PASSIVE HOUSE ALLIANCE UNITED STATES

The First Passivhaus U.S. School Building

Location:	Roanoke, VA
Climate Zone:	4; Mild; Mixed Humid
Size:	3,053 sq. ft. TFA
Levels	1
Construction:	Commercial
Walls:	Concrete: R 33.4 Frame w/ brick: R 33.5 Frame w/ EIFS + windows: R 42.3 Frame w/ EIFS no windows: R 45.5
Roof:	North: R-68 South: R-59.6
Floors	Slab on grade R 39.3
Mechanicals:	Variable speed rotary ERV w/ a 2 stage heating & cooling strategy
Windows:	Great Lakes by PlyGem. SHGC: 542 Rcog=7.41 Rframe=3.47 Yspacer=3.2 hrft2F/ BTUin Yinstallation=2.88 hrft2F/BTUin
Total Cost:	$824,000
PH Upgrades:	$25,000
Savings/Yr.:	$3,450 (see chart)
Annual Return on Investment:	10.92 after 10 years (see chart)

Overview

The Center for Energy Efficient Design (CEED) in Franklin County, Va., is the first public school (K-12) in the United States designed to the Passivhaus building performance standard. This demonstration lab and learning facility situated at the edge of the scenic Blue Ridge Mountains, showcases a variety of renewable, sustainable and energy efficient features.

Design Challenges

The CEED Project was envisioned as a demonstration of the integration of energy efficient and environmentally sustainable design principles, as a problem-based learning model for environmental science, advanced learning technologies, architecture and building systems. The CEED was to be integral with learning for middle and high school students at The Gereau Center as well as a showcase of environmental design principles to homeowners, builders, and designers. Initially, we recommended an earth sheltered approach, as this had proven in the past to be an approach which yielded energy savings of approximately 40%. At this point we had not yet discovered Passivhaus. We also

recommended that we incorporate the principals of Leadership in Energy and Environmental Design (LEED) certification in the project. Our firm then developed the design and priced the project. In addition to the money already pledged, our firm pledged $150,000 and raised $100,000 from the community. At that point, we were approximately $400,000 short of funds to start construction. The superintendent of schools approached the school board with the project concept and budget and in early 2008 the project received the final amount needed to build the project from the school board. It was during this period that I received my training in Passivhaus. We approached the superintendent of schools with the proposition of saving an additional 30% energy on this project and with the ultimate goal of creating a plus energy building as funds became available for on-site generation. The school superintendent's response was unequivocal, pursue this option, but it cannot cost more than the amount already approved by the school board. After exhaustive studies and analysis we settled on a revised design that would both meet Passivhaus standards and would actually be $26,000 less expensive than the original building!

Design Solutions: Site

From conception, the CEED was intended to act as both a classroom for advanced placement environmental studies students and as a practical demonstration of sustainable building practices. In addition, this new learning center was intended to be a demonstration project for Southwest Virginia and the Mid-Atlantic region, open to surrounding schools jurisdictions as well as having its real time data and curriculum available on the internet for long distance teaching. The location is a rural setting in a mild mixed humid climate, and the building is situated at an altitude of approximately 1,050 ft. above sea level.

Design Solutions: Usage Pattern

The building has a diverse and challenging occupant loading pattern. For the most part the

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> Structures Design/Build LLC

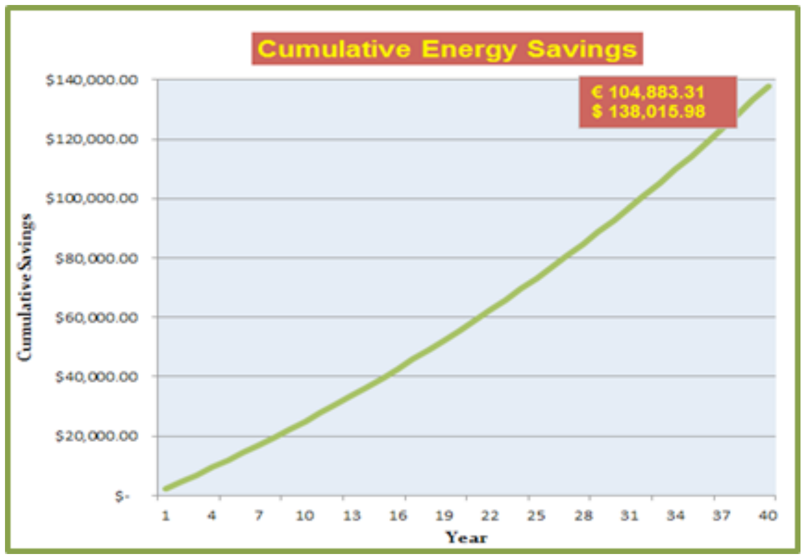
building is used by one teacher with about 24 students. Interestingly, the intended use as a demonstration project also allows for groups of up to 100 people to use the building for tours and events. It was necessary to model the project with this very diverse usage to ensure that the building would perform under all conditions. This being the first Passivhaus for a US public school, we could not have a demonstration project that was uncomfortable for the occupants, even for the briefest periods. American buildings are typically kept in a very tight comfort range in all climates, in all seasons, through the use of massive heating and cooling systems. This building had to provide for this American expectation of comfort as we recognized that we may not have a second chance to prove the Passivhaus approach to potentially skeptical public policy makers. We therefore modeled the building with a worst case scenario of 100 person occupancy in mid-summer with high humidity to determine mechanical system loads. What we found was that under most conditions the building would require only minimal additional heat or cooling, but under the worst case design, we needed about 2.5 tons 31,650 kJ/hr (30,000 BTU/hr) cooling to overcome the sensible and latent loading from the occupants

