UBC LIVING LAB: INNOVATION IN ACCELERATING THE ADOPTION OF SUSTAINABLE TECHNOLOGIES FOR CAMPUS INFRASTRUCTURE

by

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Abstract

Any group that creates challenging goals for the future also requires a strategy to achieve them. In the University of British Columbia's (UBC) case, the goals are to reduce greenhouse gas emissions to 33% below 2007 levels by 2015, 66% by 2020, and 100% by 2050 (UBC 2010c). The strategy was to develop the University Sustainability Initiative and the Campus as a Living Lab to assign authority and responsibility to help manage this endeavor. The Campus as a Living Lab at UBC provides a process for simultaneously meeting increasing infrastructure capacity requirements while achieving sustainability goals. The Campus as Living Lab accomplishes this by collaborating with industry partners, operations, and researchers to utilize the campus as a test bed for commercialization of sustainable technologies. This thesis explores the Campus as a Living Lab program at UBC and the replicability of it as a tool to expedite the adoption of sustainable technologies for campus and municipal infrastructure. Part of this exploration involved developing and amalgamating business process models for current practices at UBC, and conducting a 16-month long ethnographic study to extract key transferable characteristics for replicability. The research culminates in a series of comprehensive and generic business process models that illustrate what is required to develop and maintain a Campus as a Living Lab program.

Preface

The author identified and designed the research, performed the research and analyzed the research data. The author is the sole creator of all the material in the thesis other than the following contributions:

Appendix J *Chronological Order of Implementation for the Centre for Interactive Research on Sustainability*

Roughly 60 percent of material was content written in a joint paper by Laura Fedoruk and the author, of which the author wrote approximately 35 percent of the 60 percent (Fedoruk & Save 2012). The joint paper was completed on March 10th, 2012, and the material is part of an unpublished work due to some portions being confidential. The title of the work is “The Centre for Interactive Research on Sustainability Retrospective”, and material was obtained from the section with sub-title “Timeline (Appendix 3)”.

This thesis contains an ethnographic study where meetings of public record were attended to aid with collecting information about the organizational practices, not about individuals or their opinions. A member of the UBC Behavioural Research Ethics Board was contacted and responded that the TCPS Article 2.1 should cover the research.

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List of Abbreviations

APQC	American Productivity and Quality Center
BPM	Business Process Model
CIRS	Centre for Interactive Research on Sustainability
CFI	Center for Innovation
CLL	Campus as a Living Lab
CO_2	Carbon Dioxide
COV	City of Vancouver
FTE	Full Time Equivalent
GHG	Greenhouse gas
IDEF	Integrated DEFinition
ICOM	Input Control Output Mechanism
NGO	Non-Governmental Organization
PMI	Project Management Institute
RFI	Request for Information
RFP	Request for Proposal
UBC	The University of British Columbia
UML	Unified Modelling Language
USI	University Sustainability Initiative
SEEDS	Social Ecological Economic Development Studies

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Thomas Froese: For opening a door for the first commerce student to transfer directly to graduate studies at the University of British Columbia to pursue a dream of making a positive impact on society. The continued support, patience, and perseverance through the many extra-curricular activities I undertook while under your supervision are greatly appreciated. The advice on framing the thesis, structuring the chapters, and on how to continually improve the thesis throughout the writing process proved invaluable.

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Jeffrey Giffin: For contribution to the Academic District Energy System section, including providing the background for the development of the BPMs for Figure 3.15 and Figure 3.16, and responding to e-mails when time was of the essence.

NSERC CREATE and the University of British Columbia Sustainable Building Science Program: For providing funding for this research, and access to a diverse network of faculty and students involved in sustainable buildings. The program also provided connections to find another co-founder of a company – Structured Reports Corp.

Dedication

I dedicate this research to my family and friends.

To my family, Norman and Diana Save, who have provided support through university and have always encouraged me to pursue my dreams. You have always been there when I needed you. You are awesome.

To my friends, who have been asking when I would graduate, I will provide you with a couple hundred page clue. It has been great to people to “decompress” with at times.

Thank you to everyone who supported me through this experience, I greatly appreciated it.

Chapter 1. Introduction

1.1 Introduction

The focus of this research is to explore the contributions of the University of British Columbia's (UBC's) "Campus as a Living Lab" (CLL) program and to develop replicable processes for other universities and municipalities to expand their sustainable practices in similar ways.

CLL is the focus of this research because it is believed by the author to be a practical and effective way to advance the development of new sustainable technologies. The CLL concept assists with the need to develop innovative technologies in order to become more sustainable. There are many steps along this process, including idea creation, implementation, and alteration of mainstream processes. One of these development steps is to pilot new technologies for widespread adoption. Although there are barriers to this, one way to alleviate them is to provide companies with an avenue to test their technologies within the UBC environment—using the University's campus and community itself as a "Living Lab". Through this process, barriers to the implementation of these technologies can be identified and solutions can be developed. It is through these innovative technologies that greater energy conservation, sustainable energy production, water conservation, and larger overall greenhouse gas (GHG) reductions can be realized. An example of one UBC CLL project is the Academic District Energy System implementation which converts the current system from steam to hot water. The result of this conversion will potentially reduce GHG emissions by 22 percent while saving "$5.5 million in annual savings including the cost investment for not reinvesting an aging steam system". (Giffin 2014, UBC 2011d)

The reasons for targeting universities and municipalities to achieve sustainability goals with the CLL concept are threefold.

First, universities and municipalities have the right balance of having control over their respective jurisdictional assets, executives that are fairly accessible to promote the CLL concept, the potential to rapidly initiate organizational change, and for this change to have considerable impact on the environment. They also resemble each other in their governance and infrastructure systems.

Although achieving positive environmental change at a larger scale such as a country can be possible, not all countries have the ambition to actually reach targets they even agree to. In 1997, 38 countries signed the Kyoto Protocol which bound them to reduce their GHG emissions to a weighted average of 4.95 percent below 1990 emissions levels for the period of 2008 to 2012 (United Nations 1998), United Nations 2011b). [1] Although 23 countries were succeeding at meeting these targets as of 2011, one of the world's top ten producers of GHGs was not; namely Canada (United Nations 2011c, United Nations 2011b). [2][3] Additionally, as of December of 2011, Canada withdrew from the Kyoto Protocol all together (United Nations 2011a). There is, however, hope in the grass-roots movements of universities and municipalities to target their own emission reductions with a greater chance of success. UBC and the City of Vancouver (COV) have both charted paths for reaching ambitious goals. UBC is planning to be GHG neutral by 2050, and the COV is aiming to be the greenest city in the world by 2020 (UBC 2010b, UBC 2010c, City of Vancouver 2012). It is an opportune time to provide other universities and municipalities a proven template for improving environmental stewardship.

Second, in comparison to entire countries or provinces, universities and municipalities are smaller and more agile. This ability to change quickly enables these smaller entities to adapt with less bureaucratic hurdles than a federal or provincial structure. Additionally, once a new technology has been proven at the university or municipal scale, it will be easier to replicate at hundreds of other places throughout Canada, and thousands throughout the world.

Third, there is an increased strain placed on global municipal and university infrastructure. This is due to a combination of increasing population, expanding built space, and ageing and/or inadequate infrastructure systems; including water management, energy, transportation, and telecommunications (Rahman & Vanier 2004, Bliss 2007, Li et al. 2010, Dodson 2009).

[1] See Appendix A – Kyoto Protocol GHG Emission Reduction Calculation
[2] See Appendix A – Kyoto Protocol GHG Emission Reduction Calculation
[3] Canada was to be at 94 percent of 1990 emission levels, but as of 2011, it was at 132.9 percent.

This research is aimed to provide a tool for achieving a wide-scale roll out of the CLL structure. Emphasis is placed on addressing problems surrounding the implementation and development of a CLL structure at the university and municipal scale. Two outstanding problems are that 1) there is a vast amount of information for people to digest and develop a shared understanding of in order to create a CLL, and 2) developing business process models (BPMs) in order to create a visual aid to succinctly represent vast information would help, but most of the models do not exist or have not been formalized. In order to overcome these problems the BPMs involved with implementing and developing the CLL format are analyzed at varying levels of granularity in order to gain context into how these processes involving multi-stakeholders work. As case studies involving the UBC CLL are used the initial BPMs in Chapter 3 are developed specific to UBC. Key transferrable characteristics are then identified and implemented into generic templates where modularity will allow for others to use only the applicable components. The two main results of this research are as follows:

- UBC will have BPMs for documenting processes necessary for implementing and developing the CLL
- Generic templates will be created for universities and municipalities to implement and develop their own CLL

1.1.1 Campus as a Living Lab

Campus as a Living Lab was an initiative that arose from the year-long development of the UBC "Sustainability Academic Strategy" which completed in 2009 (UBC 2009b). The main components of the Sustainability Academic Strategy are Campus as a Living Lab (CLL) program, Agent of Change program, and the "University Sustainability Initiative" (USI) organizational unit that governs them. To accompany UBC's goal of eliminating GHG emissions by 2050, a method of achieving it also needed to be developed. The CLL is a collaboration between UBC's Building Operations, external companies, and researchers in an effort to creatively and economically meet operational requirements while striving towards the goal of eliminating GHG emissions; an example of this is the district energy system installation which is explained in Chapter 3.6.2.3. Agent of Change is a way of influencing the larger community to change their sustainability practices. One particular example of the Agent of Change is UBC's requirement to have all requests for proposals (RFPs) submitted to UBC contain a sustainability component worth 20 percent of the evaluation criteria. With thousands of RFPs submitted yearly, this begins to develop a different way of thinking for many companies. More details are discussed in Chapter 3, "UBC's Campus as a Living Lab".

1.2 Motivations

In order to facilitate significant change, it can be quicker and easier to give municipalities and universities the tools to implement the adoption of sustainable technologies rather than to wait for a change in federal or provincial policy. UBC and the City of Vancouver (COV) are two examples how change can be rapidly implemented at a smaller scale. UBC has set a goal to become GHG neutral by 2050 and the City of Vancouver has the goal to become the greenest city in the world by 2020. There are 33 universities and colleges and 400 municipalities with over 10,000 people in Canada.(AUCC 2012) (Canada 2011) The average campus and municipality above respectively expelled approximately 61,855 and 1,166,606 tons of CO_2 equivalent GHGs in 2011. (See Figure 1.1and Figure 1.2) [4,5]

[4] See Appendix B – Average Green House Gas Emission for Canadian Municipalities With Populations Over 10,000 people

[5] See Appendix C – Average Green House Gas Emission for Canadian Colleges and Universities With Populations Over 10,000 people. Not all provinces were used in this sample as not all universities in these provinces had GHG data available. More details are in Appendix C.

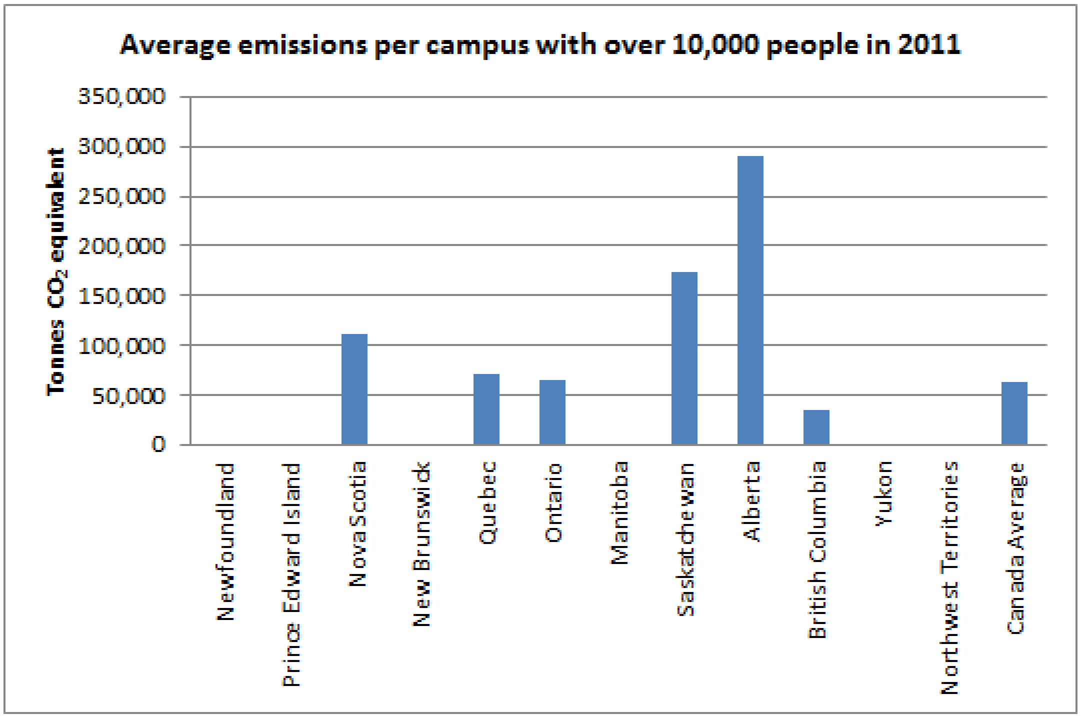

Figure 1: Average emissions per campus with over 10,000 people in 2011

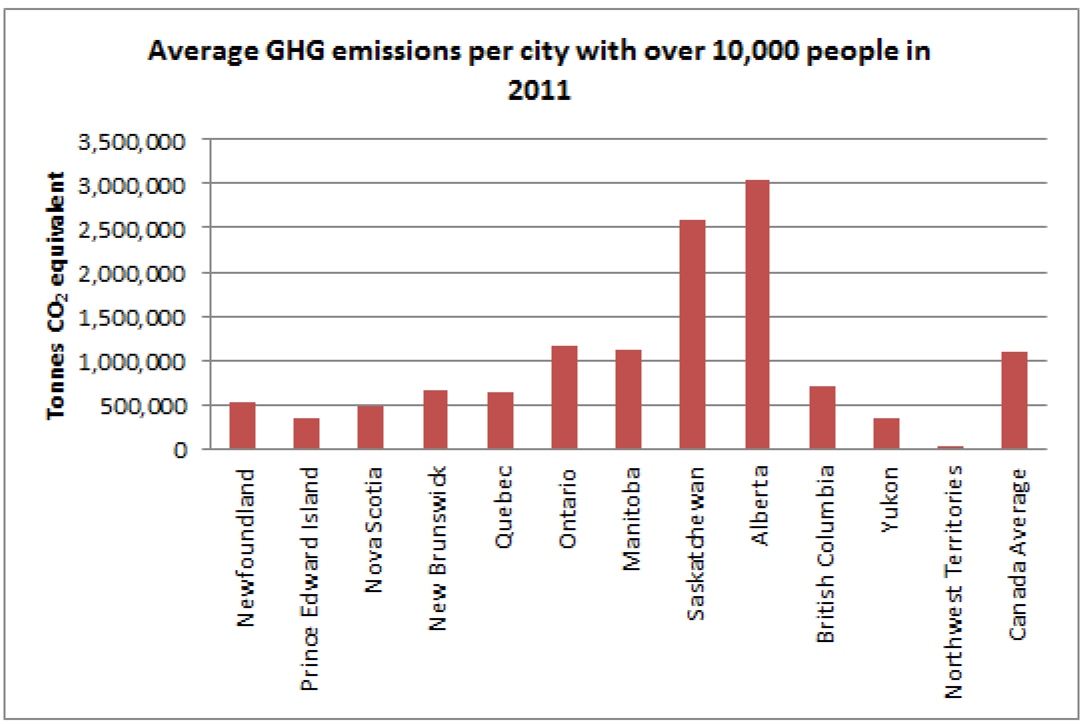

Figure 2: Average GHG emissions per city over 10,000 people in 2011

A sustained ten percent reduction in GHGs for these campuses and municipalities would mean a savings of over 125,781 tons of CO_2 equivalent GHGs per year. The CLL BPMs may not be able to be used by all institutions, but there are likely many that could adopt components of it in order to make a difference. If a “roadmap” via a set of generic templates could be created for these places to implement a CLL structure, then it could create greater environmental stewardship and further green jobs.

Additionally, the CLL is still rapidly evolving with the introduction of many new processes and strategies being adopted from how unsolicited proposals flow through the system to how contractual obligations form. Providing these learnings could help reduce the learning curve for others to adopt similar practices.

With that in mind, it was the author’s goal to assess how much of a success the Living Lab is, how successful it could be, and to create a replicable process for other municipality scale entities to utilize.

1.3 Objectives

1.3.1 Thesis Statement

It is possible to model the CLL with the use of BPM as seen by previous models already created.

Development of BPM templates to form a replicable “roadmap” of the Campus as a Living Lab concept at UBC could facilitate the acceleration of the adoption of sustainable technologies at other universities.

1.3.2 Objectives/Research Questions

The main purpose of this research is to create the foundation of a “roadmap” for other institutions to adopt a UBC CLL strategy. The sub objectives of this research are as follows:

1. Document and model the processes
2. Reconcile the models with emerging processes
3. Create improvements

1.3.3 Scope

The goal of this research is to create generic BPM templates for universities and municipalities to implement and develop their own CLL. Although many processes were developed, not all the BPMs involving the CLL were produced. The BPMs developed underwent many iterations involving input from people experienced in those specific processes, but it is possible that more refinement could be useful. This research is meant to be a starting point for future research to develop as opposed to being the final version of all CLL BPMs. Additionally, this focus of this research was to solely concentrate on the UBC CLL even though there are currently many other examples of Living Labs.

1.3.4 Research Challenges

There are a number of challenges regarding this research.

First, the business processes currently available are detailed, but are not available for all components, or for each layer of granularity; therefore, the whole picture of the CLL is not available. If there was clear documentation for all of the business processes involved with the CLL at UBC, then it would be easier to not only relay this information visually, but to create templates for other institutions, municipalities and other entities to utilize.

Second, in order to gain this data, all the available documented business processes need to be collected from various sources and, if required, standardized. Then missing components and layers of granularity need to be identified and developed. As not all of the components of the CLL have been implemented; such as NGO collaboration, and interdisciplinary sustainability research in the social sciences, this forms a problem and opportunity for designing untested BPMs.

Third, there is similar difficulty to above when creating generic templates for other institutions, municipalities and other entities to implement new processes.

Fourth, not only is it a challenge to have a group gain consensus on the BPM for a current processes, but even more so for something that has not been implemented yet and/or is undergoing continual improvement.

1.3.5 Required Criteria

The UBC CLL specific business process charts will be validated by consulting members of the USI to assess whether or not they accurately demonstrate what is occurring on the CLL at UBC.

