AFRESH Home: Residential Energy Systems
Case study completed September 2010
Prepared by Shana Johnstone for BCIT

The AFRESH Home Project

AFRESH Home is a project that showcases innovations in sustainable housing construction. It began as a housing demonstration project designed to show how a home can be created that will provide life-long comfort for its occupants, using the most innovative yet practical ideas in housing to date. The Home was developed using off-the-shelf technology, a flexible design, and health conscious, high quality building practices. It remains an affordable, durable, healthy, and environmentally conscious demonstration house.

The building is located in the northeast part of the BCIT Burnaby Campus, and is part of BCIT's Sustainability Precinct. The Precinct aims to advance the state of practice in the adaptive restructuring of the built environment to achieve significant reductions in energy and materials consumption without compromising service levels. The Home fits with BCIT's GHG and Energy Management Vision "to demonstrate the wisest energy and GHG management in B.C.… BCIT will be viewed as the place where industry comes for training…to achieve energy saving and reduce carbon emissions." BCIT is committed to its Polytechnic mandate, and AFRESH Home provides opportunities for students to learn about all aspects of current and new technologies, thereby helping to ensure the future development and use of sustainable energy technologies in B.C. and Canada.

The Home is a wood-frame structure with two stories (2,000 square feet) plus convertible attic (785 square feet, but not designed to hold significant weight) and crawlspace below. It is designed to fit a typical urban lot of 33 ft by 122 ft, with rear lane access. Currently configured as a code-compliant vertical duplex, it can be easily converted into a four-bedroom single-family home.

Project Background and Context

The project was originally developed as Home 2000, the result of a team effort by BCIT, Canada Mortgage and Housing Corporation, Greater Vancouver Homebuilders' Association, Canadian Plywood Association, UBC School of Architecture, and many other product and service providers. Home 2000 was featured at the B.C. Home Show in 2001, then relocated to BCIT's Burnaby campus. Now called the AFRESH Home (AFRESH: Accessible & affordable, Flexible, Resilient, Energy efficient, Sustainable, Healthy), it continues to demonstrate best practices in sustainable residential construction and energy systems. Current partnerships include BC Hydro and applied research centres at BCIT.

The project provides an opportunity for BCIT to work in cooperation with industry partners in the development and demonstration of new housing and construction products and technologies. The flexible design of mechanical and electrical systems in AFRESH Home enables system retrofits to integrate new technologies. This allows the Home to continue to showcase the most current technological developments, assisting industry partners by bringing attention to new, efficient and sustainable construction methods and technologies.

In 2006, BCIT's School of Construction and the Environment signed a Memorandum of Understanding with BC Hydro to participate in the Distributed Power Connections Study. BCIT's role as a technology leader enabled the Institute to partner with industry to research emerging energy technologies (including geoexchange, photovoltaics, fuel cell, smart meters and smart appliances) by providing a site with the requisite technology in place, ready to be observed. That site is the AFRESH Home.

In addition to its contribution to the BC Hydro study, the AFRESH Home serves as an applied research facility supporting research projects through BCIT's Building Science Centre, the Centre for Energy Systems Applications, the Centre for Infrastructure Management, and the Group for Advanced Information Technology. The AFRESH Home is also an integral educational resource within the School of Construction and the Environment. Programs that utilize the AFRESH Home for educational purposes include:

- Interior Design
- Electrical
- Architectural and Building Technology
- Piping
- Architectural Drafting
- Carpentry
- Joinery
- Environmental Engineering
- Sustainable Energy Management

AFRESH Home demonstrates many aspects of design, construction, systems, interiors, and management. The remainder of this case study will focus on the Home's energy systems.

Energy Systems

The "E" in AFRESH stands for energy efficiency. At the time it was built in 2000 (Phase 1), a number of strategies were used to maximize energy efficiency, including materials, assembly, energy and HVAC systems, lighting and appliances. From 2006 to 2009 (Phase 2), the Home was retrofitted with newer energy system technologies and other features.

Phase 1

Materials
Construction of the building included the use of the most energy-efficient products and materials commercially available for the exterior walls, foundation, windows, and insulation. A rain screen wall assembly allows any moisture to either escape the walls or to dry, while keeping the envelope airtight. High-performance windows prevent the loss or gain of heat, as do two layers of rockwool insulation in the envelope (RS12.47 (R14) batt insulation towards the inside, and RS10.95 (R5.4) draining insulation towards the outside of the envelope).

