

Contact: Mike Schwarz, 215.569.2900, x3687, mschwarz@klingsubbins.com

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Rising to the 2030 Challenge: Answering the call for design and building professionals to achieve carbon-neutral buildings by 2030

by Michael Lorenz, PE, LEED® AP and Michael Schwarz, PE, LEED® AP

Global warming is gaining attention in the scientific community. Numerous scientific institutes and consortiums have issued new and alarming evidence that has raised the level of awareness and imminent concern about global warming throughout the world.

But how can we prevent the negative impacts of global warming? Some would say reduce or eliminate the artificial release of greenhouse gases--most significantly, carbon dioxide (CO₂)--into the atmosphere. Unfortunately, this is no small task. The majority of economically feasible technologies that generate electricity to support manufacturing, comfort cooling and heating, and transportation still use fossil fuels as a primary energy source. Therefore, the answer to global warming must start with the development and deployment of non-fossil-fuel energy options, such as hydrogen and fuel-cell technologies, along with a broader acceptance and improvement of existing options, such as solar, wind, nuclear, hydroelectric, and geothermal power.

The world's industries and governments will need to play significant roles in this process, as they will be challenged to help balance economic, efficiency, and practicality issues. Resource conservation also will play a major role, as will our ability to find new and better fossil-fuel-friendly systems, materials, and applications.

The 2030 Challenge

These global developments have prompted many in the green-building community to set goals and objectives aimed at reducing CO₂ emissions related to energy use in new construction. The American Institute of Architects (AIA) has endorsed Architecture 2030's 2030 Challenge, which calls for architecture and building communities to adopt targets that will help eliminate new buildings' fossil-fuel-based energy consumption by 2030. The 2030 Challenge also advocates an immediate 50-percent reduction--as compared with the regional or national average--in the fossil-fuel-based energy consumption of new buildings. The AIA has sent an open letter to the U.S. Green Building Council (USGBC) suggesting that new buildings meet this 50-percent-reduction guideline as a prerequisite for Leadership in Energy and Environmental Design (LEED) certification. This proposal is under consideration, and other organizations, such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), publicly have endorsed it and are encouraging the engineering community to take up the challenge ("Guest Editorial," July 2006).

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The Design Project

But what will it take to reduce the fossil-fuel-based energy consumption of new buildings by 50 percent? To answer this question, a near-complete design of a building project was examined. The building was designed as a multifunctional facility with office, food-service, retail, and public-assembly components. The building was designed to exceed ANSI/ASHRAE Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings, and registered for LEED Silver certification. Several high-performance features were incorporated into the design, including CO₂-based demand-controlled ventilation, daylighting control in many perimeter spaces, high-efficiency chillers, and low-temperature air distribution with seriesfan-powered terminal boxes.

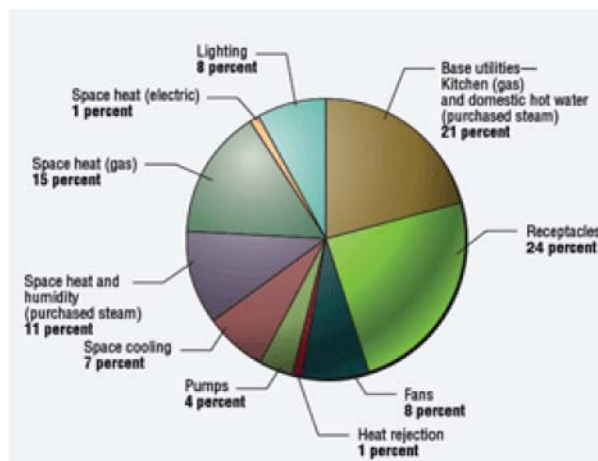


FIGURE 1. Estimated annual energy consumption of proposed building by end use.

Located in New Jersey, the building is within Climate Zone 4a, as defined by Standard 90.1-2004. Although the properties of the building envelope's opaque portions exceed the prescriptive requirements of Standard 90.1-2004, the vertical fenestration area is more than 50 percent of the gross wall area, which meets the prescriptive limit of the standard. However, the glass rating (U-factor, solar-heat-gain coefficient, etc.) also surpasses the prescriptive requirements. Figure 1 is a breakdown of the proposed building's estimated annual energy consumption by energy type and end use.

Energy Consumption

The first phase of the building-design evaluation was to determine how the building compared with a "code/baseline energy model." The projected energy consumption was 20,000-Btu-per-square-foot less (128,739 Btu per square foot vs. 148,711 Btu per square foot) than required by Standard 90.1-2004 Appendix G, "Performance Rating Method (PRM)," which is the building energy-simulation analysis required for LEED for New Construction Energy & Atmosphere Credit 1, Optimize Energy Performance.¹ Although a detailed interactive computer energy model was required, the PRM provided a means of estimating the energy usage of the proposed building and ASHRAE baseline energy model.