1.4 Methodology

A summary of the methodology for this thesis is provided below. For supporting evidence on the research method, please see section 2.6 Ethnographic Research, and section Chapter 4 Analysis of Campus as a Living Lab Activities.

- Literature Review
    - The technology transfer process
        - Provide a background about the technology development and transfer process, barriers, and how the CLL can overcome these barriers
    - Ethnographic research
        - Introduce the techniques available for this type of qualitative analysis
    - Business Process Modelling
        - Summarize attributes of models and determine model type to use
- Business Process Models
    - Gather documentation related to the USI and CLL
        - Archive the history of the development of the CLL
        - Uncover what BPMs have been developed for the CLL
    - Develop BPMs for UBC's CLL
        - Gather documentation to develop BPMs
        - Obtain feedback from USI members on the BPMs developed
        - Integrate the feedback on the BPMs
        - Outline key transferable characteristics
    - Create generic BPMs for other universities and municipalities to integrate a living lab

- Identify key transferable characteristics from the models developed for the CLL
- Integrate these characteristics into generic models

1.5 Thesis Document Readers Guide

Brief summaries of subsequent chapters are outlined below.

Chapter Two outlines the barriers to sustainable technology adoption in campus infrastructure systems with focus on performance, schedule and cost. A background on the increase of available technology, technology readiness levels, the technology transfer process, economic clusters, value chain, the technology adoption curve, and living labs are presented. To provide a foundation for analyzing CLL meetings Chapter 4, an overview to ethnographic is provided. Business process modelling and the various types available are then introduced, and explanations on how these were narrowed down until the final choice of using a modified flow chart is provided. These business process modelling techniques are used to present case studies in Chapter 3 and to illustrate analysis completed in Chapter 4 and Chapter 5.

Chapter Three provides a history on the development of the CLL, a picture of the current state, reasons why the CLL is helpful for industry, and BPMs for evaluating industry collaboration for energy consumption, transmission and generation all in various stages of CLL development; namely the following:

- Centre for Interactive Research in Sustainability (CIRS) – Occupancy was granted on October 16, 2012 (Lin 2012)
- Academic District Energy System – Installation to continue through June 2015 (Engineers 2014)
- Bioenergy Research and Demonstration Facility – Operational as of September 13, 2012 (UBC 2013c)

Key transferable characteristics of these models are identified and recommendations for improvement are provided.

Chapter Four Analyzes the CLL meetings through an ethnographic study. This is achieved by inputting 517 aggregated meeting items from 36 CLL Working Group meetings across eight categories and 40 processes. These processes were either adapted from the frameworks developed by the Project Management Institute and the American

Productivity and Quality Center, or created new specifically for the CLL. From these findings emerged proposed processes from key findings to be implemented in the generic BPMs in Chapter 5.

Chapter Five culminates research from Chapter 3 and Chapter 4 to provide comprehensive business process models to support organizational transformation during implementation of a Campus as a Living Lab structure in other municipality scale entities.

Chapter Six summarizes the thesis dissertation while highlighting the research contribution and areas of potential expansion.

Chapter Seven contains the references.

Chapter Eight provides supporting appendices for the chapters.

Chapter 2. Point of Departure

2.1 Introduction

Through the Sustainability Academic Strategy, UBC is positioning itself to be a world leader in sustainable development. To achieve this goal, the University has crafted the concept of the Campus as a Living Lab (CLL) as an innovation and commercialization hub for sustainable technologies.

The University's March 2012 signing of a memorandum of understanding with Germany's largest applied research institution, Fraunhofer, has increased links with industry as well as opportunities for commercialization (UBC 2012e). Additionally, with the arrival to UBC's of a technology and innovation-savvy President, Dr. Arvind Gupta, the opportunities for continued increase with industry collaboration and student research on CLL projects can be anticipated (UBC 2014f). An example of the opportunity and obligation of Universities for CLL projects is best summed up in UBC's Vice President of Finance's 2012 speech at a Regenerative Neighbourhoods Summit: "Universities have a unique opportunity to serve as centers of experimentation and role models to demonstrate the benefits of sustainable urban design. With 4,500 institutions and 20 million students in the US and Canada, higher education has an obligation to help scale up solutions quickly and disseminate them throughout society" (Ouillet 2012).

By reviewing current CLL practices, this research aims to create generic Business Process Modelling (BPM) templates for universities and municipalities in order to implement and develop their own CLL programs in order to achieve their sustainability goals.

This chapter explores barriers to sustainable technology adoption, particularly relating to campus infrastructure systems. The chapter reviews a number of related issues: the risk associated with performance, schedule and cost; the increase of available technology associated with patents; how technology readiness levels relate to CLL; how taxonomies of the technology transfer process differ; why economic clusters are valuable; how to utilize the value chain; why the technology adoption curve is important to understand for commercialization; and how living labs integrate into this mixture. An overview of ethnographic research is also provided to form a foundation for the analysis described in Chapter 4. As a significant portion of this thesis centers on BPM, the background of BPM and various modelling techniques are explained, and a rationale for using flow charts as the BPM of choice is provided.

2.1.1 Objectives

The main objectives of this chapter are as follows:

- to develop an understanding of the barriers to technology adoption,
- to lay a foundation of knowledge about technology transfer for later reference,
- to explain the framework chosen for this research,
- to provide a background of BPMs and the rationale for selecting flow charts.

2.2 Barriers to Sustainable Technology Adoption in Campus Infrastructure Systems

Even though technology is more prevalent than ever, it is rarely adopted to the level of its potential due to the barriers associated with new technology. This is an important issue in the field of sustainability, where emerging technical solutions that could substantially improve society's sustainability performance are not achieving their potential because of slow rates of technology transfer and adoption. Some of these barriers include problems with identifying and accepting risk, lack of decision-making power, limited human resources for innovative and risky projects, and lack of opportunity to collaborate with society's intuitions (such as universities) to initiate new projects.

There are three main variables associated with new projects that lead to uncertainty around project management risk: performance, schedule, and cost. (Mankins 2009)

- ***Performance*** refers to the reliability and durability of a project that is functioning at an expected rate. Using an example of a bio-energy plant, the client of the project would want the plant to continuously (reliably) function at the expected

Megawatt output (rate) for the expected life under normal operation (durability) of the plant.

- ***Schedule*** is the length of time that it would take from the beginning of conceptual design to the operational start-up at the expected performance.
- ***Cost*** not only includes construction, but commissioning and operating as well.

Figure 2.1 illustrates that, as products mature over their technological lifecycle, their performance increases while their cost and the learning curve associated with their design and use tends to decrease (Kemp 1994). As projects are repeated and learning curves are reduced, schedules for design and construction are compacted. Additionally, industry-wide construction improvements may also occur, which can lead to shorter construction times.

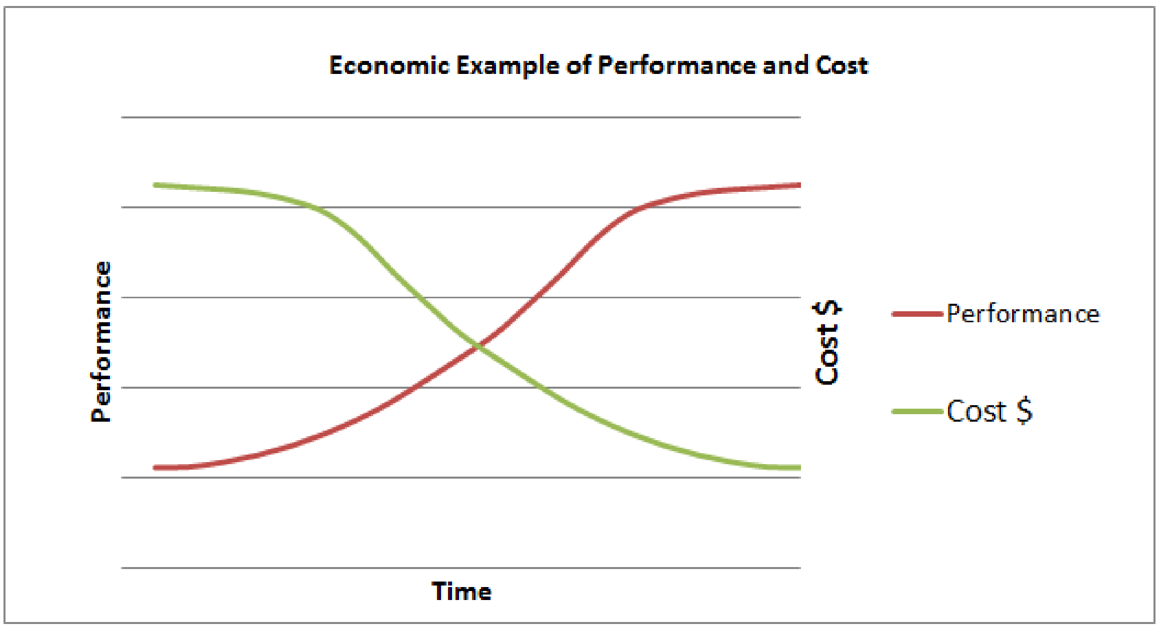

Figure 3: Economic example of performance and cost over time

Decision-making power can become an issue when people in campuses who want to enact change do not know how to do so, since it can be unclear as to who, if anyone, has the authority (Moore et al. 2005).

Additionally, human resources for risky projects on campuses can be limited since younger faculty may have too high of an opportunity cost to be involved (UBC 2009b).

Both tenured and tenure-track faculty agree that those who are pursuing tenure may choose not to be involved in a project, even though they may have the relevant experience. The risk of not publishing as expected, or the strain placed on teaching requirements, is simply too high. Also, campuses may not actually have mechanisms in place to collaborate on large projects. Additionally, many campuses may develop a request for qualifications in order to shortlist candidates on projects that already have preliminary approval, but some may not have processes developed on how to efficiently respond to unsolicited requests.

UBC attempts to de-risk projects by leveraging UBC infrastructure investments with matching funds from industry and the government, by reducing potential liability on carbon taxes, and by using projects to contribute to research and teaching.

In summary, new projects can be hindered by risks associated with performance, schedule, and cost. Additionally, these projects may not be feasible due to lack of available champions with expertise.

2.3 Increase in Available Technology

As the level of world technology increases, it can require fewer resources to develop technology (Parente & Prescott 1994). A recent paper by Fraunhofer indicates that patents are also an indication of knowledge transfer and diffusion (Neuhäusler et al. 2013). As the population increases, technology advancements increase at a rate faster than population growth. This is evident in the rate that patents are applied for and granted in the US.[6] Figure 2.2 shows that patent applications are increasing, although at a decreasing rate of increase.

[6] See Appendix D

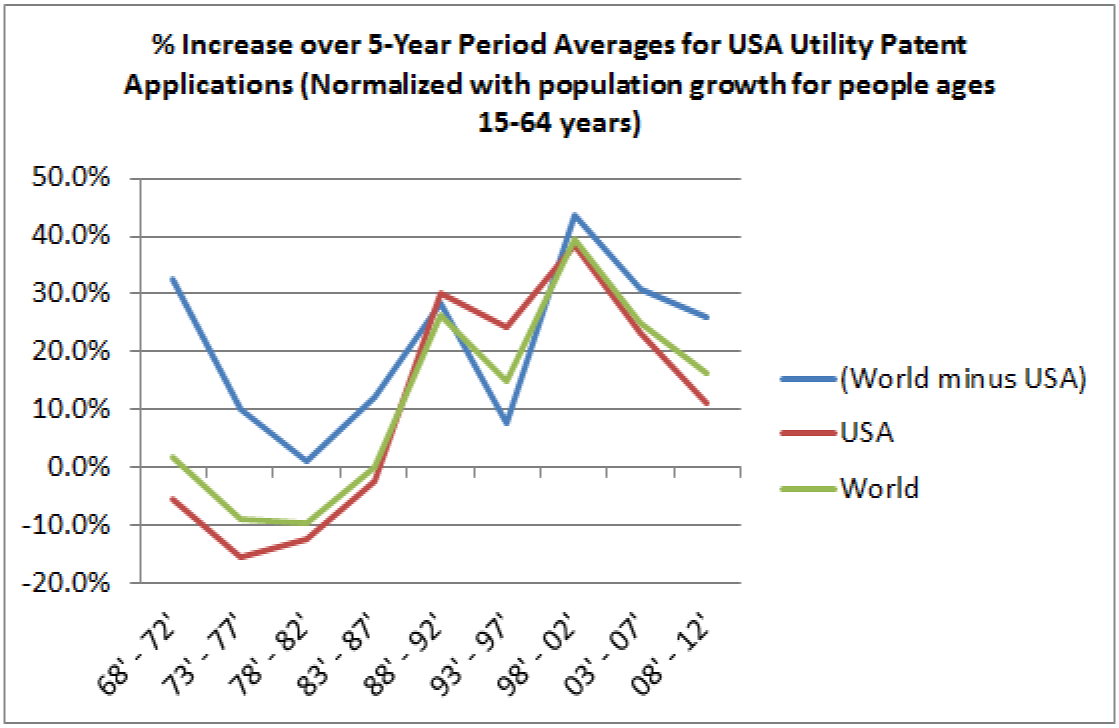

Figure 4: % Increase over 5-year period averages for USA utility patent applications. (Normalized)

In addition to the increase in patents, websites such as Kickstarter provide widespread and rapid accessibility of state-of-the-art devices for others to build their projects upon. [7] There has never been a time when technology has been more accessible and more widespread. This technological advancement in society also brings with it new and innovative sustainable technologies, such as biofuel, smart grid systems, smart HVAC systems, and infrared reflective paints. Although a campus could benefit from cutting-edge technologies that reduce power consumption and GHGs, these technologies are not always adopted. One of the reasons for this could be the variability and uncertainty surrounding the performance, schedule and cost of new technology.

To summarize, technology accessibility and development is increasing, which could lead to more widespread adoption if the inhibiting barriers were reduced.

[7] From the launch of Kickstarter on April 28th, 2009 through April 4th, 2014, an equivalent of $1,066,901,944 US dollars had been pledged to Kickstarter projects (Chen 2010, Kickstarter 2014). Additionally, 59,823 projects have been successfully funded (Kickstarter 2014).

2.4 Technology Development and Transfer

2.4.1 Introduction

Although there is a wide array of definitions of technology transfer, a new definition was adopted for this research and is provided below..

Technology Transfer: The transfer of knowledge, software, or physical technology to aid with the evolution of mechanisms required to perform a technological function.

The following sections outline related concepts such as technology readiness levels, technology transfer processes, clusters, value chains, technology adoption, and technology investments.

2.4.2 Technology Readiness Levels

Unrecoverable mistakes can occur when a technology is adopted before it is ready. Technology readiness levels were thus developed by NASA (Mankins 1995). These levels help assess how mature a technology is and to allow measurement of this maturity against other technologies. The nine stages of maturity in the model are listed in Figure 2.3 with citations from the 1995 white paper by Mankins.

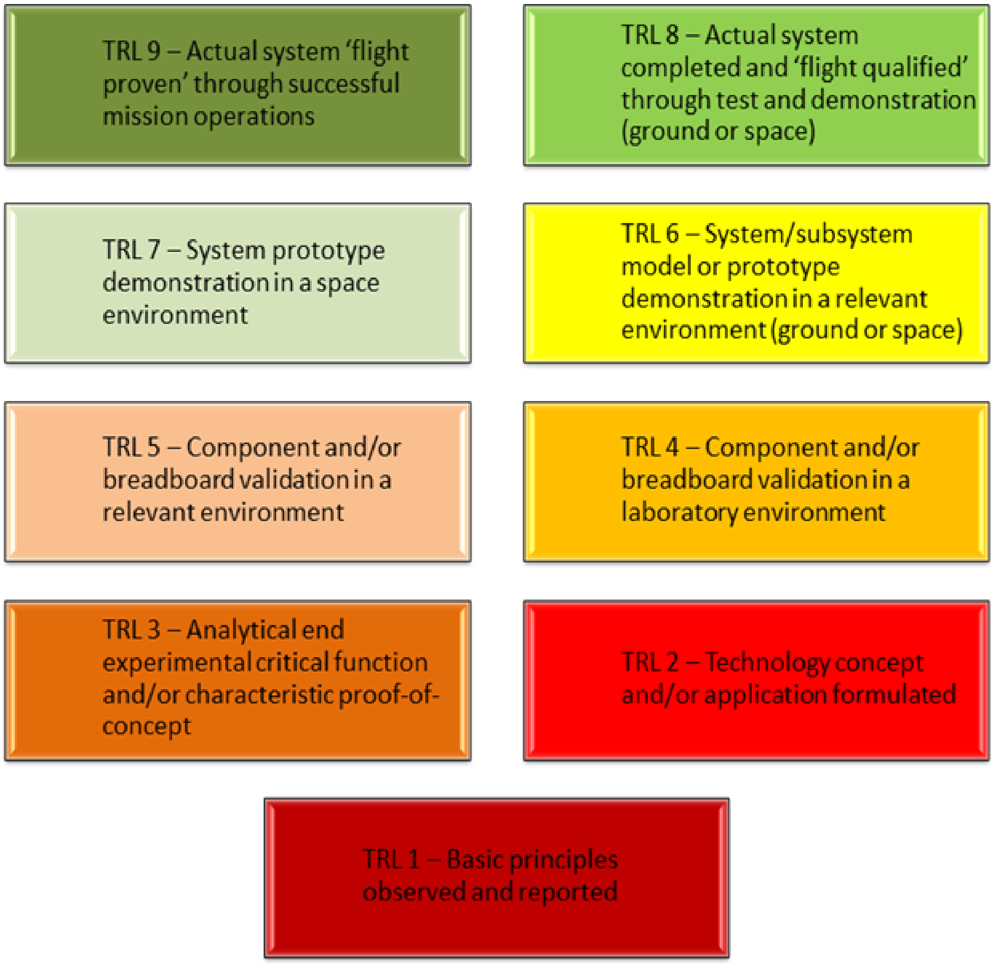

Figure 5: NASA Technology readiness levels (Mankins 1995)

As technology readiness levels have been modified for other purposes, such as investment readiness for a start-up, this approach was also taken to develop a model more applicable to a university (Blank 2014). In order to do so, the technology readiness levels six through nine (developed by Mankins, 1995) have been changed to take into account questions that have been raised about projects at past CLL Working Group meetings regarding technology. These changes are shown in Figure 2.4 below.

