

## The Centre for Interactive Research on Sustainability, UBC: Creating Net Positive Benefits at Multiple Scales

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**ABSTRACT:** This paper examines three key ways in which the Centre for Interactive Research on Sustainability (CIRS) building at the University of British Columbia is expected to provide ‘net positive’ benefits to the environment and its inhabitants. First, while CIRS has added a 5,800m<sup>2</sup> building to the UBC campus, it reduces campus energy use and carbon emissions, and causes a reduction in potable water demand for the campus. Second, the CIRS building has been designed to produce a suite of benefits and engagement opportunities that are designed to increase the health, productivity and happiness of its inhabitants. Third, the project not only responds to its immediate micro-site requirements, but also is intended to have positive environmental and social impacts at the community scale. The paper presents the design features embedded in the building that collectively support net positive performance, the efforts underway to monitor performance through time and the range of supporting research initiatives.

### 1. INTRODUCTION

#### 1.1 *Centre for Interactive Research for Sustainability (CIRS)*

The Centre for Interactive Research on Sustainability (CIRS) is a 5,800m<sup>2</sup> building on the campus of The University of British Columbia (Figure 1) that was designed to operate at the frontier of sustainable performance in both environmental and human terms, and serve as a living laboratory of, and research test-bed for, sustainable practice over its lifetime. CIRS achieved occupancy in September, 2011. From the outset, the design of CIRS was guided by the desire to be Green, Humane and Smart, and achieve net positive performance in both human and environmental terms (regenerative sustainability). These overarching notions have defined a set of specific performance goals. This paper will explore the potential ways and extent that these guiding principles and goals shaped the design of CIRS and the subsequent direct and indirect consequences for the anticipated building inhabitants. Moreover, since CIRS aims to be highly replicable, the paper will identify the extent to which these approaches are different from conventional practice and transferable to other situations and building projects. Although the CIRS program extends beyond typical green building technologies and practices, this paper focuses on the building design and implementation.

The CIRS building is intended to provide ‘net positive’ benefits to the environment and its inhabitants. First, while CIRS adds to the UBC building stock, it was designed to reduce campus energy use and carbon emissions, sequester more carbon in its structure than required to build the building and reduce the campus demand for potable water<sup>xi</sup>. This is intended to be supportive of UBC’s long-term goal of showcasing the Vancouver campus as ‘the world’s first net positive energy and water campus. An effective, integrated energy and water plan will be critical to

success in that venture.’ (UBC, 2008) Second, the CIRS building has been designed to produce a suite of benefits and engagement opportunities that are designed to increase the health, productivity and happiness of the inhabitants. Third, the project not only responds to its immediate micro-site requirements, but is also intended to have positive environmental and social impacts at the scale of the district or community.



*Figure 1: Centre for Interactive Research on Sustainability, UBC  
(Perkins+Will, 2011/Photo: Martin Tessler)*

### *1.1.1 Environmental Characteristics*

The use of onsite renewable energy and other fortuitous energy supply options derived from the surrounding context became an important strategic choice after all possible energy efficiency and passive strategies had been pursued. Based on LEED energy modeling performed by Stantec Consulting in August 2010, energy use in the building is expected to be 78 kWh per square metre of floor-space (gross) per year. Once unregulated energy uses have been subtracted to allow comparison, this is roughly equivalent to the German Passivhaus and Swiss Minergie Label standards. Onsite renewable energy options (building integrated PV cells, a solar thermal hot water system, and a ground source heat pump (GSHP) system sized to the building cooling load are place-specific – dictated by the seasonal climatic variations and any modifying effects resulting from the surrounding physical context. Fortuitous energy sources and exchange opportunities are also place-specific and dependent on the ways and extent that the energy profiles of an adjacent building and associated heating system match that of the one being designed.

The CIRS building captures waste heat exhausted from the nearby Earth and Ocean Sciences (EOS) building, satisfying its remaining thermal needs (over those provided by the GSHP and solar hot water systems) and then returning excess back to EOS. Since this reduces natural gas use at the university’s central steam plant by more than the total amount of electricity purchased for CIRS, the overall effect is to reduce the university’s overall energy use. And since that purchased electricity is much lower carbon than the natural gas burned in the university’s steam plant, this also reduces the campus’ carbon emissions.