To calculate the energy-reduction target proposed by the 2030 Challenge, energy-use data classified by space and building type from the 2003 Commercial Buildings Energy Consumption Survey (CBECS) were referenced. Although the multifunction building did not fit neatly into any one CBECS space/building type, averaging data from applicable categories yielded an energy budget of 129,720 Btu per square foot.² This corresponded to the PRM estimate of the building's energy use, but was lower than the ASHRAE baseline energy model's performance.

These results were unexpected because the CBECS is supposed to consist of average data taken from existing buildings that presumably are not as energy-efficient as proposed ones. Reasons for this discrepancy included the high process energy use, such as receptacle loads and kitchen equipment, of the example building.

Interpreting 2030 Challenge energy-use targets can cause confusion because the targets are listed in terms of total energy use, not greenhouse-gas emissions, even though reducing fossil-fuel usage and resulting CO₂ emissions is the initiative’s main goal. However, CBECs data on fuel type is available from the Energy Information Administration.

The PRM commonly used to calculate LEED energy-optimization points quantifies savings in terms of energy costs, not the reduction of CO₂ emissions. In short, even at current (and rising) utility rates for electricity and natural gas, designing a building to earn a LEED rating or even multiple points for optimizing energy performance does not guarantee compliance with the 2030 Challenge.

Energy-Saving Alternatives

The next step in the building-design evaluation was to select some viable design features and technology options that could further reduce energy usage and, more specifically, CO₂ emissions. Because the proposed design already included significant energy-saving features, which saved 13.4 percent more energy than the ASHRAE baseline-energy-model budget (Table 1), adding more “practical” energy-saving features proved to be difficult.

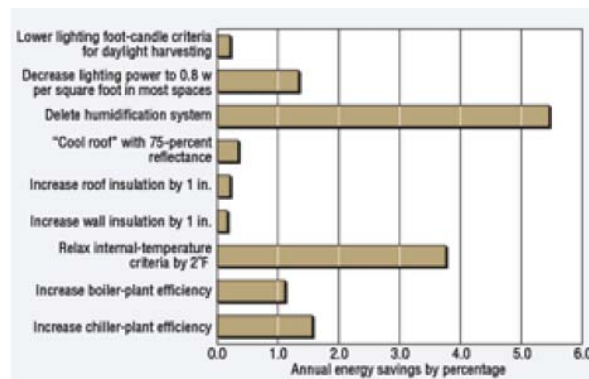


FIGURE 2. Annual energy savings of direct efficiency.

Figure 2 shows the nine direct energy-saving alternatives that were evaluated and their associated energy savings as compared with the proposed design. Some methods, such as relaxing internal-temperature criteria by 4F in most spaces and eliminating various windows, were deemed impractical and, therefore, not included.

Table 1 lists the simulation results of the nine direct energy-saving alternatives that were evaluated. Each alternative’s energy savings is expressed by a percentage calculated using the PRM as compared with the ASHRAE baseline-energy-model budget.

Each of the considered alternatives, on its own, offered marginal additional savings. The greatest savings were associated with the elimination of humidification during winter (18.2-percent reduction in energy/10.3-percent reduction in CO₂, as compared with the baseline), while the least were associated with the decrease of lighting foot-candles in perimeter spaces to maximize daylight harvesting (13.6-percent reduction in energy/8.6-percent reduction in CO₂, as compared with the baseline). If the combined savings of all of the alternatives were added to the savings offered by the proposed design, the total potential savings would include a 27.6-percent reduction in energy and a 19.6-percent reduction in CO₂, as compared with the baseline. However, if all of the alternatives were combined in an interactive computer energy model, the calculated savings would include a 24.5-percent reduction in energy and a 17.8-percent reduction in CO₂, as compared with the baseline.

To measure the proposed building’s total annual carbon footprint, source energy was calculated, taking into account metered site energy, as well as the additional energy used in the production and transfer of it. In the proposed building design, electricity was consumed by multiple components, natural gas fueled hotwater boilers for space heating and kitchen equipment, and purchased campus steam was used for humidification and domestic-hot-water heating. Direct and indirect CO₂ emissions were calculated separately for each energy component in the proposed measures.