UBC's CLL program tends to accept projects that lie between the technology readiness levels five through eight. This is mainly due to the CLL desire to pursue technology that is ready to be commercialized for the first time, or to open up the Canadian market to technology that may exist elsewhere, which is how UBC intends to help with the technology transfer process.

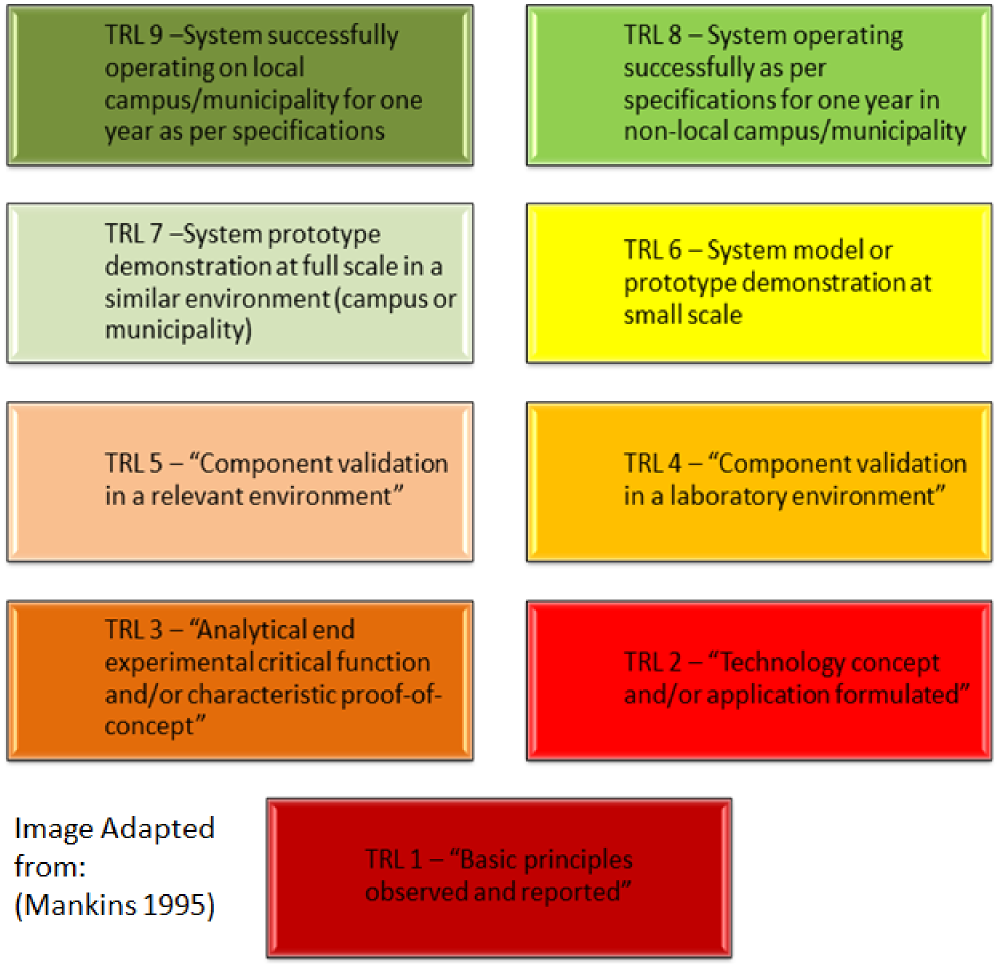

Figure 6: Campus as a Living Lab technology readiness levels

In summary, technology readiness levels can reduce the potential for untimely errors by providing an assessment tool to help guide when technologies should be implemented.

2.4.3 Technology Transfer Process

Rogers et al. (2000) provides five methods through which technology transfer from university research occurs: spin-off companies, licensing, publications, meetings, and cooperative research, and development agreements (Rogers et al. 2001). Rogers et. al. noted that "spin-offs are a particularly effective means of technology transfer, leading to job and wealth creation" (Rogers et al. 2001). While the CLL program may not create as many spin-offs, it facilitates the use of the campus as a testing ground for the commercialization of new technologies. The process of lending the campus as a testing ground allows companies to potentially develop new corporate branches and to build capacity to further develop and sell newly proven technologies. These can also facilitate competition to develop similar technologies in an effort to compete in similar markets. In the case of UBC's CLL, cooperative research and development agreements are forged in a way that companies may be able to maintain their intellectual property while utilizing UBC resources.

Adopting technology from abroad in order to provide a method of inward technology transfer supports the "creation and development of a skilled production and technical labour force" (Mowery & Oxley 1995). This occurs with the CLL when university researchers and staff contribute to the development, implementation, and operation of the technology. Additionally, when companies create local subsidiaries or branches, these provide another avenue for inward technology transfer to occur.

When investigating technology transfer, it is possible to look at it from two different types of regimes: science based and development based (Gilsing et al. 2011). Table 2.1 outlines these differences. The method of technology transfer is dependent upon the regime that the technology has evolved from. Using consultancy for technology transfer for a science based regime means to use "academic staff [for] the transfer of more tacit knowledge" (Gilsing et al. 2011). Gilsing et al. tested a number of hypotheses by collecting 575 valid responses (Gilsing et al. 2011). The results of these tested hypotheses are provided in the following assertions.

Table 1: "Taxonomy of two different types of technology regimes" (Gilsing et al. 2011)

	Key characteristics and its importance to industry			Key characteristics of transfer process	
	Degree of differentiation of knowledge base	**Nature of scientific knowledge**	**Importance of scientific knowledge to industry**	**Intensity of interaction**	**Dominant mechanisms employed**
Science-based Regimes	Low (stand-alone knowledge: relatively independent pieces of knowledge)	Basic knowledge	High to very high	Low to medium (division of labour model)	Publications, patents, consultancy, spin-offs
Development-based Regimes	High (systemic knowledge: relatively interdependent pieces of knowledge)	Applied knowledge	Low to medium	Medium to high (participation to application)"	Joint R&D programs, participation in conferences, regional / professional networks, inflow if PhD graduates

For both types of regimes, there are barriers that can seriously inhibit technology transfer: "risk of information leakage, risk of a conflict of interest, and scientific knowledge being too general to be useful for firms" (Gilsing et al. 2011).

Furthermore, there are specific barriers that apply to the different regimes. The science-based regimes have more of a barrier from "high costs of managing joint research projects" and development-based regimes have more of a barrier from "being too theoretical for a firm" (Gilsing et al. 2011).

While there are methods of technology transfer and potential barriers, it is also important to understand the motives that each party may have in the transaction (Siegel et al. 2003). Table 2.2 outlines some of these motives.

Table 2: "Characteristics of University Industry Technology Transfer Stakeholders" (Siegel et al. 2003)

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Organizational Culture
University scientist	Discovery of new knowledge	Recognition within the scientific community	Financial gain and a desire to secure additional research funding	Scientific
Technology transfer office	Works with faculty and firms / entrepreneurs to structure deal	Protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firm / entrepreneur	Commercializes new technology	Financial gain	Maintain control of proprietary technologies	Entrepreneurial

While there is potential for motives to conflict between stakeholders, there is also potential for these motives to agree, given the right alignment of technology transfer processes.

In brief, the characteristics of the transfer process differ between science-based and development-based regimes, with the former preferring "publications, patents, consultancy, and spin offs", and the later preferring "joint R&D programs, participation in conferences, regional/professional networks, and [an] inflow of PhD students" (Gilsing et al. 2011). Within these regimes, there are also three main stakeholders for university knowledge transfer: "university scientists, technology transfer office, and firms" (Siegel et al. 2003). All of whom have varying levels of financial motivation.

There is an opportunity for industry to begin to agglomerate in an area where there is potential to develop their technology, such as in a CLL context. The impact of such agglomeration is explored in Section 2.4.4, Economic Clusters.

2.4.4 Economic Clusters

Porter defines a cluster as "a geographically proximate group of interconnected companies, suppliers, service providers and associated institutions in a particular field, linked by externalities of various types" (Porter 2003). Some examples of these include wine in California, technology start-ups in Silicon Valley, and finance in New York.

“Untangling the paradox of location in a global economy reveals a number of key insights about how companies continually create competitive advantage” (Porter 1998). Leveraging the value chain model, clusters provide access to highly trained employees, the ability to leverage technology transfer for technology development, and suppliers for procurement. “Even when some inputs are best sourced from a distance, clusters offer advantages. Suppliers trying to penetrate a large, concentrated market will price more aggressively, knowing that as they do so they can realize efficiencies in marketing and service” (Porter 1998).

“Regional studies have [also] highlighted at least three distinct drivers of agglomeration: knowledge spillovers, input-output linkages and labor market pooling” (Delgado et al. 2010). Additionally, “industries participating in a strong cluster register higher employment growth as well as higher growth of wages, number of establishments, and patenting” (Delgado et al. 2011).

In short, economic clusters provide a number of benefits to the local region and companies alike.

A CLL environment would be able to assist with knowledge spillovers and labour pooling and, possibly, input-output linkages. This would also translate to improving participating firms’ competitive advantage through these aspects of the value chain.

2.4.5 Value Chain

Analyzing a value chain enables a firm to determine how much additional value is generated by the firm’s activities and what costs are incurred for each activity. “Activities also provide the basic tool for examining the competitive advantages or disadvantages of diversification” (Porter 2008). These activities also have links to the environment: inbound and outbound logistics as well as operations have the greatest environmental impacts. Inbound and outbound logistics have transportation impacts, such as emissions and congestion (Porter & Kramer 2006). Operations are the largest culprit with the following impacts:

- “emissions and waste,

- biodiversity and ecological impacts,
- energy and water use,
- worker safety and labour relations,
- hazardous materials" (Porter & Kramer 2006).

Figure 2.5 shows how these activities interlink and are classed as primary and support activities.

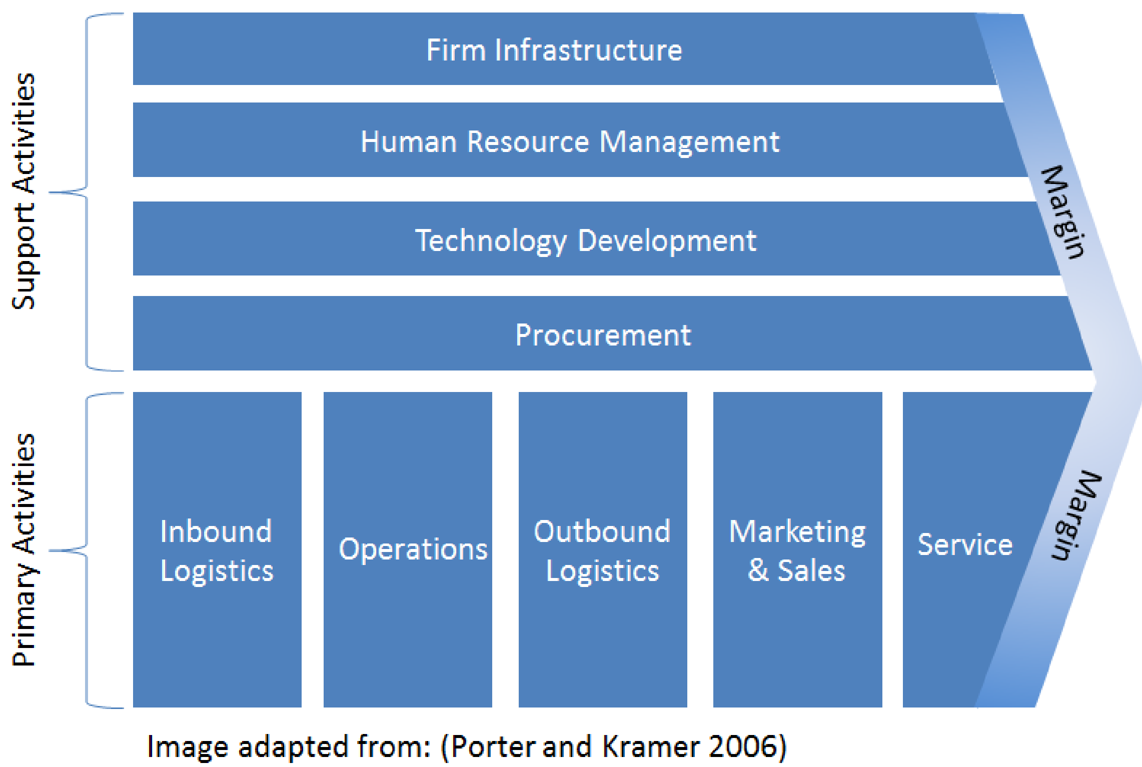

Figure 7: Value Chain

The CLL targets operations while assisting other companies with their technology development and demonstrating their technology for commercialization. In this way, both entities are improving their value chains. Branching off of their work regarding the value chain, Porter and Kramer also developed a connection between competitive advantage and social issues, as illustrated in Figure 2.6 (Porter & Kramer 2006).

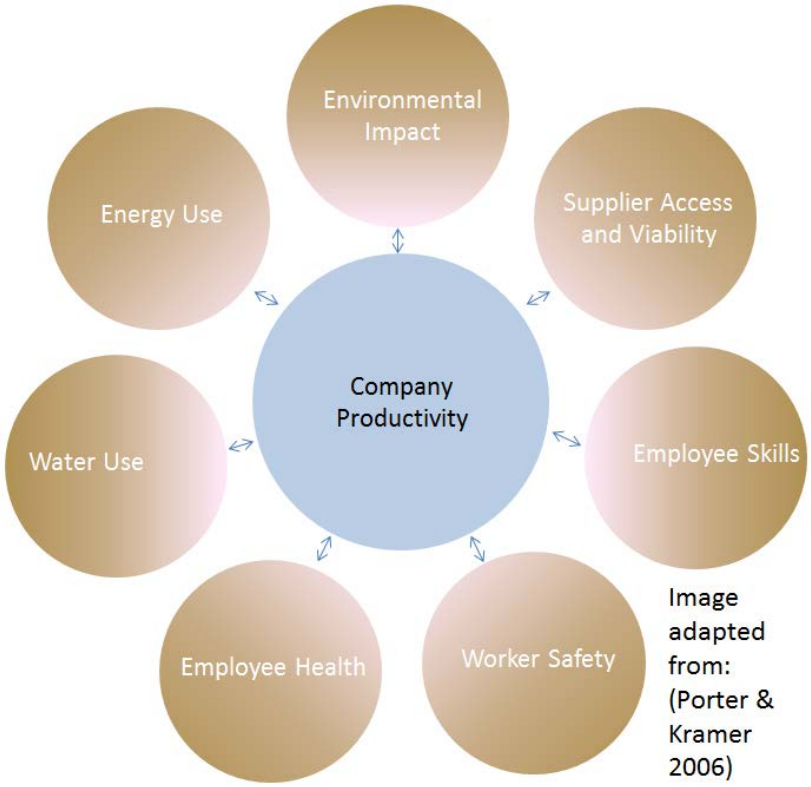

Figure 8: Connection between competitive advantage and social issues

To summarize, the value chain enables a firm to determine how much additional value is generated by the firm's activities, what costs are incurred for each activity, and provides a method of analysis for improvement. There are a number of activities that contribute to environmental impacts, with the main activities being operations, followed by inbound and outbound logistics.

2.4.6 Technology Adoption Curve

The concept commonly known as the "technology adoption curve" started as an adoption curve with five categories: innovators, early adopters, early majority, majority, and non-adopters (Bohlen & Beal 1957). This was later integrated with Moore's (1991) idea of a "chasm" that prevented technology from being adopted by the early majority. Table 2.3 outlines the differences between the five categories. Innovators obviously adopt new technology easily and laggards do not, but less obvious is that there is a "chasm" between the early adopters and the early majority.

Table 3: Technology adoption life cycle category differences (Moore 1991)

Category	Pursuit of Technology	Information Required to Make a Purchase	Reason for Business Purchase
Innovator	Aggressive	New properties of devise	Love of technology
Early Adopters	If there is a strong match	Closeness of a match	Change Agent – to get a jump on competition Visionary
Early Majority	If it is practical	Well established references – want to ensure no disruption to organization	Productivity Improvement
Late Majority	Need support	Established standards	Productivity Improvement
Laggards	Fine with what they have	Will only purchase if deeply imbedded in a familiar technology	Necessity

This chasm is illustrated in Figure 2.7. "The early majority and late majority fall within one standard deviation of the mean, the early adopters and laggards within two, and … about three standard deviations from the norm, are the innovators" (Moore 1991).

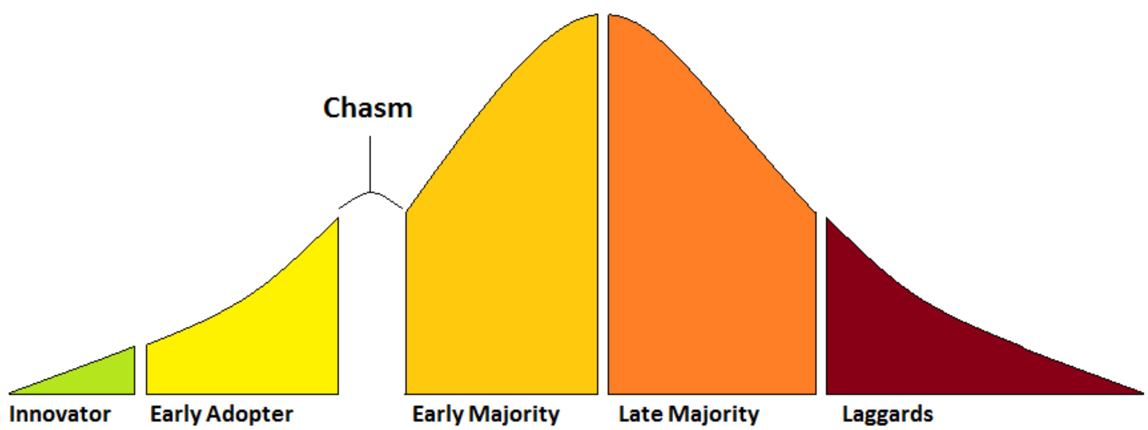

Figure 9: Technology adoption curve (Moore 1991)

While it is relatively easy to engage the innovators and then branch to the early adopters, engaging the early majority is fairly difficult due to a chicken-and-egg dilemma. As it turns out, "the only suitable reference for an early majority customer is another member of the early majority, but no upstanding member of the early majority will buy without first having consulted with several suitable references"(Moore 1991).

In addition to these problems listed with the early majority, companies also face a range of other potential barriers preventing the adoption of technology that a university could provide assistance with. These include further refinement of the product, commercially proving the technology for the first time, providing 3rd party verification for already proven technology that may have other 3rd party verification, providing local 3rd party verification at the project scale required, and assisting with local policy changes.