CIRS relies entirely on rainwater to meet its potable water needs, and all the wastewater generated in the building will be treated on-site and recycled in the building to meet non-potable

water requirements. Rainwater falling CIRS that cannot be used as a source of potable water for the building is redirected into an infiltration well that recharges the local aquifer, eliminating storm water discharges from the building. Because of advantageous economies of scale, the CIRS wastewater treatment system was designed to treat roughly four times the amount of wastewater generated in the building which enables CIRS to import sewage from surrounding buildings and return reclaim-quality water to campus for non-potable applications, thus reducing the campus demand for water.

Finally, CIRS is also designed to be net positive in structural carbon. The building structure sequesters more carbon than all the carbon emitted in building and in manufacturing all the furniture, fixtures and fittings found in the building.

### *1.1.2 Human/Social Attributes*

CIRS aims to provide a socially and biophysically healthy environment for human habitation which adapts to changing needs and uses over time, and which contributes to a continuous improvement in the health, productivity and happiness of building inhabitants. In addition to offering fully daylit, wood-intensive, and naturally ventilated interiors, the project provides opportunities for inhabitants to connect with others through informal meetings and interactions, to the natural world with views to living things, and to the campus by permeable campus pathways that invite people to pass through parts of the facility. It allows inhabitants to share ideas and food in its on-site sustainable food café and its generous and accessible meeting spaces. Finally, the building will provide not only real-time display of building performance for all environmental systems, but also the ability to vote on controls strategies for the building. The goal is to convert building occupants (i.e., passive recipients of building technologies), into inhabitants with a sense of place and engagement with the building.

### *1.2 Synergies*

While a university campus allows opportunities not often permissible in most contexts that architects operate, CIRS nonetheless is illustrative of the opportunities and potential implications of how design strategies can offer multiple environmental and social benefits beyond the boundaries of an individual building. In order to achieve the potential offered by the synergistic biophysical and social links outlined above, the building program must engage with a host of sociocultural factors such as a willingness to accommodate renewable energy, matching of energy quality to operation use, enabling inhabitants to understand energy processes and adjust the systems to meet their changing needs, developing programs that allow building operators to interact with building inhabitants and meet performance goals, etc. These factors in turn intersect in complex ways with the net positive human system goals of CIRS.

The CIRS building allows testing of the hypothesis that there need not be a “scalar contraction” between aspirations and realities in the design profession – environmental synergies support the mutualistic co-evolution of sociocultural and ecological systems and provide evidence that regenerative interventions are possible at the scale of a single architectural commission. As a “living lab” in which changes will continue to be made over the life of the building, the CIRS project does not attempt to guarantee a certain future but to enable the emergent flourishing of both human and environmental systems that permits choice, creativity, exploration and adaptability. Its unfolding performance and consequences will be fully monitored and documented, and such feedback mechanisms used to support the notion of emergence and a co-evolutionary process. A major goal is to document and learn from these engagement processes.

### 1.3 Transformation of Process

All of the key aspects of the CIRS vision—the inter-institutional academic partnerships, the relationship with non-academic partners, the governance structure, the sustainability goals, the building design process, obtaining funding, negotiations between capital and operating costs in new ways—involved going beyond standard operating procedures for UBC and other partners. Moreover, mobilization of the various stakeholders and industry partners required the development of new partnership models based on principles of mutual benefit and synergy of goals. The transformation they underwent as they began to realize and fulfill their critical role in the integrated design process of CIRS became a lasting legacy of the process. (Brown *et al.*, 2009) The shift is evident in the larger process of campus planning in which CIRS has become enmeshed.

Partly as a result of the discussions engendered by CIRS’ plans to scavenge heat from a neighbouring building, and partly because of a strong tradition of sustainability analysis and planning that has been established at UBC over the past decade, UBC has adopted an approach to campus planning that envisions the whole campus as a test-bed for sustainable energy, water, waste and food systems (Robinson, *et al.*, 2013).