Heat recovery ventilator
A ventilation heat recovery system operates continually to supply fresh outside air, and to exhaust moist, stale air from bathrooms and kitchens. It can operate at low or high speed as needed, located on each floor and in the attic. The ventilator captures heat from exhaust air to preheat outdoor air coming in, reducing the amount of energy needed to heat outdoor air to indoor temperatures.

Boiler and forced air system
Additional heating and cooling technology installed in Phase 1 used a central natural gas boiler with an outdoor condensing unit, and a separate system for each floor containing heating and cooling coils, an air handler and ducts. The separated systems ensure that air, odours, sounds, and fire do not travel between floors. (See Phase 2 – Geoexchange for retrofits to this system.)

Photovoltaic panels (BIPV)
Building-integrated photovoltaic (BIPV) panels use solar energy to supply most of the Home's electricity. BIPVs were integrated with roof and window elements: Blue Photowatt solar cells are arranged in glass-on-glass panels with 1 cm to 1.6 cm spaces to allow daylighting of the third floor attic. This BIPV system provides on-site energy generation of approximately 2 kilowatts.

The BIPVs in the roof represent a trade-off between the demonstration aspects of the Home and the insulation properties of the roof. The large area of window in which visitors can view the photovoltaic cells in detail also results in large temperature fluctuations in the attic during summer and winter as much of the roof is without insulation. This trade-off supports the primary purpose of AFRESH Home as a demonstration site.

Lighting and appliances
Energy-efficient lighting and appliances, including refrigerator, oven and stove, and dishwasher, were installed to reduce domestic energy use.

Phase 2

In its current incarnation as AFRESH Home, the building has been retrofitted with newer systems as part of two different studies.

Distributed Power Connections Study
In 2006, the Distributed Power Connections Study was initiated with an MOU between the School of Construction and the Environment and BC Hydro. The intent of the joint project was to transform the AFRESH Home to become a net energy producer and to study the way that energy migrates to and from the grid. The study will also facilitate the analysis and demonstration of photovoltaic cell and fuel cell technologies. The time frame for the project was for three years, renewable upon mutual agreement by both parties. Several retrofits have since been completed to provide the Home with distributed generation technologies and energy management capability, including new PVs, fuel cell, energy management system, wireless thermostats, geoexchange, smart meters, mechanical room, and a plan to include a hybrid vehicle.

Photovoltaic panels (external mount)
Second-generation photovoltaic panels were installed on the Home's south-facing roof. The six POLY-Si panels are not integrated with the building, but have been positioned for maximum efficiency by directly facing the sun. This new array produces approximately 1.2 kilowatts (in addition to the 2 kilowatts generated by the BIPVs).

Fuel cell
A natural-gas-fired residential fuel cell generation system supplies electricity up to 0.5 kilowatts and hot water (by-product) on demand. Within its first year of operation, the fuel cell has had to be removed from site for repairs. Fuel cell generators for residential use are close to becoming commercially available, expected to rise in Europe and Japan in coming years. The demonstration of a fuel cell at AFRESH Home is intended to develop standards and procedures for the safe installation and operation for residential fuel cells in BC. Rather than having individual homeowners purchasing and operating this equipment, BC Hydro could operate it as part of a distributed networked system. By using smart meter technology, the utility could activate the fuel cells during peak hour loads to help manage demand.

Energy management system with backup power storage
PV cell and fuel cell generation technologies will produce electricity for AFRESH Home, with surplus electricity flowing to the BC Hydro grid. These distributed generation systems use an inverter to convert direct current (DC) to alternate current (AC) power, integrated with an energy management system (computer software) that manages battery storage for back-up use, conversion to or from the grid, and on-site use. The photovoltaics utilize the inverter in the energy management system, while the fuel cell has its own inverter. The system switches power sources as needed, monitors itself, and gathers performance data. This GridPoint system has an online user interface, allowing Home residents to monitor and control their energy use by accessing the systems remotely.

Programmable thermostats
Wireless Zigbee thermostats allow users to program desired indoor temperatures for times of day, as well as for days of the week. This allows users to save energy by reducing heating loads while away from home or while sleeping. Though any thermostat can be set to any temperature, users often do not think to reduce temperatures at the times when heating requirements are less. The ability to program the thermostat ensures that savings will be achieved. In addition, wireless programmable thermostats allow users to alter their settings using an online interface, thereby allowing access to the thermostat from anywhere in the Home, as well as remotely.