One of the goals of the CLL is to overcome barriers to technology adoption and bridge this “chasm” by becoming that “reference point” for other early majority customers to adopt the technology. Since UBC can be considered a typical campus, other typical campuses can assess technologies proven at UBC and consult numerous players involved in the implementation and operation of the technology that they are interested in. This way, institutions that fall in the early majority category will have a large number of reference points to consult for a given technology before implementing it. Since the early majority is “highly reference-orientated and highly support-orientated”, the ability to speak with not only the company that produced the technology, but also the groups who constructed, commissioned, and operate the technology is very valuable.

To conclude, technology adoption curve illustrates five types of technology adopters: innovators, early adopters, early majority, late majority, and laggards. There is a significant hurdle to overcome when crossing from the early adopters to early majority. Through the use of a living lab at a similar institution to others, technology can be proven to help bridge this hurdle.

2.4.7 Living Labs

After searching through a number of journals and Google Scholar, the earliest documented reference of the term “Living Laboratory” for technological development was found to be in 1999 by a group from Georgia Institute of Technology. The written reference is now found in conference proceedings for the second annual workshop for “CoBuild’99” held at the Carnegie Museum of Art in Pittsburgh (Kidd et al. 1999, Ståhlbröst 2008).

Living labs are a venue for societal, environmental, and economical benefits to be explored through development and demonstration of projects. Living labs can also be conduits for the reduction of research silos through trans-disciplinary collaboration initiated by the diverse networks of multi-stakeholder governance teams. They are also used for a variety of uses including infrastructure, work space, and information technology among other uses (UBC 2013a, CMU n.d., Ståhlbröst 2008).

The focus of the reminder of this section is on how university living labs support the commercialization process. They assist this area due to the overlapping of living labs' with technology adoption, technology readiness, and technology investments (Lemke 2009, Whittaker 2013). This is illustrated in Figure 2.8.

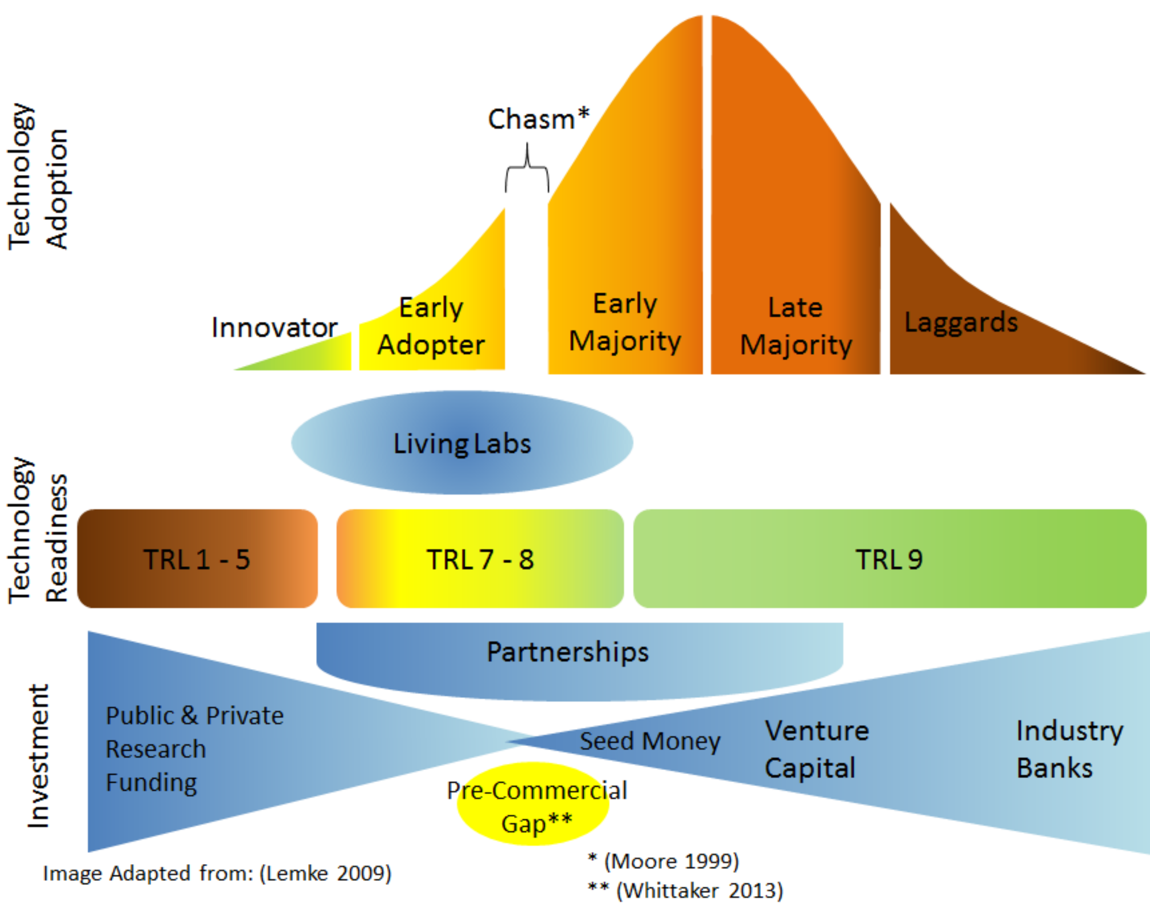

Figure 10: Intersection of Living Labs with technology adoption, technology readiness, partnerships, and investment

As Figure 2.8 illustrates, living labs contribute at the very stage where it is most difficult for technology to be adopted, where technology is ready to be demonstrated, and where there is a potential need for funding assistance. There is potential to leverage university, industry, and government funds together to increase the economic attractiveness of projects. There is also potential to aid with supporting economic clusters through technology transfer, which can also improve the value chain.

Froese and Rankin (2009) discovered through an analysis of public policy in construction of 15 different countries that an "impact on innovation was achieved through: promotion of long term value and performance; emphasis on performance versus prescription; local programs based on access to technologies; promotion of collaborations; and pre-market evaluations of products and processes" (Froese & Rankin 2009). This is, in part, what was assessed before living labs are adopted at UBC. [8]

To conclude, university living labs can help with providing a test bed for developing and demonstrating projects. This also provides an avenue for the financing of a demonstration project that can lead to commercialization of the technology to be adopted by others. Additionally, given a multi-stakeholder governance model, they can also foster trans-disciplinary collaboration.

2.4.8 Summary

This section touched upon technology readiness levels, the technology transfer process, economic clusters, the value chain, the technology adoption curve, and living labs. These help to provide an insight into the technology development and transfer process.

Technology readiness levels can reduce the potential for untimely errors by providing an assessment tool to help guide when technologies should be implemented. In order to develop this technology to higher point of "readiness," it is valuable to understand how technology can progress through university technology transfer.

The characteristics of the transfer process differ between science-based and development-based regimes, with the former preferring "publications, patents, consultancy, and spin

[8] See Section 3.4.1.2 and Appendices 8.7 and 8.8 for details on how these items are evaluated at UBC through the review of a slide deck and spider chart.

offs”, and the later preferring “joint R&D programs, participation in conferences, regional/professional networks, and [an] inflow of PhD students” (Gilsing et al. 2011). Within these regimes, there are also three main stakeholders for university knowledge transfer: “university scientists, technology transfer office, and firms” (Siegel et al. 2003), all of whom have varying levels of financial motivation. This transfer process and the building of industry to support it could help build an economic cluster.

Economic clusters provide a number of benefits to the local region including access to highly trained employees, the ability to leverage technology transfer for technology development, and suppliers for procurement. Companies that are part of an economic cluster that will see higher wages, increased employment, innovation, and improved competitive advantage. Additionally, a CLL environment would be able to assist with knowledge spillovers and labour pooling and, possibly, to input-output linkages. This would also translate to improving participating firms’ competitive advantage through these aspects of the value chain. The firms participating in a cluster can improve their value chain to increase their competitiveness.

The value chain enables a firm to determine how much additional value is generated by the firm’s activities, what costs are incurred for each activity, and provides a method of analysis for improvement. Furthermore, there are a number of activities that directly link to environmental impacts, with the main activity being operations, followed by inbound and outbound logistics. Understanding these linkages and impacts enables firms to make decisions on whether to make improvements or not.

The technology adoption curve illustrates that there is a significant hurdle to overcome when crossing from the early adopters to early majority. This is because “the only suitable reference for an early majority customer is another member of the early majority” (Moore 1991). Through the use of a living lab at a similar institution to others, technology can be proven to help bridge this hurdle.

Finally, university living labs can help provide a test bed for developing and demonstrating projects. This also provides an avenue for the financing of a demonstration project that can lead to commercialization of the technology to be adopted by others.

Additionally, given a multi-stakeholder governance model, they can also foster trans-disciplinary collaboration.

2.5 Knowledge Diffusion

2.5.1 Introduction

As the aim of this thesis is to provide a method of diffusing knowledge created in the CLL, a brief context on the types of knowledge and methods of creation is provided. This context includes themes pertaining to tacit versus explicit knowledge, knowledge modes in relation to heterogeneous and homogenous growth, and helices that have branched off of these modes for a broader understanding of stakeholders involved. Expanding upon these, various general barriers and enablers to knowledge diffusion are discussed.

This foundation will also aid as a double check that the type of BPM selected in Section 2.7.2, Model Evaluation, will assist with the type of knowledge transfer required.

2.5.2 Tacit (Implicit) versus Explicit Knowledge

Tacit knowledge is "know how"; attempting to distil this knowledge would inevitably omit key components, whereas explicit knowledge is "formal and systematic" (Nonaka 1991). There are four methods to convey (transfer) this knowledge: tacit to tacit, explicit to explicit, tacit to explicit, and explicit to tacit (Nonaka 1991). Tacit knowledge is more difficult to translate into explicit knowledge and can require a greater degree of expertise in achieving something that could be useful to others. This is also one of the types of knowledge transfer that is attempted in this thesis.

The UBC CLL assumes the continuous role of developing tacit knowledge and transforming it into explicit knowledge by developing procedures, methods of evaluation, and metrics for success. It is important for organizations to understand that this is a continuous process, and that a state of "perfection" will never be achieved.

2.5.3 Knowledge Modes 1 – 3 and Helices 1 - 5

As knowledge systems progress, the methods to diffuse the information become simpler and more abundant at the same time that more systems for knowledge creation are introduced, which brings more complexity to the picture. This section introduces knowledge modes and helices to describe increasingly complex forms of knowledge creation.

Mode 1: Knowledge is created and diffused within a specific discipline for largely academic interest and is homogenous in nature.

Mode 2: "Knowledge is produced in context of an application", it is trans-discipline and heterogeneous in nature (Gibbons et al. 1994).

It could be conceived that society's current state of knowledge creation is actually in flux between mode 2 and mode 3. The definition of mode 3, as follows, encourages a more acute awareness of the direction that society is heading.

Mode 3: "People, technology, and culture" become the "knowledge production system" in a "top-down policy-driven" and "bottom-up entrepreneurship-empowered" systems thinking environment to "catalyze creativity, trigger invention, and accelerate innovation across scientific and technological disciplines, public and private sectors" (Carayannis & Campbell 2011).

Branching off of these modes, the term "helices: was coined to portray the stakeholders involved in the creation of new knowledge. As more helices overlap, a systems-thinking approach to knowledge creation also progresses. This progression is illustrated in Figure 2.9. As each additional helix is introduced, it overlaps with all those prior; which, in turn, results in a broader perspective for knowledge creation.

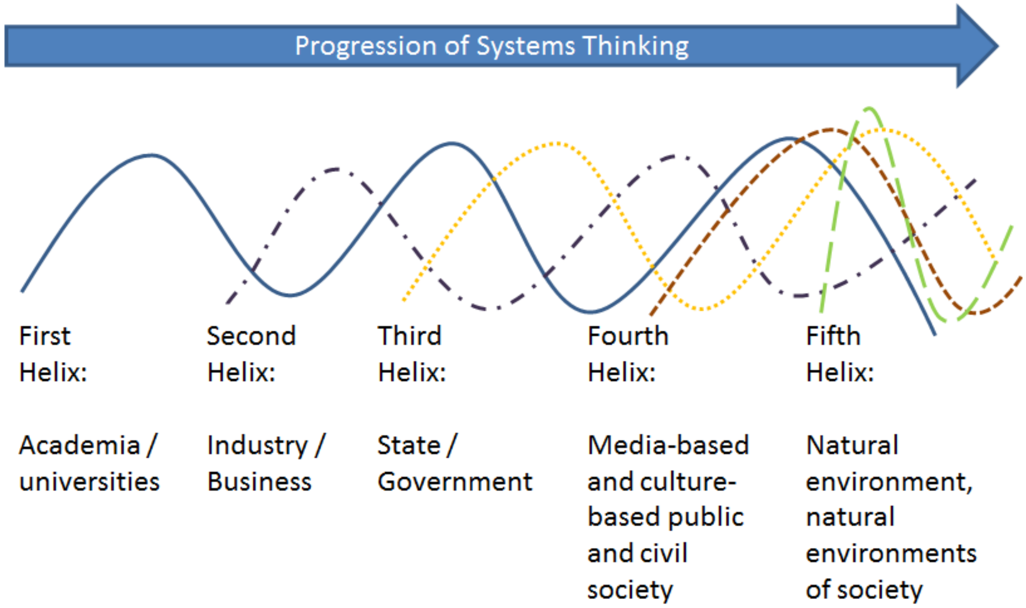

Figure 11: Knowledge creation helices and systems thinking development (Carayannis & Campbell 2011)

This depiction of these states of knowledge creation shows a progression from thinking about a project only within the confines of a university toward a broader understanding of society and the impacts of people and new technology.

In summary, knowledge modes and helices offer a method of understanding knowledge creation systems and the layering of involvement with academia, industry, government, public and civil society, and the natural environment.

2.5.4 Barriers to New Knowledge Diffusion in Organizations

There are two categories of barriers for new knowledge creation and diffusion: individual and organizational. Individual barriers include “limited accommodation” and “threat to self-image”, with the following definitions adapted from Krogh et al. (2002):

Limited accommodation: When people are introduced to a new sensory input, they attempt to compare and assimilate this to a previous experience. If there is no previous experience to associate this new sensory input, then an individual will try to include this in their experience. When the inclusion of a new experience with no reference point is too challenging, then a barrier arises.

Threat to self-image: Being presented with contradictory evidence that challenges one's own knowledge base or being placed in an environment with people of different expertise can result in people "mentally checking out". This occurs since people generally do not want to be wrong or may not want to point out faults in others, and may be uncomfortable working with people with different skillsets.

There are also four organizational barriers that can create difficulty in diffusing knowledge in organizations (Von Krogh et al. 2000):

The need for a formalized language: Unfamiliar terms might be used when converting personal tacit knowledge to explicit group knowledge. This can create confusion and reduce the ability for everyone to engage equally in the learning experience.

Organizational precedents: Stories surrounding how things worked (or did not work) in the past at the organization, or similar examples brought in from other organizations, could prevent people from developing new knowledge that would deviate from the norm.

Procedures: Employees can lose motivation from creating new knowledge if it does not adhere to procedure. They are "rarely motivated to fight an ineffective procedure because they know that the more diligently they follow it, the less likely they are to experience the negative consequences of bucking the system—such as acquiring a bad reputation." (Von Krogh et al. 2000)

Company vision: If an idea is not thought to conform to the company vision, even if it is a great idea, it may never be developed.

Table 2.4 outlines how the BPMs created for this thesis could allow for reduction in these barriers.

Table 4: Potential Methods of Barrier Reduction for New Knowledge Creation Integrated into this Thesis

	Potential Methods of Barrier Reduction
Individual Barriers	
Limited Accommodation	CLL specific BPMs create a base of reference for others to be more receptive of such a program
Threat to self-image	Documentation is referenced as a starting point, rather than a strict model to follow, which may allow greater input from others
Organizational Barriers	
The need for formalized language	A formalized language base is presented for talking about CLL
Organizational Precedents	A story is built with the UBC CLL as an organizational precedent
Procedures	The procedures provided are meant to be adapted to meet the needs of other organizations and should be continuously improved, this could reduce the notion that they cannot change
Company Vision	The notion that the vision should be grand and allow for

Validation for whether or not these BPMs actually reduce these barriers is beyond the scope of the thesis.

Beyond the organizational difficulties, there are also inter-organizational difficulties in diffusing knowledge that is "hypothesized to affect the level knowledge ambiguity in alliances. [These are] tacitness, asset specificity, complexity, experience with competence, partner protectiveness, cultural distance, and organizational distance between partners" (Simonin 1999).

To summarize, there are also personal barriers (personal accommodation and threat to self-image), and organizational barriers (the need for a formalized language, organizational precedents, procedures, and company vision) that prevent new knowledge from being created and diffused.

While there are barriers to knowledge transfer, some solutions have been provided, and Section 2.5.5 provides some additional methods of securing the creation and diffusion of knowledge.

2.5.5 Enablers to New Knowledge Diffusion in Organizations

Although there are barriers to the diffusion of new knowledge, there are also enablers; these include instilling a knowledge vision, managing conversations, mobilizing activists, creating the right context, and globalizing local knowledge (Von Krogh et al. 2000):

Instilling a knowledge vision: This is a guide for the organization to understand what knowledge they should be creating. The CLL is still developing a vision for this.

Managing conversations: The goal here is to provide a platform of openness, encouragement to participate and listen, and to be polite. For the UBC CLL, this was partly achieved by the forming, storming, norming, and performing stages of group development.

Mobilizing Activists: By supporting and mobilizing the activists who produce new knowledge and coordinate initiatives, the organization is able to further advance the creation of new knowledge. The UBC CLL has a Strategic Partnerships Office, which creates a significant amount of new documentation and processes and initiatives which are supported by the CLL Working Group.

Creating the right context: There are four kinds of interaction for developing this space: originating, conversing, documenting, and internalizing. Once new (and useful) knowledge is created, it needs to be shared and internalized within the company. UBC CLL achieves this by presenting new concepts for discussion and comments, iterating these concepts until they are accepted, then internalizing the results in the form of a document. One example of this is the spider chart in Appendix I Spider Chart Criteria.

Globalizing local knowledge: Once knowledge is created, it should be shared with an effective mechanism within the company. In the case of the UBC CLL, this is mostly achieved through the use of a SharePoint intranet site and documentation sharing at meetings.