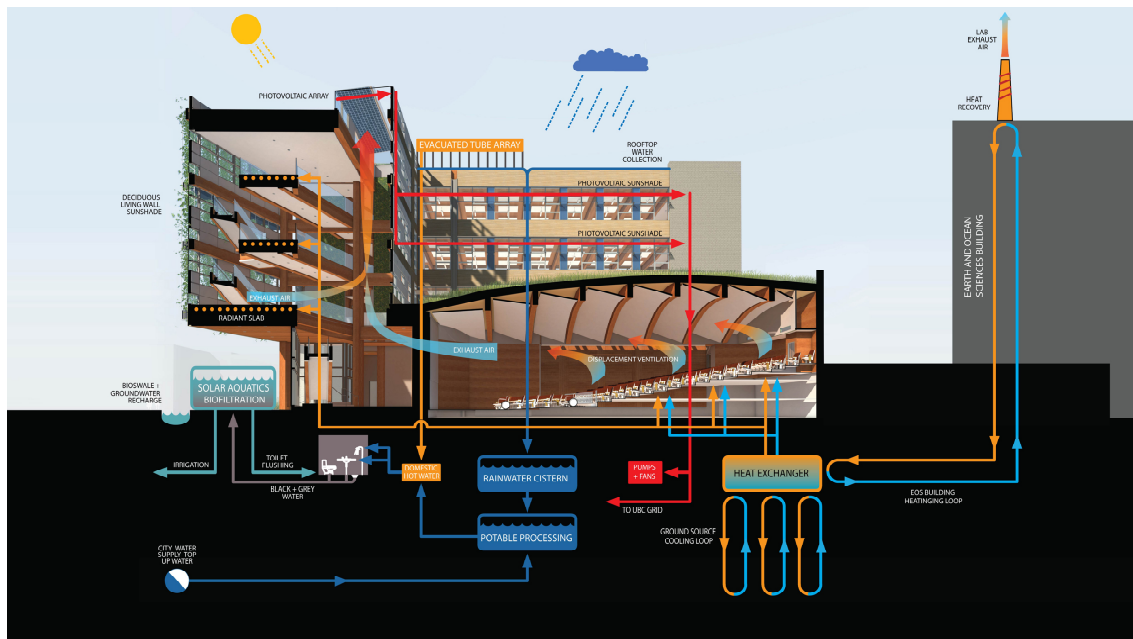


Figure 2: CIRS Environmental Systems (Perkins+Will, 2011)

## 2. DESIGN FEATURES SUPPORTING NET-POSITIVE GOALS

To meet the CIRS vision and agenda, the building itself is used as a research laboratory for operations, monitoring and assessment of energy and water use, daylight harvesting, indoor environmental quality and inhabitant behavior. To determine operating conditions of the building, over 3000 points of monitoring have been implemented in CIRS to measure total energy use and CO<sub>2</sub>e emissions, total water use, captured waste energy from EOS, harvested solar and geothermal heat, PV electricity produced, grid electricity consumed, energy use by different building systems (lighting, HVAC, plug loads, etc.), heat returned and accepted by the EOS building, as well as its associated natural gas savings and CO<sub>2</sub>e emissions, energy savings

associated with natural ventilation and day-lighting strategies, rainwater treated and supplied to the building, wastewater treated and reused in the building, and storm-water runoff redirected into the local aquifer, among others

The design process engaged the active participation of the user community, including researchers as well as public and private sector partners. The CIRS progressive regenerative process stands as an example of an explicit recognition of the need to engage social and behavioral dimensions of comfort, as well as the potential for improved dialogue and communication to improve building performance. Not every goal for CIRS was achievable with present technologies at reasonable cost on opening day. But the CIRS facility was not ‘finished’ the day it opened; it has been designed for change over time, adopting and adapting new technologies. The overall goal is continuous improvement over time in human and environmental conditions.

### 2.1 CIRS as ‘Green’

Moving beyond providing a building that is “less bad” than conventional practice, the CIRS goals were to have a positive impact on both the local and global environment, while living within, and contributing to, the biophysical flows available on its own site. The specific Green design goals for CIRS that were developed through an integrated design process and several charrettes were ([www.cirs.ubc.ca](http://www.cirs.ubc.ca)):

#### 1. Design with time in mind:

- Climate Change: Heating, cooling and water systems designed to adapt to anticipated changes in climate over the next 100 years.
- Life Cycle Analysis: Building structure and systems are to be evaluated and designed over a time frame of 100 years.

#### 2. Zero materials waste:

- Design for assembly, modification, and disassembly.
- Avoid toxic materials.
- Materials choices informed by life-cycle analysis of environmental impact, including embodied energy and greenhouse gas emissions—minimize CO<sub>2</sub> emissions associated with construction.
- Design a materials-handling strategy for supplies and components entering the building over their life that seeks to eliminate solid waste going to landfills.
- Process all liquid ‘waste’ into pure water and useful feed-stocks.