Geoexchange
A geoexchange system provides hot water, heating and cooling for AFRESH Home, replacing the natural gas boiler. This retrofit system is a vertical closed-loop borehole, installed with the assistance of BCIT Piping students. The system uses the thermal mass of the ground to heat or cool the liquid medium passing through the borehole piping. Warm or cool air is captured in the heat exchanger, and compressed or expanded in the heat pump to further increase or decrease air temperature. The geoexchange system has a high coefficient of performance (COP), indicating that it generates significantly more power than it takes to operate.

Smart meters (see below)

Mechanical Room
To house the fuel cell and heat recovery tank, battery storage and energy management system, smart meters and components of the geoexchange system, a larger mechanical room was added to AFRESH Home. The room has outdoor access, sharing an interior window with the entryway of the Home. The room provides both direct and visual-only access to the energy systems, allowing for demonstration and learning opportunities for students.

Plug-in hybrid electric vehicle
The Distributed Power Connections Study will also include a plug-in hybrid electric vehicle. The vehicle's internal combustion engine is combined with batteries that can be recharged by plugging into a general power outlet. The intent is for this component of the project to gather data on retrieving electrical energy from the vehicle and returning it to the grid during peak demand and recharging the battery during off-peak hours. The plug-in stations have been installed directly beside AFRESH Home. The vehicle has not yet been obtained.

Intelligent Microgrid Project
The second of the two current studies is the Intelligent Microgrid Project. BCIT's Group for Advanced Information Technology (GAIT) has undertaken to develop and study a smart microgrid on the BCIT campus. A mini version of the power grid managed by utility companies, the campus microgrid provides a test site for the study of "smart" technologies, including meters and appliances. Both of these technologies have been installed in AFRESH Home. The project studies how localized power generation sites (solar, wind, and thermal) can be integrated into the microgrid to allow for the development of command and control models for distributed generation and integration of such alternative energy sources into the future Intelligent Grid of British Columbia.

Smart meters
Smart meters are installed across campus, measuring and communicating energy consumption data in real time. These meters also communicate with the utility to provide peak time and rate information to consumers. This allows energy consumers to make decisions about when they will use power, how much they will use, and what it will cost. A smart meter collects energy consumption data from AFRESH Home for use by GAIT.

Smart appliances
Smart appliances work hand-in-hand with smart meters, and can be programmed to reflect user needs based on energy costs. The appliance has a modem that receives real-time rate information and peak times from a smart meter, allowing the appliance to function according to how it is programmed. For example, if the user programs the dishwasher to only be able to run during non-peak times when rates are less, the dishwasher will refuse to start if the user tries to engage it during a peak time. Smart appliances have override switches to allow users to override the programming without altering it, for times when an appliance must be used that does not conform with the user's programming. Smart appliances have replaced the original energy-efficient appliances.

Results and Project Success

The original Home 2000 succeeded in demonstrating healthy and flexible home design and construction at the time it was built. The Home has continued to successfully demonstrate flexibility as over time its systems have been retrofitted in response to changing needs and new technologies. New systems work in tandem with original systems to produce energy on-site, reduce energy consumption, and manage energy storage and conversion.

AFRESH Home is demonstrating the integration of a variety of alternative energy systems. Resulting from the Distributed Power Connections Study in partnership with BC Hydro, the AFRESH Home is capable of being a net energy producer. The two sets of PVs produce approximately 3.2 kilowatts, and the fuel cell is expected to produce 0.5 kilowatts. This total of 3.7 kilowatts is more than the Home requires most of the time, resulting in an anticipated net energy production from time to time.

The Home has received over 55,000 visitors, and it continues to bring awareness of new, alternative energy technologies to campus visitors, staff and students.

Lessons Learned

A number of recent challenges have emerged during AFRESH Home's transformation to becoming a net energy producer through the Distributed Power Connections Study and its participation in GAIT's Intelligent Microgrid Project.