In addition to these enablers within organizations, there are also enablers for knowledge transfer between organizations. In reference to solutions for the last barriers listed in Section 2.5.4, it has been “shown that as companies deploy resources dedicated to knowledge transfer from their alliances, smaller effects of tacitness on ambiguity occur and in conjunction with a drop in the effect of complexity, cultural distance, and prior experience on ambiguity" (Simonin 1999).

In brief, there are various methods that aid with knowledge creation and resources should be invested in achieving all of these if sharing, further development, and potentially capitalizing on this knowledge interests the organization. These enablers could be used as tools for UBC and other institutions to further develop the CLL concept.

2.5.6 Summary

There are two types of knowledge: tacit and explicit, with the former being the more difficult to convey. Knowledge modes and helices were introduced to offer a method of understanding knowledge creation systems and the layering of involvement with academia, industry, government, public and civil society, and the natural environment. Barriers that prevent new knowledge from being created and diffused were introduced, which included personal barriers (personal accommodation, and threat to self-image), and organizational barriers (the need for a formalized language, organizational precedents, procedures, and company vision). Potential barrier reduction methods for each of these in relation to this thesis were also introduced as a means to improve the chance of ideas from this thesis being adopted. Furthering the chance of successful knowledge creation and diffusion, specific enablers (instilling a knowledge vision, managing conversations, creating the right context, and globalizing local knowledge) were provided as tools for use in further developing the CLL within UBC and beyond.

2.6 Ethnographic Research[9]

2.6.1 Introduction

"Arguments which put forward the need to consider context in research tend to support qualitative techniques" (Harvey & Myers 1995). However, there is a range of principle methods available including: action research, case studies, interviews, life history

[9] Ethnographic research conducted in this thesis involved collecting information about the operations of UBC's "Campus as a Living Laboratory" (CLL) program, which involved information about the organizational practices and processes. The only information collected was facts on actual events, not about personal opinions. Chapter 5 includes more detail on the research conducted.

research, participant diaries, structured observation, and ethnographic research (Greener 2008). Among these, ethnographic research is most focused on a descriptive study to capture "a group's customary ways of life" (Zaharlick & Green 1991). "These include ways of:

- accomplishing the everyday events of daily life;
- interpreting actions and interactions;
- establishing, checking, interpreting, modifying, suspending, and re-establishing norms and expectations for daily life adhered to by members of the group;
- the nature, range, and role of artifacts (i.e. materials, items of culture such as books, written materials, visual documents, buildings);
- establishing and limiting the range of possible action;
- constructing the roles and relationships that exist within the group;
- defining the rights and obligations that membership in the group places on members;
- developing the cultural knowledge required for appropriate participation;
- and exploring how particular cultural spaces function within the social group (e.g. literacy, formal schooling, child care, ability, grouping)" (Harvey & Myers 1995).

The research conducted in this thesis required an understanding of what was discussed at CLL meetings to create business process models, knowing what changes occurred over time to adjust the models, and suggesting improvements upon these models. Since ethnographic research provides a range of attributes that complement the research required for this thesis, it was decided to explore this methodology.

Ethnographic research immerses the researcher amongst the people or groups they intend to study. "The ethnographer enters into a social setting, and gets to know the people involved in it; usually, the setting is not previously known in an intimate way. The ethnographer participates in the daily routines of this setting, develops ongoing relations with the people in it, and observes all the while what is going on" (Emerson 1995). It is also carried out in a variety of disciplines including anthropology, sociology, and psychology, among others.

In general, ethnographic research through observation and field notes involves self-reflection, selection of a research paradigm, building a local theory, collecting data (with field notes), coding data, and analysis (Schensul et al. 1999, Emerson 1995). Additionally, ethnographic research can capture “a group’s way of life” by immersing the researcher in the environment through participant observation (Zaharlick & Green 1991).

2.6.2 Gaining Access to Data

There are two methods for collecting ethnographic data: interactive and non-interactive. Interactive methods include “participant observation, key informant interviewing, career histories, and confirmation surveys”; while non-interactive methods include “non-participant observation, archival and demographic collection, and physical trace collection” (LeCompte & Goetz 1982a). These are all described as follows:

Participant observation: This has been a consistently popular method of collecting data and is therefore given greater attention in this section (LeCompte & Goetz 1982a, Zaharlick & Green 1991, Bernard 2006b). The four roles for participants in research were developed by Gold in 1958 (Gold 1958). A later succinct summary of these roles are provided by Greener (2008): “[There are] four roles for participant observers: complete participant (covert observer), participant-as-observer (complete participant, but overt researcher too), observer-as-participant (primary role is researcher but can participate in work) and complete observer (no participation in work and little communication with those observed)” (Greener 2008). It has been acknowledged as early as 1955 that having some activity in a meeting that is being observed can increase the researchers “identification with the observed and [is] better able to become aware of the subtleties of communication and interaction (Schwartz & Schwartz 1995). There are a number of benefits to participant observation including the following:

1. “Participant observation opens things up and makes it possible to collect all kinds of data.

2. Participant observation reduces the problem of reactivity—of people changing their behavior when they know they are being studied.

3. Participant observation helps you ask sensible questions, in the native language.

4. Participant observation gives you an intuitive understanding of what's going on in a culture and allows you speak with confidence about the meaning of the data.

5. Many research problems simply cannot be addressed adequately by anything except participant observation" (Bernard 2006b).

Key informant interviewing: This method places the researcher with a person who possesses knowledge that would assist the researcher with their study (Zeldich 1962).

Career histories: This provides a historical and cultural background on the participant through questions and dialogue.

Confirmation surveys: These are replicable studies with key informants that are conducted through structured interviews or questionnaires.

Non-participant observation: This involves the researcher to be concealed from the people being researched either from hiding or using recording devices (Pelto & Pelto 1978).

Archival and demographic collection: These are written documents and symbolic records produced by and/or used by the group.

Physical trace collection: This is the "collection of physical traces, the erosion and accretion of artifacts and natural objects used by people in groups" (LeCompte & Goetz 1982a).

In short, there are a number of methods available for collecting ethnographic data. While participant observation may be a widely used method, there are other methods available to supplement and support it.

2.6.3 Data Collection – Writing Field notes

Value is placed on audio and visual recordings in order to "record as much as possible and preserve to the greatest extent the raw data, so that the veracity of conclusions may be confirmed by other researchers" (LeCompte & Goetz 1982b). However, audio and/or visual recording is not always the best option as it could change the atmosphere of the meeting and potentially not allow for a natural interaction; such as in the case for this thesis (more is described in Chapter 4). This being the case, more focus will be placed on hand-written notes.

When writing field notes, "tacit knowledge is perhaps the most important consideration in determining how particular observations are deemed worthy of annotation" (Wolfinger 2002). There are four methods available to take notes for later analysis including: "jottings, a diary, a log, and [field notes] proper" (Bernard 2006a):

Jottings: These are short-form notes that can be taken throughout the day as a means to jog one's memory.

A diary: Much as it sounds; this is an actual personal diary to record how you, as a researcher, feel during the day in order to correlate it with your field notes and remove potential biases.

A log: The log is a document of what you plan to do, what you actually did, and how much money was spent in achieving what you did.

Field notes proper: Field notes fall into three categories: methodological notes, descriptive notes and analytic notes. Methodological notes account for new findings during your day in the field, such as cultural differences in relation to what time is appropriate to show up for appointments. Descriptive notes capture what is observed in the field, such as conversations, processes, actions, descriptions of surroundings, and notes of other written records observed. Analytic notes summarize a series of methodological and descriptive notes into a story of reflection on why something was occurring that required extensive time to figure out. "They are often the basis for published papers, or for chapters in dissertations and books" (Bernard 2006a).

While taking field notes, it is also important to remember not to bias the notes being taken with one's own viewpoint. To help accomplish this, it is important to take into account others' standards and values and not one's own (Emerson 1995).

In brief, there are four formats to take written notes in the field, with field notes proper being the main form, and descriptive notes being main category within field notes used. It is also important to remove one's own biases while taking notes.

2.6.4 Data Analysis – Coding and Processing

Once field notes are obtained, they will eventually need to be coded. In doing so, it can be helpful to first read over the field notes to see if there are emergent themes, codes they can be indexed into, or what the best method to analyze them could be. Techniques to code and process field notes include open coding, writing memos, selecting themes, focused coding, writing integrative memos, reflection, and computer processing (Emerson 1995, Bernard 2006a).

Open coding entails "categorizing small segments of the [field notes] by writing words and phrases that identify and name specific analytic dimensions and categories" (Emerson 1995).

Memos are used to make note of a subject that may require deeper analytical understanding and can raise questions for answering later (Emerson 1995).

Selecting themes provides a method for starting to understand how to group the field notes and form the basis for "reading and coding" (Emerson 1995).

Focused coding is implemented after selecting core themes in order to "[delineate] subthemes and subtopics that distinguish differences and variations" through a line-by-line analysis (Emerson 1995).

Computer processing can be used to analyze text or organize field notes once they have been entered into a database (Bernard 2006a).

However, it has been expressed that there are a lack of tools available for systematically, and methodically analyzing the data (Attride-Stirling 2001). One of the methods to achieve this is through thematic networks where each data point aligns with a basic theme, organizing theme, and a global theme. An illustration of this structure is provided in Figure 2.10. It also makes using a thematic themed approach an option for integrating field notes into already established frameworks of themes.

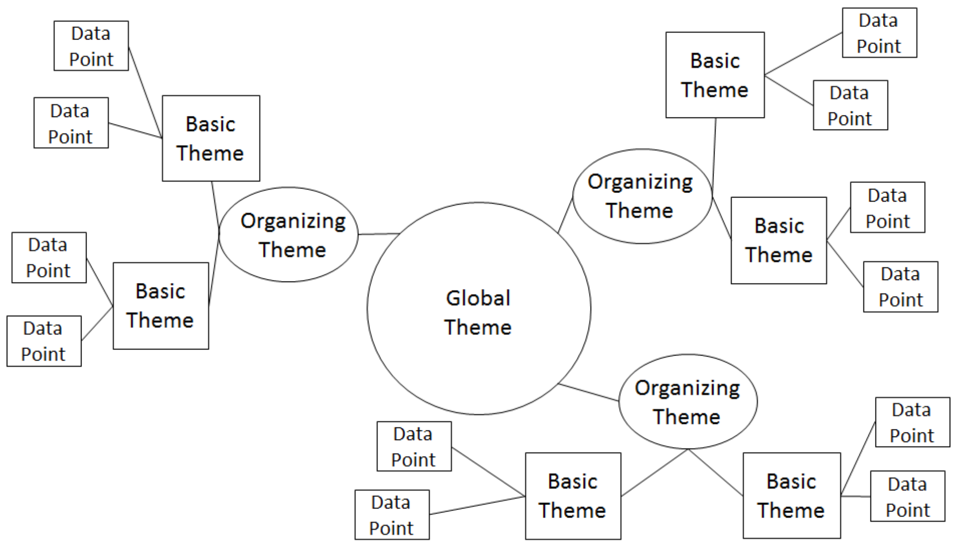

Figure 12: Structure of a thematic network. Image adapted from: (Attride-Stirling 2001)

In summary, there are a variety of methods available for coding field notes. Using thematic themes can be helpful to have already developed frameworks to organize the themes. Two of these potential frameworks are listed in the following section.

2.6.5 Classification Frameworks

There are a number of classification frameworks in existence for a variety of purposes. The ones chosen to be built upon in this thesis were decided based on their extensiveness and the number of iterations that both frameworks have undergone, the two that were chosen were version 6.0.0 of the Cross Industry Process Classification Framework from the American Productivity and Quality Centre and the fourth edition of the Project Management Body of Knowledge from the Project Management Institute. These frameworks are later amalgamated in Chapter 4 to develop a CLL specific process framework.

2.6.5.1 Cross Industry Process Classification Framework

The cross industry process classification framework is developed by The American Productivity and Quality Center, which was established in 1977. They currently also have 11 industry-specific process classifications: Aerospace & Defence, Automotive, Banking, Broadcasting, Consumer Electronics, Consumer Products, Education, Electric Utilities, Healthcare Payer, Petroleum Downstream, Petroleum Upstream, Pharmaceutical, Retail, and Telecommunications (APQC 2012, APQC 2013). After reviewing these, it was determined that the cross-industry classification would best encompass the activities of the living lab due to its breadth and non-specific nature. This classification is broken into 12 enterprise level categories and is provided in the following table.

Table 5: Categories of the American Productivity and Quality Center's Cross-Industry Classification Framework[SM] (APQC 2013)

American Productivity and Quality Center Cross-Industry Classification Framework	
Category #	**Category Name**
1	Develop Vision and Strategy
2	Develop and Manage Products and Services
3	Market and Sell Products and Services
4	Deliver Products and Services
5	Manage Customer Service
6	Develop and Manage Human Capital
7	Manage Information Technology
8	Manage Financial Resources
9	Acquire, Construct, and Manage Assets
10	Manage Enterprise Risk, Compliance, and Resiliency
11	Manage External Relationships
12	Develop and Manage Business Capabilities

Additionally, there are over 300 sub-processes for these 12 enterprise level categories to develop a robust starting point to develop CLL framework.

2.6.5.2 Project Management Body of Knowledge

The Project Management Body of Knowledge was developed by the Project Management Institute, which was founded in 1969 to further the "project, program and portfolio management profession" (PMI 2013). It has since developed a series of iterations of the well-respected Project Management Body of Knowledge. The nine key chapters that were the focus for building a CLL are listed in the following table.

Table 6: Chapters of the Project Management Institute's Project Management Body of Knowledge (PMI 2008)

Project Management Institute's Project Management Body of Knowledge	
Chapter #	**Category Name**
3	Project Management Processes for a Project
4	Project Integration Management
5	Project Scope Management
6	Project Time Management
7	Project Cost Management
8	Project Quality Management
9	Project Human Resource Management
10	Project Communications Management
11	Project Risk Management
12	Project Procurement Management

There are over 100 sub-processes for these nine chapters that aid with ensuring that the majority of major process are covered for the development of the CLL specific process framework.

2.6.6 Summary

In general, ethnographic research through observation and field notes involves self-reflection, selection of a research paradigm, building a local theory, collecting data (with field notes), coding data, and analysis. (Schensul et al. 1999, Emerson 1995). Additionally, ethnographic research can capture "a group's way of life" by immersing the researcher in the environment through participant observation (Zaharlick & Green 1991).

There are a number of methods available for collecting ethnographic data with participant observation being the most widely used method. While in the field, there are four formats to take written notes, with field notes proper being the main form, and descriptive notes being main category within field notes proper used. Once field notes are obtained, there are a variety of methods available for coding them. Using thematic networks can be helpful to combine with already developed frameworks to organize themes. Two of these potential frameworks are the Project Management Body of Knowledge and the cross industry process classification framework.

These two well-established frameworks help provide a solid foundation to later establish an amalgamated version for a CLL specific process framework in Chapter 4. Combined, there are 435 sub-processes upon which to base a comprehensive CLL framework.

2.7 Business Process Modelling

2.7.1 Introduction

It has been suggested that business process modelling (BPM) arose in the early part of the last century with the introduction of the scientific method (Pidd 2000). This, then, developed into a visual means to understand the evolving complexities of the organization of a business. Within these models, the business workflow, decision points, and organizational layout can all be visually displayed. This research uses BPMs to examine and explain the CLL.

2.7.2 Model Evaluation

It was suggested by Kettinger, Teng & Guha (1997) that there are as many as 72 models to choose from. (Kettinger et al. 1997) This being the case, the proposed framework of Lou and Tung (1999) is used for selecting an appropriate BPM method. This involves first understanding the three attributes of the BPM method: objectives, perspectives and characteristics. Objectives aid in defining the goal of BPM and provide increasing levels of granularity; perspectives, described by Cutis *et al.* (1992), outline the functional, behavioural, organizational and informational elements; and characteristics, as suggested by Lou & Tung (1999), pertain to formality, scalability, enactability, and ease of use. Summaries of these three attributes models are detailed in Table 2.7 through Table 2.9.

Table 7: Objectives of business process models (Luo & Tung 1999)

Objectives of Business Process Models		
Objective	**Detail**	**Function**
Communication	Low	Represents a snapshot of the business processes
Analysis	Medium	Used to improve existing processes
Control	High	Aids with monitoring the existing business processes to a finer detail for refinement

As the models currently in use are at the "communication" stage, this research will aim to upgrade the models to the analysis stage. As concentrating too much in depth on any particular process may not allow time for viewing the broader picture of the CLL, the level of models produced will not reach the "control" stage.

Table 8: Perspectives of business process models (Curtis et al. 1992)

Perspectives of Business Process Models		
Perspective	**Detail**	**Function**
Functional	Low	Represents *what* processes are performed
Behavioural	Low	Represents *when* the processes are performed
Organizational	Medium	Represents "*where and by whom* in the organization" the processes performed
Informational	High	Represents *what information* is "produced or manipulated" by a process

Since a sub-objective of this research is to document and model the process in order to create improvements all the perspectives are almost equally important with a slightly greater emphasis on the functional perspective; without knowing what processes to model, there would be no models.

Table 9: Characteristics of business process models (Luo & Tung 1999)

Characteristics of Business Process Models		
Characteristics	**Detail**	**Function**
Formality	Low - High	How precise and consistent does the language need to be?
Scalability	Low - High	"How large and complex a business process can the modeling method represent?"
Enactability	Low - High	"Does a modeling method support automated enaction and process manipulation?"
Ease of Use	Low - High	How difficult is it for people to follow?

The strategy behind designing the models was to follow Apple's concept of simplicity in order to allow for the greatest potential for uptake in use. As such, there is a focus on ease of use of the models, which reduces the level of detail. This is compensated for by writing more detail to describe the model in case people have further questions not immediately addressed by the model. Formality in the models used is strict for the types of objects placed in the model, but not as strict for the language used. For example, when a document is created, a document object must be used. For the purposes of this research, language in the models is consistent, but this does not need to be as strict for organizations—the language simply needs to relay what is occurring.

For purposes of replicating a "Living Lab" concept at another university or municipality, the focus of the BPM chosen should both provide an overview and a level of granularity that can help other organizations at the most difficult stages. It would appear from UBC's case that the early and middle stages consist of rapid and consistent improvement, so the focus of models used for this research are targeted to reduce the learning curve for these stages.