#### 3. Energy use has a net positive impact on ecological health:

- CIRS facility will reduce the overall UBC campus energy use.
- Direct energy consumption target: 75 kWh/m<sup>2</sup>/yr overall, 15kWh/m<sup>2</sup>/yr for heating.
- Building operation should be greenhouse gas neutral.
- Efforts will be made to balance the scale and quality of the energy used with that required for the task.
- All energy used in the building should come from clean and renewable or scavenged energy sources.

#### 4. Ecological health:

- The facility should be able to live on the budget of the rain falling on its site.
- Efforts will be made to balance the quality of the water with that required for the task.
- Water leaving the site should be as good or better quality than when it arrived.

- Site design should provide a net positive impact to the ecological health of the surroundings.
- Net increase of biomass on site.
- Zero net runoff from site.

Many of these demanding performance requirements, while context dependent, extend beyond the footprint of the building to embrace the larger campus. The consequences of the Green goals and strategies on building inhabitants are captured in the following “Humane” and “Smart” sections.

## *2.2 CIRS as ‘Humane’*

CIRS aims to provide a socially and biophysically healthy environment for human habitation which adapts to changing needs and uses over time, and which contributes to a continuous improvement in the health, productivity and happiness of building inhabitants.

Specific design goals included:

### 1. Ongoing assessment of inhabitant comfort:

- On an ongoing basis, assess the interaction between the environment provided by the building and the health, productivity, and happiness of those who work and visit it.

### 2. Outstanding IEQ:

- Provide a comfortable, healthy environment for inhabitants, under local control to adapt to individual differences and differing activities:
  - Air that meets or exceeds outdoor air quality.
  - Light levels and quality appropriate to tasks, with the option of relying on natural light whenever available and appropriate to the task.
  - Provide for acoustic separation and privacy.
  - Provide areas for the preparation and sharing of food: deal with food human waste in ways that recognize them as an environmental opportunity

### 3. Connections within and beyond:

- Provide opportunities for inhabitants to connect with each other and the world:
  - Connect to the natural world: views to living things, breezes.
  - Connect to others in the facility: promote informal meetings and interactions.
  - Connect to the campus and world: be permeable to campus pathways to invite people to pass through parts of the facility and share food and ideas:
    - > on site café (emphasizing 100-mile diet options when available).
    - > conference, teaching centre, walk-through accessible.

The physical form of CIRS was profoundly shaped by these humane concerns:

- Narrowed floor plates ensure that all workspaces are daylit.
- A pleasant view of the green roof of the atrium is visible from office and lab spaces on upper floors.
- Inhabitants have access to ventilation, lighting and temperature controls.
- A breezeway cuts through the lobby and atrium, providing a covered pedestrian walkway and promoting public access.
- A café located on the entrance level engages the campus community and disperse the sustainability values of CIRS while providing an interaction hub for building inhabitants.
- A 60-seat auditorium presents visualizations of regions and communities in future climate scenarios, drawing the public to CIRS and to UBC campus in the interest of sustainability research.

- 3,000 monitoring points inside the building consistently monitors and assesses how the building is meeting inhabitant needs and comfort standards.
- The innovative strategies are visible, accessible and understandable to inhabitants and visitors.

In addition to the wide-reaching humane goals noted above, a program of active engagement of people working in CIRS has begun to be developed, in accordance with the objective to convert ‘occupants’ to ‘inhabitants’:

- Every person working in CIRS will sign a Sustainability Charter, committing them to engaging with the process of creating a socially and environmentally regenerative building. The Charter is not expected to directly affect inhabitant behaviour, but to contribute to creating a stronger sense of community among inhabitants.
- CIRS offers a suite of benefits and engagement opportunities to all inhabitants. These include individual control of ventilation at their work stations, access to real-time feedback and monitoring of the building’s technical systems and performance (including the opportunity to express preferences about operating conditions), high levels of air quality, a work environment characterized by wood, access to natural light, social spaces for interaction, and a sustainable food services outlet.

Inhabitants thus play a critical role in the success of the building and its community while experiencing the attributes of a workplace intended to optimize inhabitant comfort and productivity.