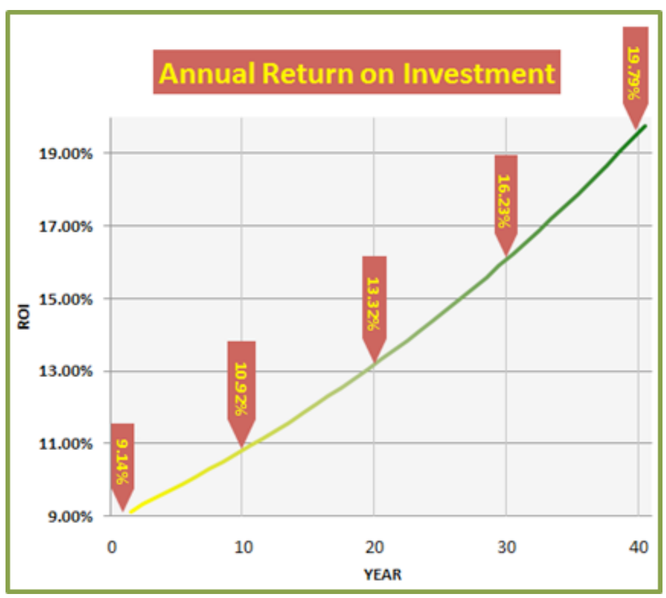
MEP Systems

The Mechanical system employs a variable speed rotary ERV with a two stage heating and cooling strategy. Stage one is pre-heating, pre-cooling and pre-dehumidification provided by a water to air heat exchanger in the intake of the ERV. This water to air heat exchanger can circulate both solar heated water and a passiv brine ground loop. Stage two is a 3 ton (36,000 BTU/hr) 2 stage ground source heat pump (GSHP) for the occasions when the occupant load will spike requiring additional cooling. There was discussion of using a high efficiency mini split heat pump unit for the second stage. This would have saved almost $25,000, but because there was no US made unit, the school board opted for the US made GSHP. We also installed a humidistat on the heat pump to combat the possibility of high humidity in summer conditions; although this was precautionary and our analyses indicate it probably will not be required. Additionally, we equipped the ERV with automatic sensor that controls a summer bypass to decrease temperature gain in the hot months. Our calculations indicate that on a day with 90F (32C) 70%RH with 60F (15.5C) brine circulating in our intake water to air loop, the stage one system should be able to

remove around 30,000 BTU/hr latent heat and 20,000 BTU/hr sensible heat. We have installed temperature and humidity monitors pre and post unit to analyse the accuracy of our calculation methodology.

Control of the system proved to be problematic. The price of US made integrated controls for this type of system was prohibitively expensive so a simple control system was opted for. The ERV is controlled simply by a CO_2 sensor with 4 pre-set levels of flow. We then installed two digital thermostats, one to control the water to air heat exchanger and one to control the heat pump. We could have used a single thermostat, but US "off the shelf" thermostats do not allow for three stages in the cooling mode, which meant we would not have the option of utilizing the two stages on the GSHP which would ultimately lead to higher energy use. We put the thermostats in sync, and programmed a 2F (1.1C) difference between stage one and stage two. It is interesting to note that in the two winters between commissioning of the building and the writing of this paper, stage one heating (solar heat delivered through ventilation air) has been sufficient, so much so that the second stage GSHP has not come on in the winter.





Lessons Learned:

"There is still a lot of resistance to Passivhaus in the United States because of a lack of education and misunderstanding," Cohen says. "But Passivhaus works. There are thousands of successful European projects to look at for proof. This is a huge opportunity for U.S. manufacturers to develop new products to serve the emerging Passivhaus market."

Cohen's team is working on additional Passivhaus projects. These include a student center at Virginia Polytechnic University, a dental office, a 40,000 sq ft 4 story dormitory and three homes.

"We want to build upon the success of the CEED project," Cohen says. "We basically delivered a $1 million state-of-the-art building for $800,000. It's comfortable, it's efficient, and now it is a plus-energy building. The fact that it serves as a learning lab – as well as a model for other school districts, policy makers and building professionals interested in learning how to design a Passivhaus building in a mild mixed humid climate – made it all a very worthwhile endeavor."

Cost benefit analysis

The project received a grant in December 2010 from the Virginia Department of Mines, Minerals and Energy to install a real-time Web-enabled monitoring system. 44 monitoring points were installed. The information will be available to anyone interested in studying a high-performance building.

In addition to Web-enabled monitoring, the grant has made possible the installation of another wind turbine (a vertical axis version) and three new PV systems. with these additions the CEED is now a plus-energy building, producing significantly more energy than it is using.

THE TEAM

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