To conclude, a model that allows for both communication and analysis will be developed for the early and middle stages of deployment. The purpose of using the communication objective is to provide a clear overall goal of what would be ideal. The analysis portion will help to assess how the proposed "Living Lab" structure would function within a new organization. The perspectives used at the various stages will also grow in level of detail through the implementation of the "Living Lab" concept. The early stages of the BPM will illustrate functional and behavioural characteristics. Informational and organizational will soon follow once the “roles” of individuals have been discussed and developed. The characteristics used at the various stages will be easy to use, semi-formal, and scalable. Automation is not foreseen to be introduced at this point, so enactability is currently not being considered.

2.7.3 Comparison of Model Types

In an effort to limit the number of models to be evaluated, the work of Giaglis, (G.M. 2001) is used to refine the number of models to 12. These models are broken into business process models (BPMs) and information systems (ISs) as listed in Table 2.10.

Table 10: Business process and information system modelling techniques (Giaglis 2001)

Business Process and Information System Modelling Techniques	
Business Process Modelling Techniques	**Information System Modelling Techniques**
Integrated DEFinition (IDEF) techniques (IDEF0, IDEF3)	Entity-relationship diagramming
Flow Charting	State-transition diagramming
Petri nets	IDEF techniques (IDEF1x)
Simulation	Unified Modelling Language
Knowledge-based techniques	
Role activity diagramming	

Giaglis (G.M. 2001) also describes a number of advantages and disadvantages of the various models which are outlined in Table 2.11 below. It is important to note that both the flowchart and integrated definition (IDEF) are both listed as simple to use and that data flow diagrams are, not surprisingly, great for illustrating the flow of data. Since the models to be used will be simple and do not require advanced functions, there are advantages to both the flow chart and the data flow diagram. Also, the Input Control Output Mechanism (ICOM) can become confusing to understand for models with many inputs since this model relies on arrows to flow in and out of each process as inputs and outputs.

Table 11: Advantages and disadvantages of various business process models (Giaglis 2001)

Advantages and Disadvantages of Various Business Process Models		
Model	**Advantage(s)**	**Disadvantage(s)**
Flow Chart	Familiar to people and easy to use	Only provides basic functions
Integrated DEFinition (IDEF)0/IDEF3	Simple to use	Only uses the Input Control Output Mechanism (ICOM) and does not represent a state of time.
Petri Nets	Provided states and transitions and helps find idle time	Unmanageable for complex business processes
Discrete Event Simulation	Is applied to a model to predict how it will function	Not actually a model
System Dynamics	Used in simulation to determine the performance of a complex structure over time	"Much emphasis is [placed] on feedback and control processes … hence unable to cope with stochastic elements … in real world business processes"
Knowledge-based techniques	"Provides a framework for the development of computer aided modelling tools endowed with automatic reasoning capability"	Long time to implement and requires computer modelling
Role activity diagram	Most useful where the human element is the crucial resource	Excludes the functional and informational perspectives
Data flow diagram	Excellent at illustrating the flow of data	Does not show "work flow, people, events, … or information on decisions"

A further breakdown of these models on their ability to provide various modelling perspective is detailed in the following Table 2.12. Building on a potential focus on the flowchart and the role activity diagram, it becomes apparent that combining the two would allow for all perspectives to be covered except for behavioural aspect of time. However, it is possible to compensate for this by providing another layer to the flow chart for time.

Table 12: Differences between modelling perspectives of business process models (Giaglis 2001)

Differences between Modelling Perspectives of Business Process Models				
BPMIISM Techniques	**Function**	**Behavioral**	**Organization**	**Information**
Flow chart	○	⊘	⊘	△
Integrated DEFinition (IDEF)0	○	⊘	△	⊘
IDEF3	△	△	⊘	△
Petri nets	○	○	⊘	⊘
Discrete event	○	○	○	△
System dynamics	△	○	○	△
Knowledge-based	△	○	⊘	⊘
Role activity diagram	⊘	△	○	△
Data flow diagram	○	⊘	△	○
Entity-relationship	⊘	⊘	⊘	○
State-transition	⊘	△	⊘	⊘
IDEF1x	⊘	⊘	⊘	○
UML	○	△	△	○

Legend: ○ = Yes △ = Limited ⊘ = No

In short, as outlined in Section 2.7.2, Model Evaluation, the model chosen needs to be able to provide increasing functionality as the organization evolves. There were several BPMs presented along with their respective advantages and disadvantages. These advantages and disadvantages were further highlighted through the perspectives lens as all four of these were thought to be valuable. The potential models have been narrowed down to flow charts and data flow diagrams. While they both have potential, preference is for flow charts based on the following reasons:

1. using swim lanes on the flow charts can capture the organizational perspective,
2. adding a time dimension on the flow chart would also capture the part of the behavioural perspective,
3. flow charts are already in use by UBC.

2.7.4 Summary

The current and future use of BPMs for the CLL was reviewed using perspectives, objectives, and characteristics. This aided in determining what attributes a model should ideally possess. As this thesis is aimed to help with CLL development through the early stages, the perspective attributes that will be attempt to be captured in the models will be communication and analysis as they would be the most helpful for this stage. Objective attributes needed were all four: functional, behavioural, organizational, and informational, since they all combined to tell a whole story. Characteristics focused on ease of use and, to some extent, formality and scalability.

Once these were determined, the advantages and disadvantages of the main BPMs and their respective ability to provide each of the four perspectives were reviewed, which resulted in the selection of a modified flow chart. As other organizations will undoubtedly have other titles for swim lanes, focus will be applied to the grouping of the elements, as opposed to who is actually doing the individual items. More research can be done as to whether or not the current groupings at UBC are the most efficient or not.

2.8 Conclusion

This chapter covered a range of topics in varying depth, including barriers to sustainable technology adoption in campus infrastructure systems, an increase in available technology, technology development and transfer, knowledge creation and diffusion, qualitative research methods, and business process modelling.

There are barriers to sustainable technology adoption in campus infrastructure systems, which include risks that could hinder projects due to uncertainty associated with performance, schedule, and cost. Additionally, these projects may not be feasible due to lack of available champions with expertise. UBC attempts to de-risk projects by leveraging UBC infrastructure investments with matching funds from industry and the government, by reducing potential liability on carbon taxes, and by using projects to contribute to research and teaching. While there are potential barriers, the available technology for adoption is increasing as well as the accessibility to new technologies.

The technology development and transfer section amalgamates technology readiness levels, the technology transfer process, economic clusters, the value chain, the technology adoption curve, and living labs. The technology readiness levels show how new technology move through different stages of maturity and in what way these stages can be used to assess when to introduce a new technology. The technology transfer process highlights how science-based and development-based regimes differ, and presents the differences between the three stakeholders for university technology transfer. Economic clusters provide a description of how a local region could benefit from them and how a CLL environment would be able to assist with knowledge spillovers, labour pooling and possibly input-output linkages. Additionally, firms within an economic cluster could improve their value chain to increase their competitiveness. The technology adoption curve illustrates the significant hurdle to overcome when crossing from the early adopters to early majority and reasons behind this. University living labs were then introduced to show how they can branch between the technology readiness levels, the technology transfer process, economic clusters, the value chain, and the technology adoption curve. They achieve this by providing a test bed for developing and demonstrating projects. This also provides an avenue for the financing of a demonstration project that can lead to commercialization of the technology to be adopted by others.

Knowledge creation and diffusion explained the differences between tacit and explicit knowledge, and how knowledge modes and helices were introduced to offer a method of understanding knowledge creation systems. Barriers that prevent new knowledge from being created and diffused were introduced, which included personal barriers (personal accommodation, and threat to self-image), and organizational barriers (the need for a formalized language, organizational precedents, procedures, and company vision). Potential barrier reduction methods and enablers for knowledge transfer were also provided.

An overview of ethnographic research established the methods available for collecting data with a focus on participant observation as the most widely used method. Various formats to take written notes were also provided with field notes being the main form, and descriptive notes being main category used. Methods available to code the field notes were outlined along with the benefit of using thematic networks amongst already developed frameworks to organize themes. Two frameworks were also proposed for use: Project Management Body of Knowledge and the cross industry process classification framework.

The current and future use of BPMs for the CLL was reviewed using perspectives, objectives, and characteristics. This aided in determining what attributes a model should ideally possess. Once these were determined, the advantages and disadvantages of the main BPMs and their respective ability to provide each of the four perspectives were reviewed, which resulted in the selection of a modified flow chart.

Chapter 3. UBC's Campus as a Living Lab

3.1 Introduction

Any group that creates challenging goals for the future also requires a strategy to achieve them. In the University of British Columbia's (UBC) case, the goals are to reduce greenhouse gas (GHG) emissions to 33% below 2007 levels by 2015, 66% by 2020, and 100% by 2050 (UBC 2010c). The strategy was to develop the University Sustainability Initiative (USI) and the Campus as a Living Lab (CLL) to assign authority and responsibility to help manage this endeavor. How did UBC develop these goals, and how could other institutions potentially use lessons from UBC's experience to avoid the same pitfalls and reduce the learning curve? This chapter addresses these questions, beginning by providing a historical context of how the CLL sprouted in 2010 from sustainability initiatives that started as early as 1990. Recent revisions of CLL processes are provided in the form of Business Process Models (BPMs) to give context on how the collaboration functions between UBC's Building Operations and Utilities, external companies, and researchers. These recent revisions of BPMs set the stage to view earlier iterations of processes for the CLL that are illustrated with three signature projects: the Centre for Interactive Research on Sustainability (CIRS), the Academic District Energy System, and the Bioenergy Research and Demonstration Facility. The examples begin with CIRS, which is a unique case since the planning started in 1999—well before the CLL term was coined at UBC, but was during a period when UBC was already doing activities that resembled the CLL. The CIRS example provides a snapshot of how things were handled early in the development of sustainability-driven university processes.. Following this, the Academic District Energy System example illustrates a more structured CLL system for soliciting proposals and determining which projects to evaluate and pursue. Then, the Bioenergy Research and Diversification Facility example shows how an unsolicited proposal flowed through the system and helped create more developed CLL processes. Key transferable characteristics are identified from the current processes and those used in the three signature projects and recommendations for improvement are provided.

3.1.1 Objectives

The main objective of this chapter is to document and model the processes that have already occurred for three main projects: the CIRS, the Academic District Energy System, and the Bioenergy Research and Demonstration Facility.

3.1.2 Methodology

The methodology for developing BPMs for UBC's CLL entailed the following:

- gathering documentation to develop BPMs,
- obtaining feedback from USI and CLL members on the BPMs developed,
- integrating the feedback on the BPMs,
- outlining key transferable characteristics and recommendations for improvement.

Data was obtained by collecting available documentation, meeting with individual people and attending meetings. Data was aggregated from online storage via SharePoint, and from asking individuals for documentation. Meetings were also scheduled with individuals to help address questions regarding processes and to verify new processes created. The vast majority of meetings attended were the CLL Working Group meetings, but CLL Steering Committee, USI Student Sustainability Committee, USI Steering Committee, and the USI Regional Committee meetings were also attended. While the USI meetings were helpful to understand the overall working of the USI, it was the CLL meetings that provided the in-depth background needed to understand the processes involved. As of March 28, 2014, there have been 162 CLL Working Group meetings; the author has attended and taken notes at 36 of these meetings spanning over 16 months. The dates of the meetings attended are provided in Appendix E CLL Meetings Attended.

3.2 Campus as a Living Lab Background

In order to understand how the CLL arrived at its current state, it is helpful to understand some of the background. The next three sections outline the development of sustainability at UBC, how the CLL arose, and the CLL organizational structure.

3.2.1 UBC Sustainability Prior to Campus as a Living Lab 1990-2008

As the CLL arose out of sustainability initiatives, is important to first understand about the development of sustainability at UBC. The first spark of sustainability at UBC began with signing the Talloires Declaration in 1990 (UBC 2012d). This declaration arose from the convening of "twenty-two university presidents and chancellors in Talloires, France, to voice their concerns about the state of the world and create a document that spelled out key actions institutions of higher education must take to create a sustainable future." (ULSF 2012) In 1997 "UBC became the first university in Canada to adopt a sustainable development policy" (UBC 2012d). This policy directed UBC to create Canada's first sustainability office in 1998 which helped initiate a campus wide energy and water retrofit on 288 buildings that lasted from 2001 to 2008 (UBC 2012c, UBC 2008). As GHGs do not only occur on campus, but on transportation to campus, UBC created a universal transit pass for all students to reduce GHGs and transportation costs (UBC 2013e). Sustainability activities accelerated in 2006 when UBC developed a four year "Sustainability Strategy" and, just a year later, became "one of six founding signatories to the University and College Presidents' Climate Statement of Action for Canada" (UBC 2006b, UBC 2010a). Sustainability then became part of UBC's core mandate with the integration of three overarching goals in the "Place and Promise" plan (UBC's overall strategic plan):

1. "Ensure UBC's economic sustainability by aligning resources with the University vision and deploying them in a sustainable and effective manner.
2. Make UBC a living laboratory in environmental and social sustainability by integrating research, learning, operations, and industrial and community partners.
3. Create a vibrant and sustainable community of faculty, staff, students and residents (UBC 2012a)".

Even though UBC had accomplished a number of sustainability initiatives, it was only after a review of UBC's strengths was commissioned in 2009 that sustainability really started to become a focus.

3.2.2 UBC Sustainability Campus as a Living Lab Development 2009-2014

Following this sustainability pathway, the university conveyed a group to explore ways to extend sustainability at UBC that resulted in the creation of a "Sustainability Academic Strategy" in 2009. The results of the Sustainability Academic Strategy informed the creation of midlevel sustainability goals for UBC's core mandate: Place and Promise. These sustainability goals included the formation of a University Sustainability Initiative (USI) where the objective was to integrate campus-wide academic and operational sustainability efforts, including the creation of the CLL program and the "Agent of Change" initiative (aimed at effective change primarily through the campus's procurement and supply chain mechanisms) (UBC 2009b). The reason the USI developed a two-pronged approach was to not only target specific initiatives within the campus with the CLL, but to have influence on the larger community outside of the campus through as an Agent of Change. An example of a CLL initiative that acted as an Agent of Change is the CIRS building as it reformed policy by allowing solar aquatics within a shorter distance to a restaurant, and gang nailed two by fours to become part of a buildings wood flooring system.

While the CLL was in its infancy, some members formed a strategic committee to determine potential sustainability goals for the university surrounding GHG reductions and energy use. This group then returned to recommend the goals to reduce GHG emissions to 33% below 2007 levels by 2015, 66% by 2020, and 100% by 2050, which were then included in the climate action plan (UBC 2010c). The USI had its first formal meeting in March, 2010 and it was able to pass a budget for the program by the following April to support the initiatives (Robinson et al. 2010). This budget would also help support the CLL in starting to reduce GHG emissions. The first two projects to be completed have been the CIRS in 2011, followed by the bio-energy research and diversification centre in 2012.

3.2.3 Campus as a Living Lab, Current State

The CLL has gone through a steep learning curve and is still rapidly evolving. The group that can be considered to be driving this is the CLL Working Group, which is comprised of management from a diverse group of people from campus operations, the USI, and the Strategic Partnerships Office. An interesting aspect of the CLL Working Group meetings is that many members attend by choice, as opposed to a contractual or administrative obligation. It has been found that "mandatory, compliance-based approaches to introducing new systems appear to be less effective over time than the use of social influence to target positive changes in perceived usefulness" (Venkatesh & Davis 2000) This bottom-up approach combined with strategic support from the top may be contributing to the effectiveness the CLL has achieved.

Through this journey, the CLL has developed from a reactive model to a proactive model of planning. This is evident from the CLL Working Group being tasked to develop terms of reference for the CLL by the CLL Steering Committee in February 2013. This was taken a step further by the CLL Working Group to include clearer goals and delineations of authority for projects. Some of the partnerships and projects that UBC has engaged in include the following: Nexterra Systems Corp. and GE for the Bioenergy Research and Demonstration Facility, and Alpha Technologies Inc. and Corvis Energy Ltd. for energy storage (UBC 2013d). A more complete list is available in Appendix F Past and Current UBC Partnerships.

These developments have led to the current state of the CLL. Sustainability has a growing interest in the world and UBC is developing a strategy of tackling some of the tough challenges related to technology adoption through the CLL. A number BPMs and documents have been developed by the CLL to assist with their efforts on these challenges. Where applicable, reference has been made to the original creator.

Figure 3.1 provides a legend for the symbols used in the BPMs presented in this thesis. All of the process models follow a flow chart with swim-lanes configuration.

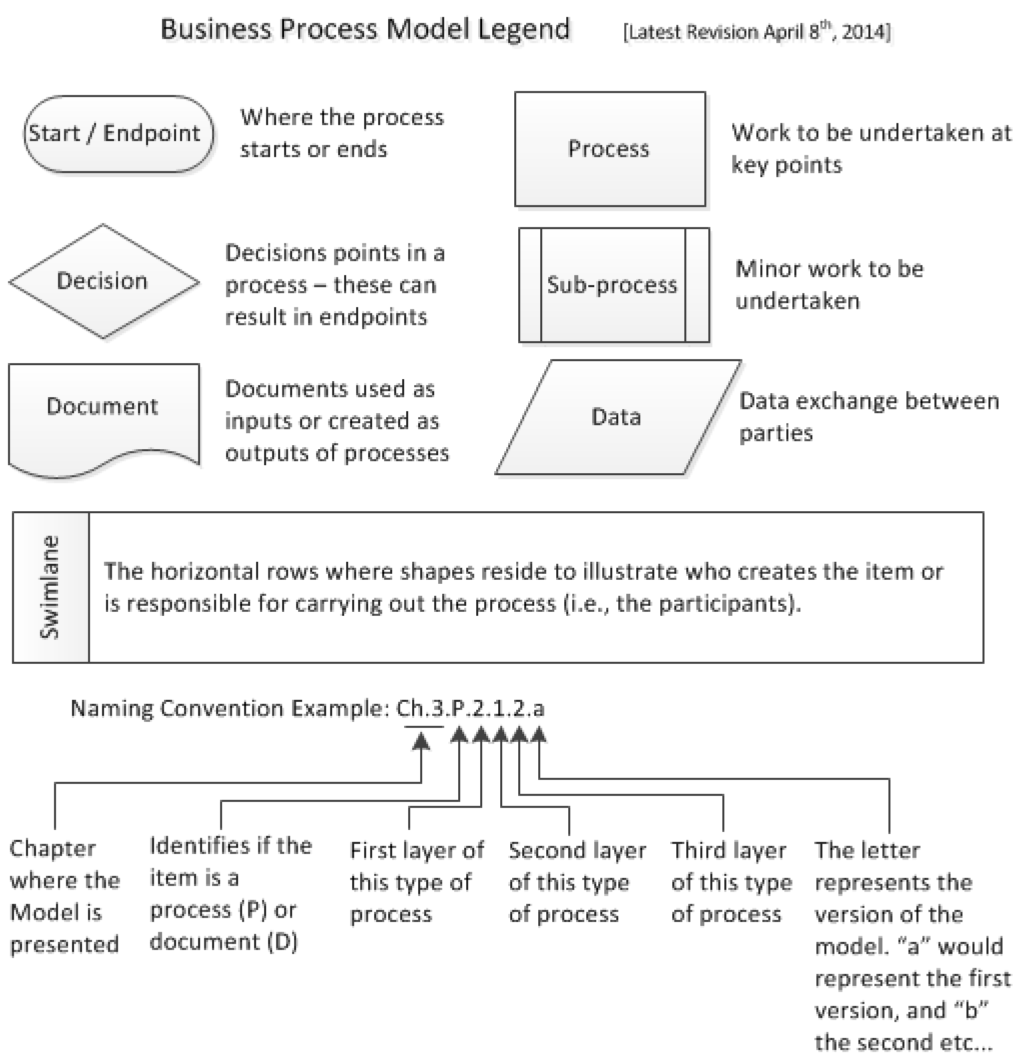

Figure 13: Business process model legend

To illustrate how all the documents and processes intertwine with each other, an overview is provided in the Figure 3.2.

