildings will reach a 10 % market share by 2035 and zero energy buildings reaching a 10 % market share by 2050. As a Fortune 500 corporate CEO has described, "We have no choice: utility rates are higher, outages are higher, electric surges are higher—and to effectively compete, we need predictability. At least with zero energy buildings and infrastructure in my corporate facilities and campuses, I have levelized energy costs for 25 years." There are suggested readings collected at the conclusion of this paper (Sklar 2007; Clark 2013; Pike-Research 2013; Pless and Torcellini 2010; Commonwealth of Massachusetts/Energy and Environmental Affairs 2013; Environmental Leader 2012; Gerdes 2012; Swallow 2012; Tuscon/Pima County and Arizona 2011; Zero Energy Commercial Buildings Consortium 2011).

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