### *2.3 CIRS as ‘Smart’*

CIRS seeks to integrate building performance with the performance of inhabitants in an ongoing interactive dialogue intended to improve the green and humane features of CIRS over time. The CIRS building process applies design intelligence augmented with monitoring and feedback to engage building inhabitants to get the most out of the available energy and material flows afforded by the site and its surroundings. ‘Smart’ is defined in terms of four key attributes: adaptiveness, responsiveness, effectiveness and economic efficiency. Feedback is considered key to ensuring the building systems and inhabitants are responsive and adaptive to changing internal and external conditions and needs. Detailed, ongoing monitoring is instrumental in meeting the ‘living lab’ vision and research agenda for the building, allowing for the assessment of existing and future building systems and technologies.

CIRS develops approaches towards constructing, operating and maintaining the building and meeting human needs at the lowest life-cycle costs, providing solutions that can be economically replicated and adapted into buildings worldwide. The Smart design goals for CIRS included:

1. Provide instrumentation and controls to allow feedback and learning:
  - The building should learn from its inhabitants.
  - Deliver comfort where and when it’s needed.
  - The inhabitants should learn from the building.
  - Provide feedback to building operations staff for identifying systems performing poorly.
  - Provide feedback to inhabitants as to how their behavior affects energy, water, and material use.
  - Allow building inhabitants to express preferences for building operating conditions and procedures.
2. Produce a core building that exemplifies replicable, economical solutions:
  - Make design and operation choices based on the lowest life-cycle costs.

- Allow for experimentation with approaches that may not yet be cost-effective.

Elements of the Smart goals for CIRS which have had a direct expression on building design process and form include:

- Inputs from UBC campus stakeholders led to insights into potential synergies with neighboring buildings, existing campus policies, infrastructure constraints and future growth plans for CIRS and for the UBC campus.
- Detailed, ongoing monitoring to:
  - Understand the energy and water flows through and within CIRS, both from quantitative and qualitative standpoints.
  - Understand the interaction of building inhabitants with the range of advanced green strategies and technologies.
  - Understand the impact of immediate and distant contexts on energy and water flows, e.g., heat exchange with a neighboring laboratory building.
  - Compare between building design and actual performance, and feedback on the operational performance of individual and collective systems and technologies.
- The use of a ‘biofilter’ approach to water treatment based on the compelling nature of the biofilter as an educational tool.
- A daylighting system that establishes a hierarchy of control over shading devices to accommodate inhabitants and different program uses.

Smart attributes of CIRS will have direct and indirect consequences for anticipated building inhabitants, particularly in the ways that inhabitants engage with adaptive opportunities provided to them and received feedback on their actions.

### 3. IMPLEMENTATION AND RESULTS

The planning and design process of CIRS spanned almost a decade. While the sustainable design goals of CIRS remained fundamentally intact throughout this time, the design strategies and local context opportunities changed over time. The site of the building moved from UBC to the Great Northern Way Campus (approximately 15 km away) and back to UBC. The last and final iteration of the CIRS design in 2008 benefited from a set of opportunities that were not available during initial attempts to develop CIRS. First, the Cascadia Green Building Council launched the Living Building Challenge rating system in 2006 which became a catalyst for the implementation of many of the design goals of CIRS. Secondly, the site chosen for CIRS at the UBC campus opened up the possibility of a more direct interaction between CIRS and its community.

CIRS was built on a previously developed site but provided a net increase in landscaped and living systems area that benefits the southeast quadrant of the UBC campus. The design of CIRS also preserved a path that existed before the construction of CIRS which became a breezeway between the main lobby/atrium of CIRS and the transparent Solar Aquatics Bio-filtration wastewater treatment facility. Through its overall water strategy CIRS has established a strong link with the adjacent Sustainability Street infrastructure, benefiting from the 90-metre deep well drilled there that is now capturing for aquifer infiltration and recharge all the surplus rainwater that CIRS cannot use as a source of potable water. The CIRS energy strategy resulted in the capture of large amounts of waste heat from the EOS building which through the return of a substantial amount of heat to EOS via CIRS, provided an opportunity to make EOS more efficient and less reliant on campus-generated steam which is produced burning natural gas. This in turn will result in a reduction in UBC’s natural gas use (greater than the increase in electricity purchases caused by CIRS), and a net reduction of UBC’s CO<sub>2</sub>e emissions.