Direct and indirect CO₂ emissions were calculated separately for each energy component in the proposed building. The direct emissions indicated in Table 1 were based on an average of 117 lb of CO₂ per million British thermal units of natural gas that would be fired in the building (CO₂ that would be emitted directly from the building). For CO₂

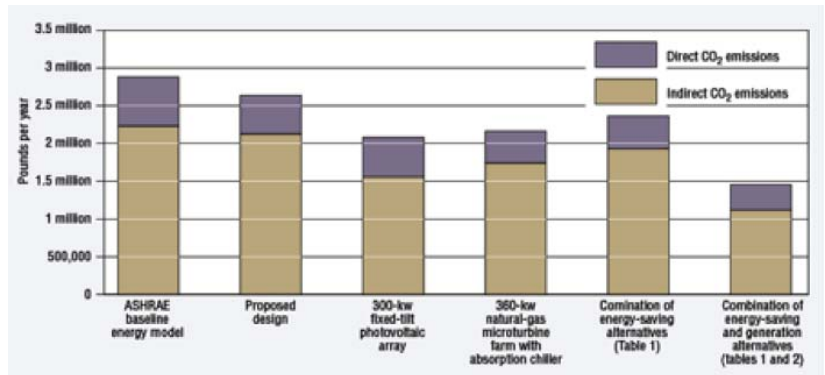


TABLE 1. Comparison of the proposed design’s energy-saving alternatives.

that would be emitted indirectly from the power plants providing the electrical energy that would be metered in the building, 1.55 lb of CO₂ per kilowatt-hour was assumed.⁴ This was an average value based on electrical power generation from many fuel sources and likely would have been higher if the electricity supplied to the building were generated using coal only.

Energy-Generation Alternatives

The final step in the evaluation was to add some viable alternative energy-generation technologies to the proposed design. The two most practical alternatives were photovoltaic solar panels and a gas-fired microturbine farm. The solar panels could offset direct emissions from local coal-fired generation plants. The microturbines could offer CO₂

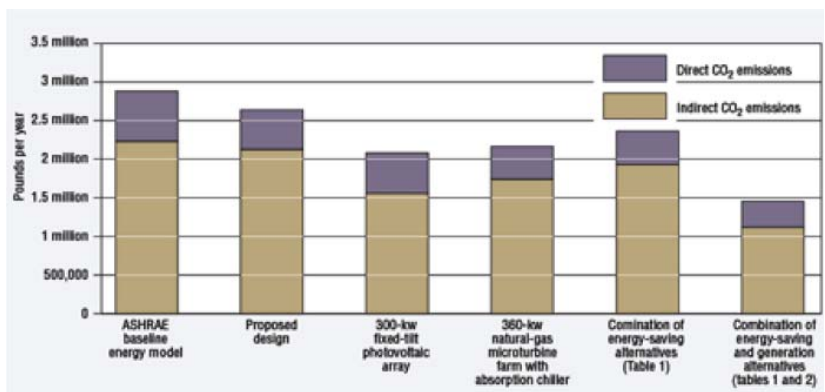


FIGURE 3. Annual estimated direct and indirect CO₂ emissions.

reductions by using waste heat produced by electrical-power generation for building heating and chilled-water production via a double-effect absorption chiller. The microturbine system was modeled to produce electricity upon building-heating demand, which, with the absorption chiller, included building-cooling demand. Figure

3 shows the combined environmental impact of each of the energy-generation alternatives, as well as the combination of the energy-saving and generation alternatives.

	ASHRAE baseline energy model	Proposed design	Energy-generation alternatives			
			300-kw fixed-tilt photovoltaic array	360-kw natural-gas microturbine farm with absorption chiller	Combination of energy-saving alternatives (Table 1)	Combination of energy-saving and generation alternatives (tables 1 and 2)
Building HVAC design load						
Peak cooling (tons)	354	272	272	272	251	251
Peak heating (thousands of British thermal units per hour)	4,121	2,971	2,971	4,876	2,019	4,209
Calculated annual site-energy consumption by component (millions of British thermal units per year)						
Lighting	812	694	694	694	556	557
Space heat (electricity)	27	74	74	0	30	0
Space heat (gas)	920	1,384	1,384	0	1,131	0
Space heat and humidity (purchased steam)	2,657	1,010	1,010	0	529	0
Space cooling	745	588	588	140	474	137
Pumps	181	374	374	266	208	179
Heat rejection	235	83	83	275	219	268
Fans	781	753	753	753	661	661
Receptacles	2,115	2,115	2,115	2,115	2,115	2,115
Base utilities—kitchen (gas) and domestic hot water (purchased steam)	1,937	1,937	1,937	1,937	1,937	1,937
Cogeneration (electricity)	0	0	0	0	0	-198
Cogeneration (gas)	0	0	0	0	0	766
Photovoltaic net energy	0	0	0	0	0	-1,235
Total net site energy	10,409.8	9,011.7	7,777.1	7,316.1	7,859.5	5,186.5
Thousands of British thermal units per year per square foot	148,711	128,739	111,101	104,516	112,279	74,093
Percentage of annual site-energy savings						
Compared with ASHRAE baseline energy model	–	13.4	25.3	29.7	24.5	50.2
Compared with proposed design	–	–	13.7	18.8	12.8	42.4
Source energy						
Calculated source energy (thousands of British thermal units per year)	21,238,498	18,885,198	15,143,133	15,190,808	16,723,309	10,258,004
Reduction in source energy compared with ASHRAE baseline energy model, percent	–	11.1	28.7	28.5	21.3	51.7
CO₂ emissions (pounds per year)						
Indirect	2,224,141	2,126,375	1,565,490	1,747,348	1,936,475	1,128,130
Direct	645,150	506,750	506,750	405,978	420,849	316,286
Total	2,869,291	2,633,125	2,072,240	2,153,326	2,357,324	1,444,416
Reduction in total CO₂ emissions, percent						
Compared with ASHRAE baseline energy model	–	8.2	27.8	25.0	17.8	49.7
Compared with proposed design	–	–	21.3	18.2	10.5	45.1
Construction-cost increase or decrease	–	–	\$900,000	\$850,000	\$75,000	\$1,825,000