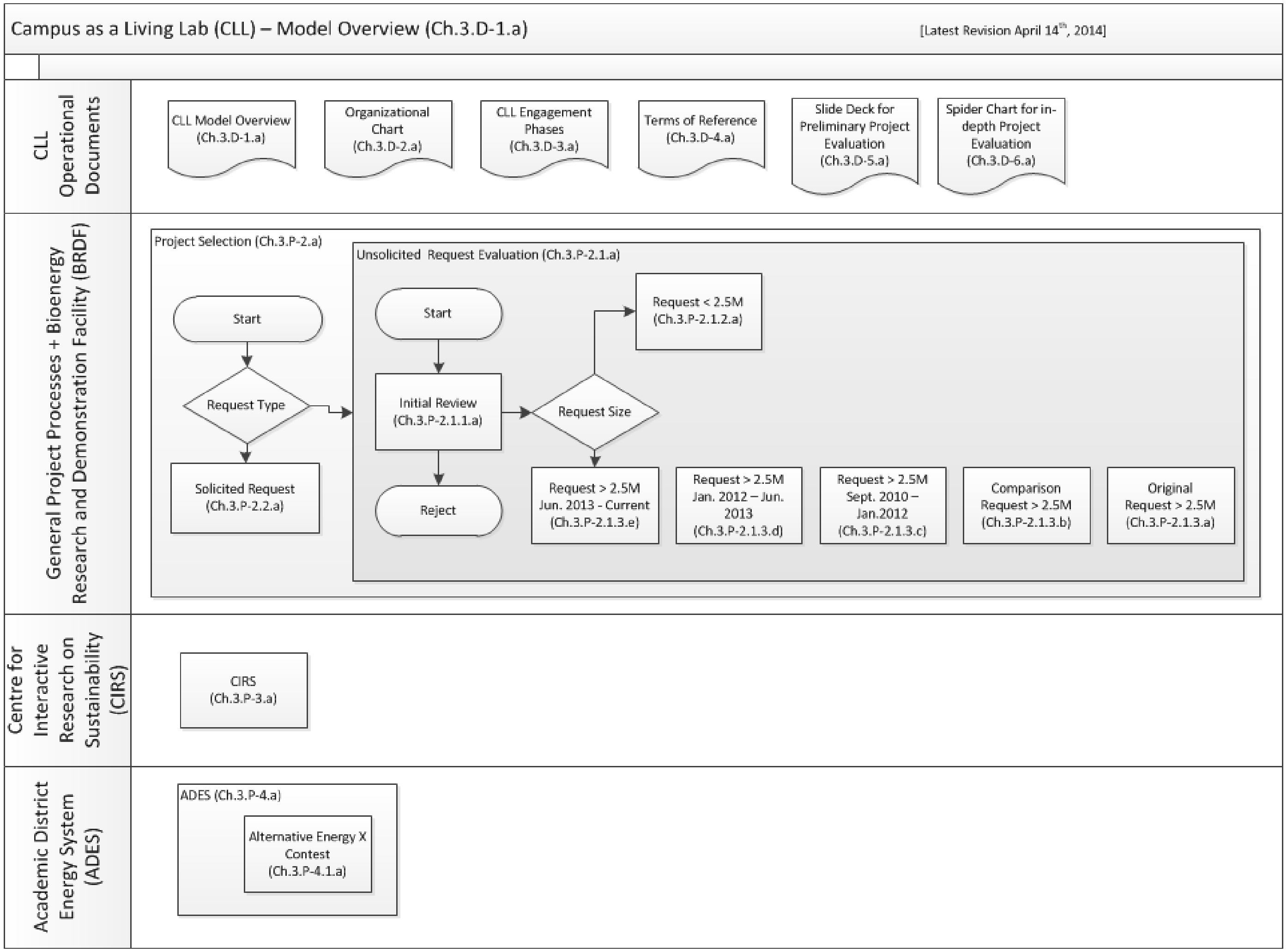

Figure 14: Overview of models and documents for Chapter 3

In order to develop an understanding of the structure of the CLL, an organizational chart for the overarching body of the USI is provided in Figure 3.3. This illustrates how the numerous committees for the USI, the CLL, and all the supporting roles are organized at UBC. Some of the members of the USI steering committee include the following:

- Provost & Vice President Academic (Chair),
- Vice Provost Sustainability
- Vice President Research and International,
- Vice President Finance, Resources and Operations,
- Deans,
- Campus and Community Planning,
- Strategic Partnerships Office,
- Student Representatives.

Since this committee has many senior level representatives, decisions that arise carry significant weight when being presented to the president. This is one example of how the top levels of the university support on-the-ground initiatives, as many items that are discussed in this committee arise from bottom-up initiatives. It is also very helpful to have support of a group such as this when taking items for approval to senior bodies, such as the Board of Governors or the Senate.

The CLL has unprecedented access to the senior decision makers at the university since all CLL committees report to the CLL Steering Committee and the CLL Steering Committee reports directly to the USI Steering Committee. Details on the membership of the CLL Steering Committee, the CLL Working Group, the Project Steering Committee, and the Sub-Committees of the Project Steering Committee are included in this section and Section 3.4.2.2.

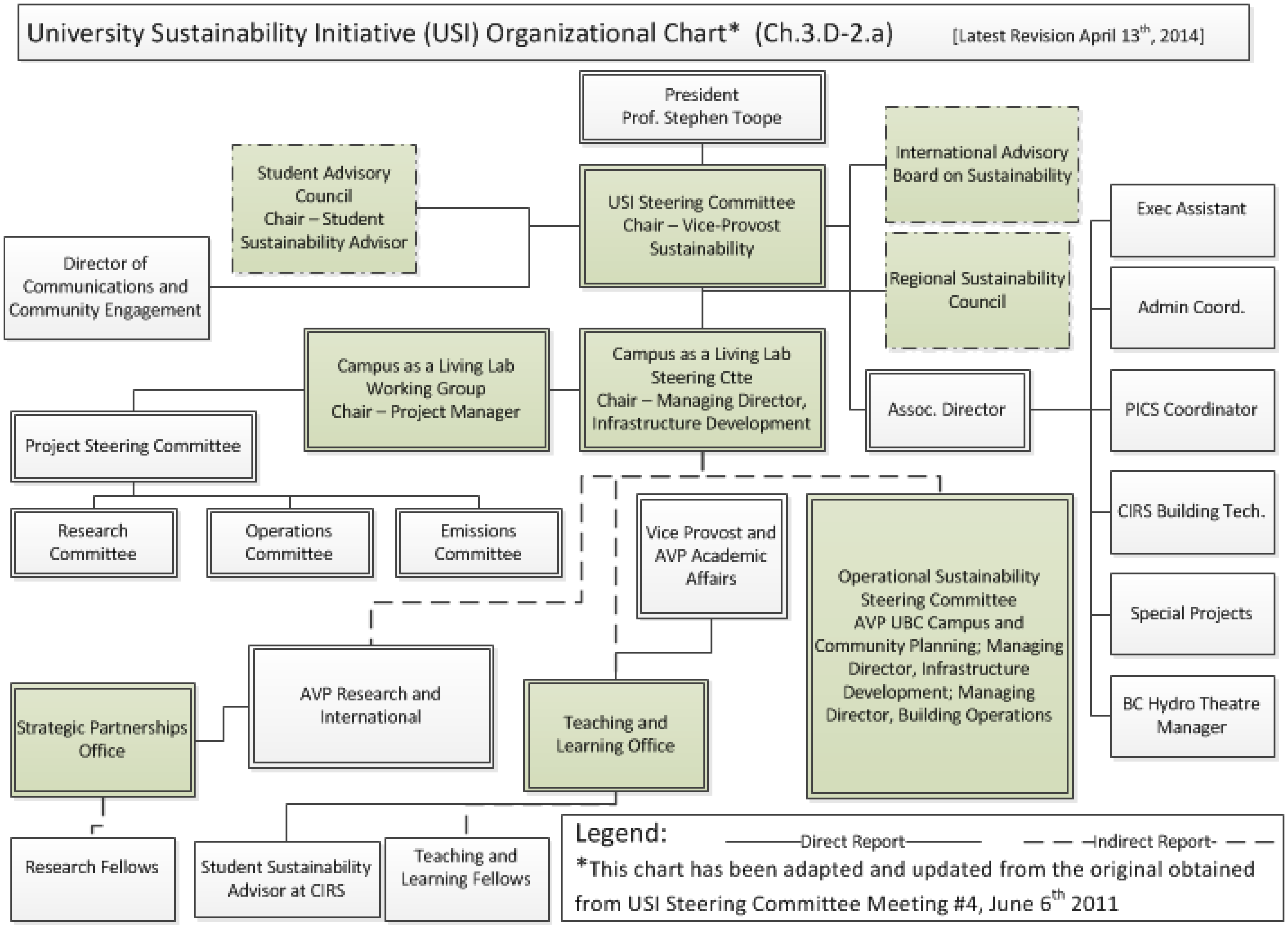

Figure 15: University Sustainability Initiative and Campus as a Living Lab organizational chart

Additional interconnecting organizational charts for UBC Infrastructure Development and the President are available in Appendix G Additional Organizational Charts. These charts outline how the USI fits into the rest of the organizational structure at UBC.

The project management process is slightly more complex than the traditional project management process due to the iterations, budgeting, procurement and delivery, and commissioning being much more involved (Collins 2014).

The level of engagement in CLL projects from various stakeholders varies through the project life-cycle phases. Figure 3.4 shows the level to which groups are typically engaged in a project during the various life-cycle phases. In addition to the traditional project phases, two additional phases are added ("Identify and Pursue Opportunities" and "Pre-Planning") in order to show all CLL activities. The addition of these was suggested from attending numerous CLL meetings and from input by committee members. The definitions to each phase are as follows:

1. ***Identify and Pursue Opportunities:*** During this stage, potential partners are identified through either a request for proposal or an unsolicited request and initial discussions begin.

2. ***Pre-Planning:*** This stage begins after a spider chart has been developed and the working group believes that the project shows merit, and it ends once a proposal is developed to go to the Board of Governors for approval.

3. ***Planning:*** After the project has been approved by the Board of Governors, the actual construction planning begins.

4. ***Construction:*** The construction phase.

5. ***Commissioning:*** During this stage, everything is verified to be working as per the initial specifications and any necessary adjustments are made to ensure that the project meets the specifications

6. ***Operation:*** The actual operation of the project.

7. ***Deconstruction:*** The deconstruction of the project, performed in a way that allows some of the parts to be re-used.

In addition to the phases of a project life-cycle, Figure 3.4 uses swim lanes to represent the key groups involved with the project. Details of these groups are listed as follows:

- ***CLL Steering Committee:*** A large representation of various groups on campus including people from campus operations, the USI, the Strategic Partnerships Office, Campus and Community Planning, UBC Properties Trust, deans, UBC VP Finance, a representative from the UBC Okanagan campus, and the University Neighborhood Association. There are 26 people on this committee.

- ***CLL Working Group:*** A diverse group of people from campus operations, the USI, and the Strategic Partnerships Office. This group reports to the CLL Steering Committee and has many of the same members. There are 24 people listed on this committee with approximately 12 representatives attending meetings regularly. There is a high level of project management experience on this team.

- ***CLL Project Group:*** Typically chaired by John Metras (Managing Director of UBC Infrastructure Development) with representatives from UBC Building Operations, Infrastructure Planning (Project Services), Campus and Community Planning, University Sustainability Initiative, UBC IT, UBC VP Research and International, Strategic Partnerships Office, and a few professors. If a project enters the planning phase, this group will also oversee three more committees, which are the research, operations, and emissions committees.

- ***Industry Partner:*** The company or non-governmental organization submitting the proposal.

- ***UBC Infrastructure Development:*** The group who manages the planning, design, construction and commissioning of many construction projects at UBC (UBC 2014e).

- ***Operations:*** The group who maintains and operates the infrastructure. (UBC 2014d).

It is important to note that the level of engagement also represents the group that is most likely to be in charge of the project during a given phase. The project lead would begin with the CLL Working Group, ownership would then transfer to the CLL Project Group, then to Infrastructure Development, next to Operations, and then back to Infrastructure Development.[10] In this way, there is always a clear project lead throughout the project life-cycle. Additionally, the CLL is working towards greater industry partner involvement once projects are in operation and this is shown in the industry partner swim lane with the "future state". All of these points are illustrated in Figure 3.4.

[10] For the procurement and project management of large infrastructure and buildings on UBC campus, UBC Properties Trust is the lead. This group was not illustrated on Figure 3.4 as the figure is CLL Working Group Centric, and UBC Properties Trust does not attend these meetings. (They do attend the CLL Steering Committee Meetings.)

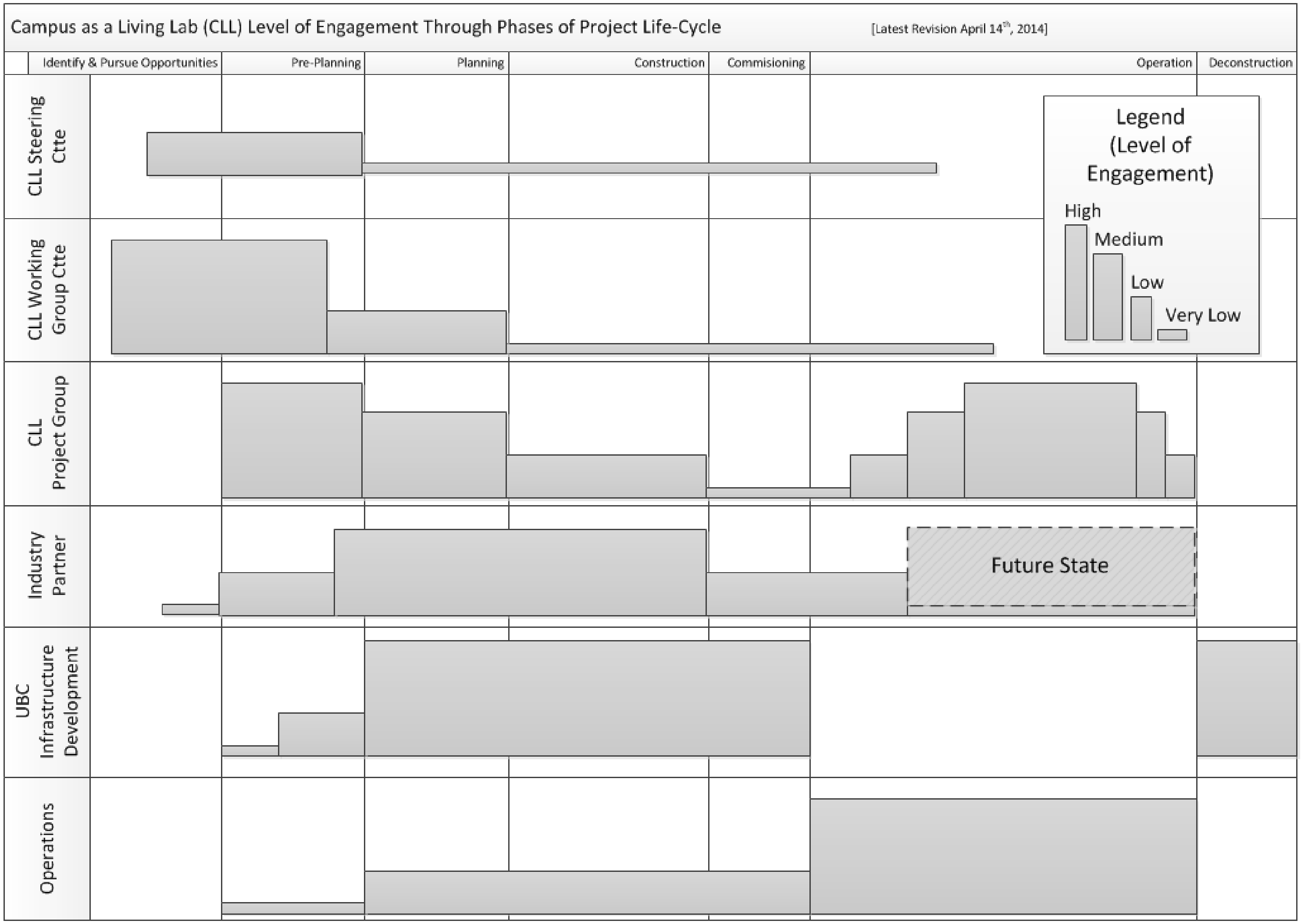

Figure 16: Campus as a Living Lab level of engagement through phases of project life cycle

3.3 Industry Scenario

As mentioned earlier, one of the goals of the CLL is to use UBC as a test bed for potential commercialization of products that can help with campus sustainability. UBC can be seen as a launching pad for technologies to move out of the lab and into main-stream use. It is also a goal to help other places in Canada and abroad benefit from technology by developing policies at UBC that can be replicated elsewhere. Conversely, there may also be practices developed in other countries, but not generally used in Canada. The CLL can help to introduce these. Companies are also interested in fast, effective and value-orientated solutions to develop their products, and the CLL can be seen as a path of least resistance.

Currently it can be difficult for industry to commercialize products as they:

- require further refinement,
- are proven in conceptually or in the lab, but not commercially,
- are commercially proven, but still require further 3rd party verification,
- have 3rd party verification, but not at the scale or with an acceptable (local) 3rd party,
- require changes in policy.