From an architectural program perspective the initial mandate of CIRS as a research and demonstration facility expanded with its 2008 design at the UBC campus. The building program now accommodates the addition of a 425-seat auditorium visited by 2,000 undergraduate students daily and the addition of a sustainable food and operations café run by UBC Food Services. The CIRS project team and UBC Food Services partnered to create ‘The Loop’, a food outlet with very aggressive sustainability objectives such as eliminating the use of plastic bottles and cans, a flexible and reconfigurable space, and a food and menu hierarchy that gives preference to produce originated at the UBC farm and other local sources.

The construction and commissioning of CIRS raised a number of significant challenges in terms of implementation, which remains a work in progress. While many of the technologies used were available off-the-shelf, some of the systems in CIRS, such as the water treatment system, had not previously been implemented at UBC or even in Canada. CIRS had an extremely ambitious program of system integration, requiring the working together of multiple subsystems, such as the various energy efficiency systems, heat scavenging processes and renewable energy technologies, or the combination of rainwater harvesting, wastewater treatment systems and use of reclaimed water.

In many cases, the significant obstacles were not technical or economic, but institutional. It took over a year after building occupancy, for example, to obtain operating permits for the water harvesting and treatment systems. The design team, construction manager, commissioning agent, and now building operators, have all had to learn to work with the integration of novel technologies and systems. System integration gave rise to challenges that could not be anticipated based on the previous use of individual technologies. Some of these, like the small vibrations felt in the atrium long-span connecting bridges, or the water damage to some wooden structural components of the building, could be solved during construction and commissioning. Others, like meeting the design intent of the heat transfer between CIRS and the EOS building, will require retrofits. Others still, like the expansion of the concrete basement of CIRS to accommodate a campus-wide need for storage space, after the structural carbon modeling had been done, will reduce the amount of the net carbon sequestration effect of the CIRS wooden structure and other wood-based components of the building.

Initial results from monitoring the environmental performance of CIRS indicate that the design goals of net positive performance are not yet being met. It is expected that the environmental goals related to energy, operational carbon and water will be met over the next few years, and further work is being undertaken to determine the structural carbon balance. On the human side, while considerable research has started on the behavioural consequences of inhabiting CIRS, the inhabitant engagement program is still under development. As of January 2013, rigorous monitoring had not started on the three net positive goals (productivity, health and happiness) in this area.

#### 4. RESEARCH PROGRAM

Research underway at CIRS goes beyond work on the CIRS building itself and focuses on the “performance gaps” between the predicted environmental performance of the built infrastructure and its actual performance; between claimed concern for environmental issues and the actual behavior of citizens; and the implementation gap between the expressed goals of environmental policies, bylaws and plans and actual outcomes. The research explores the gap between “potential” and “performance”, acting as a catalyst for the integrated study of processes, strategies, policies and technologies for regenerative sustainability at the building, urban and regional scales. The CIRS building and its interactions with its community on the UBC campus and beyond is being used as a test-bed for this analysis. The CIRS research will be integrated both conceptually and practically and will focus in three areas:

1. *Sustainable Building Design and Operation*: This includes incorporating the process of

sustainable building design and the integration and lifecycle performance analyses of environmentally sustainable technologies, systems, and strategies into the CIRS building, as well as the study of the interplay between the building and its subsystems and the building inhabitants. Energy systems, water systems, and material use, as well as the impact and influence of building inhabitant preferences and behavior will be used to assess building performance and to what degree is CIRS meeting its net positive environmental and human well-being performance goals;

2. *Visualization Tools and Community Engagement*: This includes the study of cognitive and behavioral responses of individuals and institutional stakeholders to new simulation and visualization tools for exploring sustainability issues at multiple scales. This will be underpinned by the creation of an immersion environment (decision theatre) for community engagement that links cutting-edge simulation and visualization techniques with expert knowledge to assess the impact on individual behaviors and policies on sustainability objectives;
3. *Regenerative Sustainability beyond the Building Scale*: This research theme builds on parts 1. and 2., and is grounded on the notion that whenever human activity can be made regenerative, this is preferable to merely reducing damage or harm. This research will study the aspirations and key principles of regenerative sustainability that are beginning to emerge from several converging historical threads, and explore the process of codifying, operationalizing and evaluating regenerative sustainability so that it can be applied at the neighborhood and regional scales. An important part of this research is to identify concepts and methodologies that can inform the construction of a framework that assesses regenerative sustainability at the neighbourhood level. Early findings suggest that while many sustainability assessment approaches exist, few approaches embody regenerative sustainability or are designed specifically to address regenerative sustainability at the neighbourhood level. This research will study the technical, economic, and social dimensions of technologies, systems, behaviours, and policies, as well as integrating qualitative policy analysis with quantitative data and modeling of key relationships among systems.