Scope of project
Since 2006, AFRESH Home has undergone a number of retrofits to add new energy systems and related components to the Home. This has been an opportunity to showcase BCIT's applied research capabilities and provide students with access to state of the art technologies. However, it has also been a challenge because there has been no additional increase in project management capacity or funding to address the expanding scope of the projects. To address this challenge, the original agreement with BC Hydro should be reassessed in light of future aspirations for AFRESH Home. Redefining the scope, resource requirements, and appropriate roles and responsibilities is necessary for moving forward with the initiative. Alternatively, it may be decided to bind the scope of the project at its current level. A similar approach could be used for the GAIT project and future BCIT projects to provide management capacity and funding.

Project management
A second challenge has been the lack of coordination and unsatisfactory completion of some of the projects within AFRESH Home. Several aspects of the energy technology installations were carried out on an ad-hoc basis, taking advantage of industry donations of resources. BCIT cut-backs resulted in the loss of the project manager position, creating further challenges in bringing projects to conclusion. To address this challenge, a dedicated project manager is required who can oversee the completion of the existing project work, and who can participate in decisions regarding whether and how to proceed with new initiatives related to the AFRESH Home.

Educational programming
AFRESH Home was envisioned as an educational site for students learning about the technologies associated with on-site energy production. However, some of the technological installations have resulted in inadequate learning facilities. For example, the access areas to equipment are too small for multiple students to properly see at one time and to access the equipment for learning purposes. To address this challenge, program directors and instructors should be consulted to identify instructional needs, criteria should be developed for future projects that takes these needs into consideration. Also, determining what retrofits are required to provide students better access to the existing technologies within the Home will allow for better use of what is already there.

AFRESH Home is primarily a demonstration site. A number of trade-offs have been made with the decisions to install some of the systems, for the sake of providing demonstration and education opportunities. In Phase 1, building integrated photovoltaics in the roof resulted in a lower R-value, but a powerful educational opportunity was gained. Similarly in Phase 2, during the installation of the geoexchange system by BCIT piping students, the house and its occupants were without heat for about one month during the transition from the old system to the new system. A smooth transition between technologies is more challenging when the retrofit is being undertaken for such an educational purpose, but the trade-off is the hands-on experience that students were provided. It is important that the idea of trade-offs is discussed with students and visitors to the site.

Contracting trades services
When retrofits are needed to the Home that cannot be provided by staff and students of the School of Construction and the Environment, it has been necessary to hire trades people on small contracts. However, the contracts have been difficult to fill due to the extremely small scale or specialized nature of the work. For example, building custom cabinets for an existing kitchen seems unappealing to contracting firms who are unable or unwilling to take on customized joinery work and prefer to bid on whole kitchen renovations using prefabricated materials. To address this challenge, and to maximize the opportunity to engage trades students in projects on campus, the educational needs related to student project work should form the criteria for conceptualizing and scoping applied research projects. Where these criteria do not fit with a proposed applied research project, this should be identified prior to initiation of the project, and appropriate contractor services secured in-line with the scheduling of the project.

Evaluating proposed applied research projects for net benefit
An overarching goal for the Sustainability Precinct is to reduce energy and materials consumption without compromising service levels. Transforming the

AFRESH Home to become a net energy producer enables the home to run more efficiently and to use renewable energy sources. However, whether these technologies actually contribute to a net reduction of energy and materials consumption when their embodied energy is considered in addition to the materials consumed to retrofit the Home is unclear. □□To address this challenge, proposed projects should be evaluated over their entire life cycle to determine whether they provide a net contribution of benefit. Determining whether installing a new system is going to actually reduce or merely displace energy and material demands in the context of an integrated system is key to making smart decisions about what projects to implement and why.

Next Steps

BCIT anticipates an assessment of its past partnership with BC Hydro in the Distributed Power Connections Study, and a decision whether to continue to participate in the study in its current role or with amendments made to scope and resources.

The Institute foresees some building retrofits to improve access to the Home's energy systems and increase learning opportunities for students.

AFRESH Home will continue to provide data from its smart meters to GAIT in support of the Intelligent Microgrid Project.

Awards

In 2000, BCIT's Photovoltaic Energy Applied Research team at the Technology Centre won the Canadian Institute of Energy's Applied Energy Innovation Award for its work in Building Integrated Photovoltaics (BIPV).

BCIT was a finalist for BC Hydro's 2010 Power Smart Excellence Awards, in the category of Conservation Partner, recognizing the Institute's achievement with AFRESH Home and the Distributed Power Connections Study, the Intelligent Microgrid, and other projects.