TABLE 2. Comparison of energy-generating proposed-design alternatives.

The energy generated by the photovoltaic array was estimated separately from the interactive computer energy model and deducted from the site- and source-energy totals. Assuming the photovoltaic-array system would be grid-connected with net metering, the electricity meter would spin backward when the array produced more energy than the building could consume, such as on weekends and holidays. A microturbine system would have utilized more total energy (and emitted more total CO₂) than the proposed design if it were controlled to generate electricity based on full electricity demand. This is because the average net electrical efficiency of a microturbine system is only 27 percent, compared with the average 33 percent assumed for utility-supplied electricity. Depending on the utility-rate structure, this control method could have greatly reduced owner energy costs.

However, when considering the heat exhausted by the microturbines that would be recovered and converted to usable energy in the form of hot and chilled water, net system efficiency rose to as much as 79 percent, if there were a use for all of the recovered energy. Thus, the recoverable energy from microturbines is related directly to the electrical demand and heating/cooling daily-load profiles of specific facilities. To add further perspective, consider that the total heat wasted in generating power in the United States equals the total amount of energy consumed in Japan.

Table 2 compares each of the energy-generating alternatives, as well as the combination of energy-saving and generating alternatives. The table expresses the proposed building's energy usage in terms of site and source-energy usage. While site energy is the energy metered within a building, source energy is the total energy used by a building, including losses from production and distribution. The fuel-utilization factors for the energy sources used by the example building were 33 percent for utility-supplied electricity, 95 percent for natural gas, and 75 percent for purchased steam.

The total construction-cost increase associated with implementing all of the alternatives, including government rebates and tax credits, was estimated to be \$1.825 million. This represented a 5-percent increase in estimated construction costs over the ASHRAE baseline energy model if prices escalated until the first quarter of 2008. At current utility rates, the combination of all of the alternatives would pose a lengthy 15-year simple payback period for the investment.

Using a default utility-rate structure of 8.35 cents per kilowatt-hour for electricity and 83.5 cents per therm for natural gas, the combination of all of the alternatives would pose a lengthy 25-year simple payback. If a more realistic utility-rate structure of 22 cents per kilowatt-hour for electricity and \$1.20 per therm for natural gas is assumed along with a seasonal demand charge, the simple payback shrinks to seven years. These time periods for return on the additional investment assume that the building is used according to the schedules in the energy-simulation model. If the microturbines were controlled based on electricity demand instead of heating demand, further energy-cost savings and peak shaving could be realized, but direct CO₂ emissions would increase.

Conclusion

The building-energy simulation results indicate that meeting the 2030 Challenge is possible for a commercial-building project with high process loads and relatively strict design criteria. However, the largest relative reductions in CO₂ emissions were attributable to technology changes, not energy-saving features. The simulation of the combination of all of the alternatives yielded just under a 50 percent total reduction in CO₂ emissions and a similar degree of savings in building-site and source energy as compared with the ASHRAE baseline energy model. Costs of complying with the 2030 Challenge can be significant and must be addressed early in a project to minimize their impact.

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A principal and the director of engineering for KlingStubbins, Michael R. Lorenz, PE, LEED® AP, is active in the firm's sustainable-design initiatives. With expertise in indoor-air-quality design, he has led the engineering design of some of the most advanced buildings in the world for many Fortune 500 companies. Michael H. Schwarz, PE, LEED® AP,, is an HVAC project engineer for KlingStubbins. Involved in the study and application of modeling and associated technology for the conservation and reduction of energy use in buildings, he has designed HVAC systems for a variety of spaces, including offices, laboratories, and datacenters.

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