The cross-cutting objective of the three-part CIRS research program is to accelerate the adoption of more sustainable practices in society by bringing the fruits of the CIRS research into the public, private and civil society decision-making arenas through the implementation of partnerships that demonstrate, replicate, disseminate and commercialize sustainable products, systems, practices, processes and technologies. A recent study conducted at CIRS illustrates this point. Researchers in the Department of Psychology at UBC posed the hypothesis that the unique confluence of above factors creates an environment whereby CIRS actively and intentionally embodies and promotes a message of sustainability. For instance, The Loop cafe at CIRS employs both constraining (e.g., no bottled drinks are available for purchase and all utensils are compostable) and suggestive approaches (e.g., persuasive signs which explain where the food comes from) which could shape and influence user behavior. From the perspective of evaluating the effects of these contextual factors on behavior, CIRS provides the perfect environment to test the idea that being in an environmentally conscious surrounding can elicit environmentally conscious behavior. Researchers tested this idea by secretly observing peoples' food disposal habits as this action involves a decision not constrained by the building itself (i.e., people have to make a decision about where to throw their items). As a comparison, they also observed people dispose behaviour in the eating area at UBC's Student Union Building (SUB), a building that was not designed with sustainability in mind although importantly it has comparable categories of disposal bins. The findings were clearcut: people are much more likely to correctly choose the proper disposal bin (garbage, compost, recycling) in a building designed with sustainability in mind compared to a building that was not. Perhaps the most remarkable finding however was that the researchers also determined through interviews that participants at

CIRS did not self-identify as “pro-environment” and the majority were also regular patrons of the SUB. Patrons of The Loop were at CIRS because of convenience. The effect of CIRS represents a power example of the principle that human cognition and behaviour is ‘situated’, meaning that real-world contexts can actively and subtly change how one perceives the world and acts within it. In short, being in a sustainable context, acting on objects designed for sustainability induces pro-environmental behavior in CIRS. Convergent with this conclusion the researchers found that the patrons in CIRS rated themselves significantly higher in environmental consciousness compared to patrons at the SUB. Thus this study exemplifies the importance of environmentally sustainable developments. Not only are these developments themselves more sustainable in a physical sense, but they influence a large number of users within them to act and think more sustainably as well.

## 5. CONCLUSIONS

CIRS represents an ambitious attempt to implement a regenerative sustainability agenda at the building and community scale. While the actual degree of achievement of the sustainability goals of the building, both human and environmental, remains to be determined, important lessons have already been reached about the development of design, construction and commissioning processes required to develop and implement such goals. Future work will document these lessons in more detail, and begin to report on the operating performance of CIRS, and how it adapts over time to changing conditions, and the learning of building operators, inhabitants and the building systems themselves.

Through the design, building and operation of CIRS, UBC is exploring the hypothesis that it is technically and financially feasible for buildings to harvest from renewable sources and return to their communities more energy than they take from utility grids; that buildings can live off rainwater (where geographically appropriate), and treat and recycle their liquid waste and generate no municipal storm-water runoff; that buildings can sequester more carbon within their structures than is emitted during the extraction, manufacturing, transportation, installation, and decommissioning of other materials used to build them; that a high quality indoor environment coupled with an active *inhabitant-building interplay* can result in measurable increases in inhabitant productivity, health and happiness; and that regenerative sustainability performance in both human and environmental terms can be achieved cost-effectively and with current off-the-shelf technologies.

Finally, the aggressive floorspace expansion underway at UBC to meet the growing demand for new academic and student housing buildings on campus represents a significant opportunity to implement a “regenerative” building development framework based on CIRS principles that in turn can directly contribute to meeting UBC’s overall sustainability objectives and GHG emission reduction targets.

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#### ENDNOTES

<sup>1</sup>Vancouver Coastal Health did not permit surplus reclaimed water to be re-injected into the local aquifer due to concerns about endocrine-disruptive chemicals and other human-originated pharmaceuticals that cannot be removed by the onsite Solar Aquatic System treatment process. However, the building recharges the aquifer with rainwater it cannot use thus completely eliminating storm-water runoff, and, by treating raw sewage from other facilities and returning reclaimed water back to campus for non-potable uses, it causes a net reduction in campus potable water demand.