As noted in Chapter 2, it is the demonstration phase within the technology readiness scale that UBC is most interested in when it comes to the CLL. Occasionally, exceptions to this are made for first-time projects in Canada or British Columbia that aid with adapting government policy to allow these projects. The value proposition of the CLL to industry is that it can provide additional researcher capacity for development, assistance with potentially matching government funding with industry investment, monitoring and verification of results. UBC is also at a scale that is large enough to prove that a technology could work for other campuses or municipalities.

3.4 *Current Business Process Models for Campus as a Living Lab, Unsolicited Proposal Requests*

3.4.1 Introduction

This section describes BPMs for current CLL processes, which provide a baseline for comparison to past projects in Section 3.6. Additionally, key documents that have been added to the CLL processes recently, such as a slide deck for companies to pitch their value proposition and a spider chart to analyze the merits of a potential project are listed in detail.

3.4.2 Process Modelling

After UBC issued a Request for Information to develop strategic partnerships with industry in 2011, an increasing number of companies approached UBC wishing to collaborate. UBC had been following ad-hoc processes to pursue projects, but it found that a more formal structure was needed if it was to scale its CLL efforts successfully. The models listed in Chapter 3.4 provide an overview of how the CLL's business processes for unsolicited proposal requests have developed since September 2010.

The BPMs presented are the *Overall view of Unsolicited Requests for Project Plan Submissions* (Figure 3.6), and the *Unsolicited Project Plan Submissions Greater than $2.5 Million – September 2010 through Current Practice* (Figure 3.8-Figure 3.10). These BPMs provide a demonstration of the hierarchical flow and illustrate the improvements that the CLL has contributed. The major participants, represented using swim lanes, have been described previously.

3.4.2.1 Overall View for Unsolicited Requests for Capital Projects

While UBC has a formal process for CLL requests for proposals, for strategic sustainability reasons and in accordance to its innovative CLL approach, UBC also entertains unsolicited proposals. However, these are subject to a screening procedure that is as rigorous as the formal request for proposals process.

As explained in Figure 3.1: Business process model legend, there can be multiple layers to processes. Each additional layer increases the detail of the process. Two illustrations of this are provided in Figure 3.5 and Figure 3.6. Each model is numbered so as to correspond to another layer in the model. For example, in Figure 3.5: Campus as a Living Lab project selection, the model is labelled "Ch.3.P-2.a" and more detailed layers are provided in "Ch.3.P-2.1.a" and "Ch.3.P-2.2.a". These are presented in Figure 3.8 through Figure 3.10 (including modifications made to the processes through three time periods). These figures demonstrate how it is possible to involve many layers to a process.

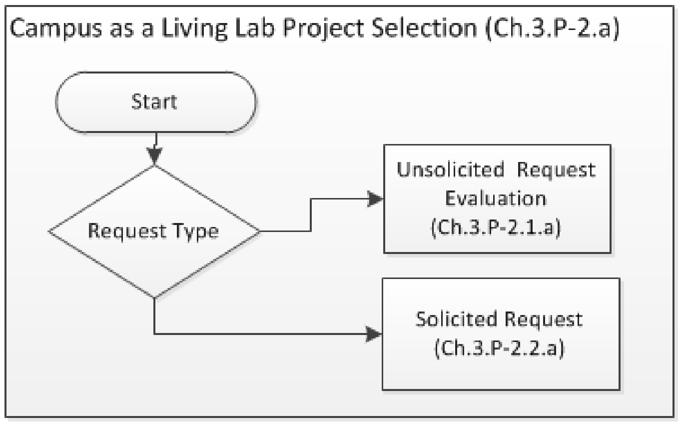

Figure 17: Campus as a Living Lab project selection

The idea for the following BPM was adapted from an original model created by Brent Sauder, Director, Strategic Partnerships Office. Revisions from the original model include condensing the submission and initial review phases into one process and the addition of a project time component to illustrate typical durations.

The integration of the time length to complete projects was added in consultation with CLL committee members. As of 2013, unsolicited project plans were categorized into two sizes; those greater than \$2.5 million, and those less than \$2.5 million. For the first two years of the CLL, the threshold for projects required to go to the Board of Governors was \$1.5 million—it was found that most projects were above these threshold values. Projects not requiring this approval were able to proceed much quicker than those that required it. In either case, the length of time required to complete a project can be longer than a company anticipates, so clearly expressing the process and a longer time frame at the start is important (Collins 2014).

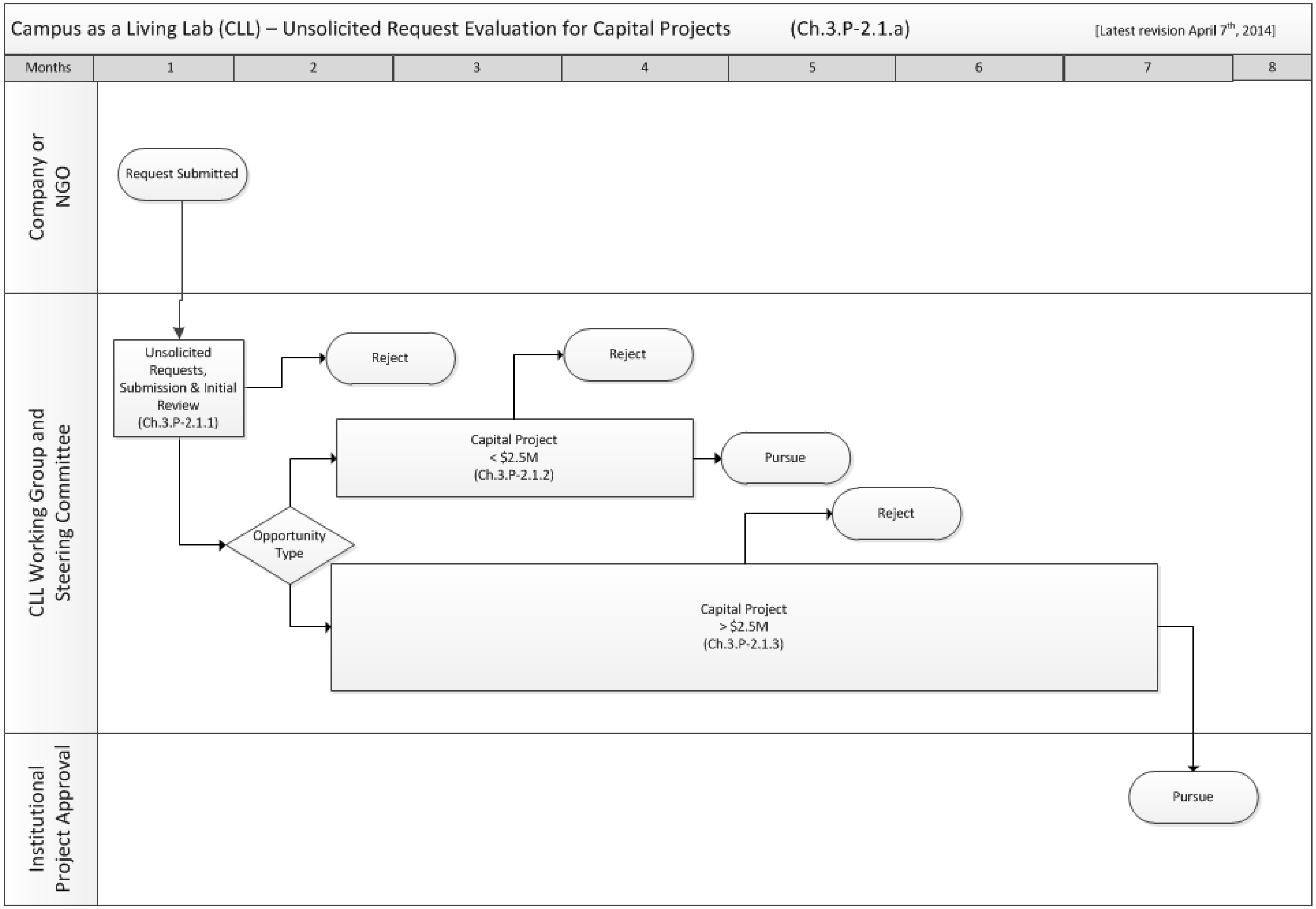

Figure 18: Campus as a Living Lab – overall view for unsolicited requests for capital projects

3.4.2.2 Unsolicited Project Plan Submissions Greater than $2.5 Million – September 2010 through Current Practice

The first stage of an unsolicited request requires completing an online form and submitting a two-page proposal. This first step is crucial in ensuring that UBC's objectives align from the beginning of the project and that it has been tailored to ensure that the information addresses specific questions. The proposal is then reviewed by the Strategic Partnerships Office, who provides feedback to the CLL Working Group for review. This is an important step since these reviews are carefully done by a diverse team of individuals who contribute various areas of campus expertise and who examine the four cornerstones of CLL projects:

1. "The integration of UBC's core academic mandate (research and teaching) with the University's operations;
2. Partnerships between the University and private sector, public sector or NGO organizations;
3. Sound financial use of UBC's resources and infrastructure;
4. The potential to transfer the knowledge UBC gains into practical, positive action applicable to the greater community" (UBC 2013b)

If the working group considers the project to have potential, then the Strategic Partnerships Office will pursue the company for additional information to further review with the CLL Working Group. If the CLL Working Group agrees that there is a fit, then a champion for the project is identified (appointing a champion for a project can prove challenging when everyone already is balancing a full-time workload). Once a project champion has been appointed, then a presentation is made to the CLL Steering Committee for final vetting before an informal steering committee is created to develop a memorandum of understanding. Once the memorandum of understanding is in place, four formal committees are struck to govern the project. The four committees are the following:

1. Project Steering Committee. Membership: Chaired by the Managing Director of UBC Infrastructure Development with representatives from UBC Building Operations, Infrastructure Planning (Project Services), Campus and Community Planning, UBC Sustainability Initiative, UBC IT, UBC VP Research and International, Strategic Partnerships Office, and a few select professors (Evans 2014).

2. Research Committee. Membership: dependant on the project, but it will “typically be led by a professor who then invites 10-12 colleagues from various faculties” (Evans 2014).

3. Operations Committee. Membership: “typically lead by Project Services, but with heavy engagement from building operations and other units within the UBC VP Finance Resources and Operations portfolio” (Evans 2014).

4. Emissions Committee: Membership: “led by building operations, with partners from University Neighborhood Association and other stakeholder communities (depending on who may be impacted)” (Evans 2014).

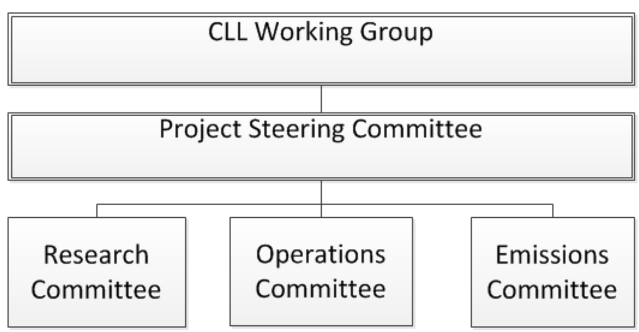

Figure 19: Project Steering Committee structure

The CLL Steering Committee consists of a group of individuals from various areas and levels of authority that provide another thorough review of the project. If UBC funding is required, then a detailed business case would also be created for institutional project approval. For UBC, this body is the Board of Governors. The number of review points and the number of groups reviewing projects before presenting proposals to the Board of Governors helps to ensure that a majority of stakeholder representatives have had a chance to provide input before a project is initiated. Not only does this allow involvement in the CLL, but it provides many opportunities to refine the scope of a project, improves the value proposition, and develops the greatest number of leads for researcher involvement. Refining the scope of the project can help ensure that UBC receives just what they need at the time they need it. Improving the value proposition can occur by learning that a group on campus may have a spare component that can be integrated into the project at little or no cost. As integrating researchers on projects is a key component of the CLL, it is important to develop as many avenues as possible to find the right people to work on a project. Finding the right people can involve breaking down silos and fostering greater interdisciplinary collaboration. This can also be seen as a benefit of the CLL.

An illustration of this process is provided in Figure 3.8.

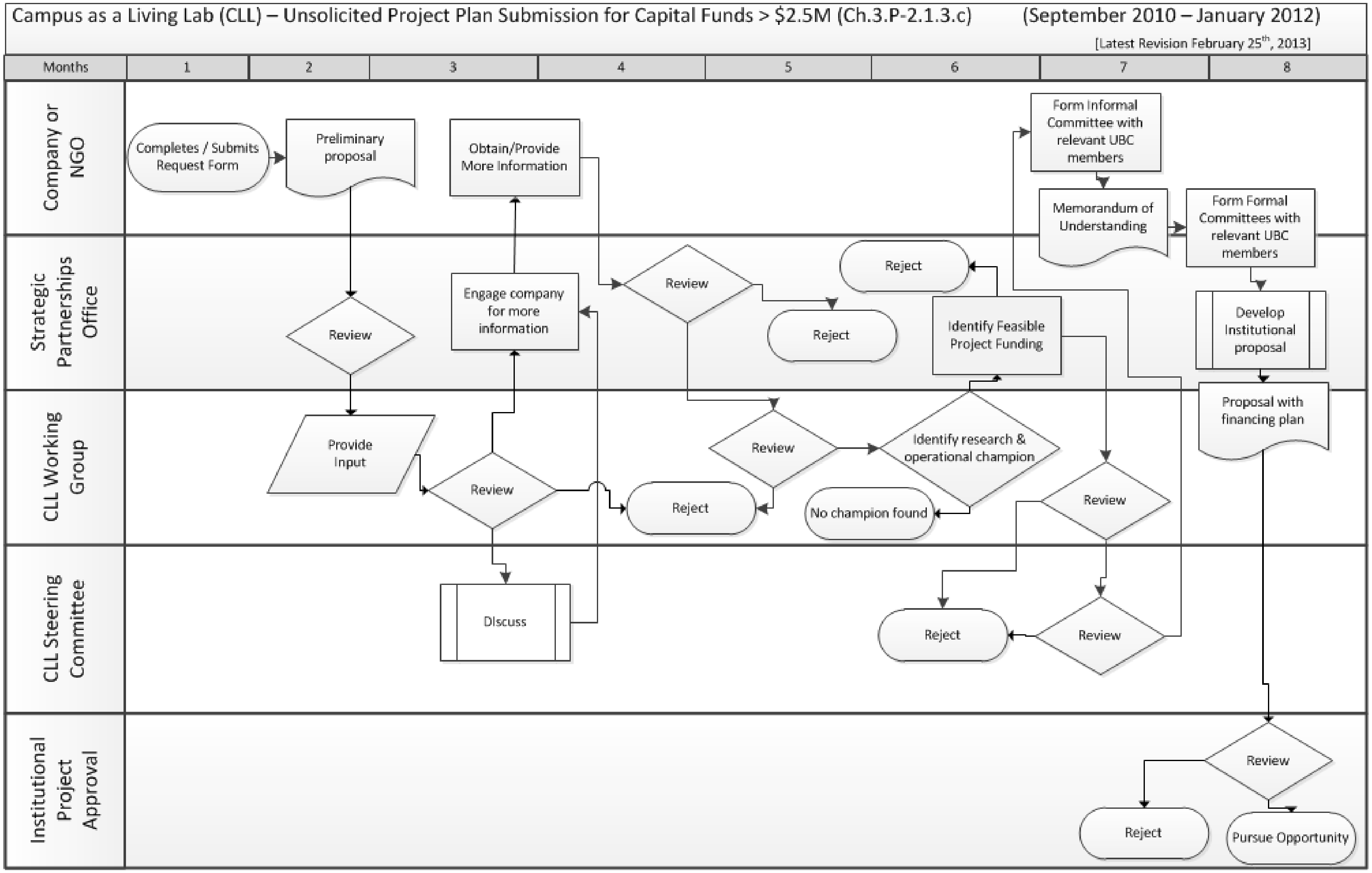

Figure 20: Campus as a Living Lab project plan submission for capital funds > 2.5M (September 2010 – January 2012)

Over time, the Strategic Partnerships Office noticed that the business plans being provided by companies wanting to pursue projects often did not provide a value proposition. This led to the CLL trying to extract information from the company to try to develop a value proposition for them. As this is not the most effective use of the CLL time, an approach similar to the venture-capital model was applied to investigating potential projects that required a 12 page slide deck with a clear value proposition. This consisted of a template developed by the Strategic Partnership Office that was accepted by the CLL Working Group to be provided to companies that passed the first step of the process. This slide deck provided insight into the technology, how well the company knew UBC as a customer and whether or not the company fundamentally understood what UBC was trying to accomplish (Evans 2014). The slide deck was intended to easily relay the idea behind the project to multiple stakeholders in order to make a decision.

Appendix H Slide Deck for Unsolicited Proposals to Present Value Proposition to the Campus as a Living Lab contains a full copy of the slide deck, a general outline is provided in Table 3.1.

Table 13: Slide deck overview for companies presenting opportunities to UBC (Evans 2012)

Slide Deck (Ch.3.D-5.a)	
Slide # & Item	**Contents**
1) Introduction slide	Project Name, Company Name, Company Location, Company Lead
2) Presentation Outline	Slide headings of 3 to 12 on this list
3) Executive Summary	How UBC helps achieve the company's corporate goals
4) Opportunity Positioning	The key problem they are solving and why it is unlike any other product
5) Solution Overview	Outlines the value proposition and core technology
6) Solution Example	Describes how problems will be overcome
7) Program Plan	Provides key resources, tasks and milestones
8) Program Partnerships	Partnerships that will develop within BC and beyond
9) Product Cost Assumptions	A detailed cost breakdown
10) Innovation Opportunities	Researcher involvement opportunities, risks and barriers to commercialization
12) Operations and Maintenance Support Plan	How support will be provided to UBC
12) Value-added Opportunities	Other potential synergistic opportunities for UBC

It has been found in the CLL Working Group that the presentation of this format of a slide deck prepared has helped to clearly outline where the potential benefit is to UBC and to industry as a whole. There have been occasions where the technology may be cutting edge, but if a company is not able to produce a benefit to UBC and to industry as a whole, then the project would not be pursued.

The slide deck is obtained when requesting more information from the company and is shown in Figure 3.9 as highlighted in dark grey. As shown, the slide deck is first reviewed by the Strategic Partnerships Office and then by the CLL Working Group. This adds a consistent, efficient, and effective aspect to the project review process.

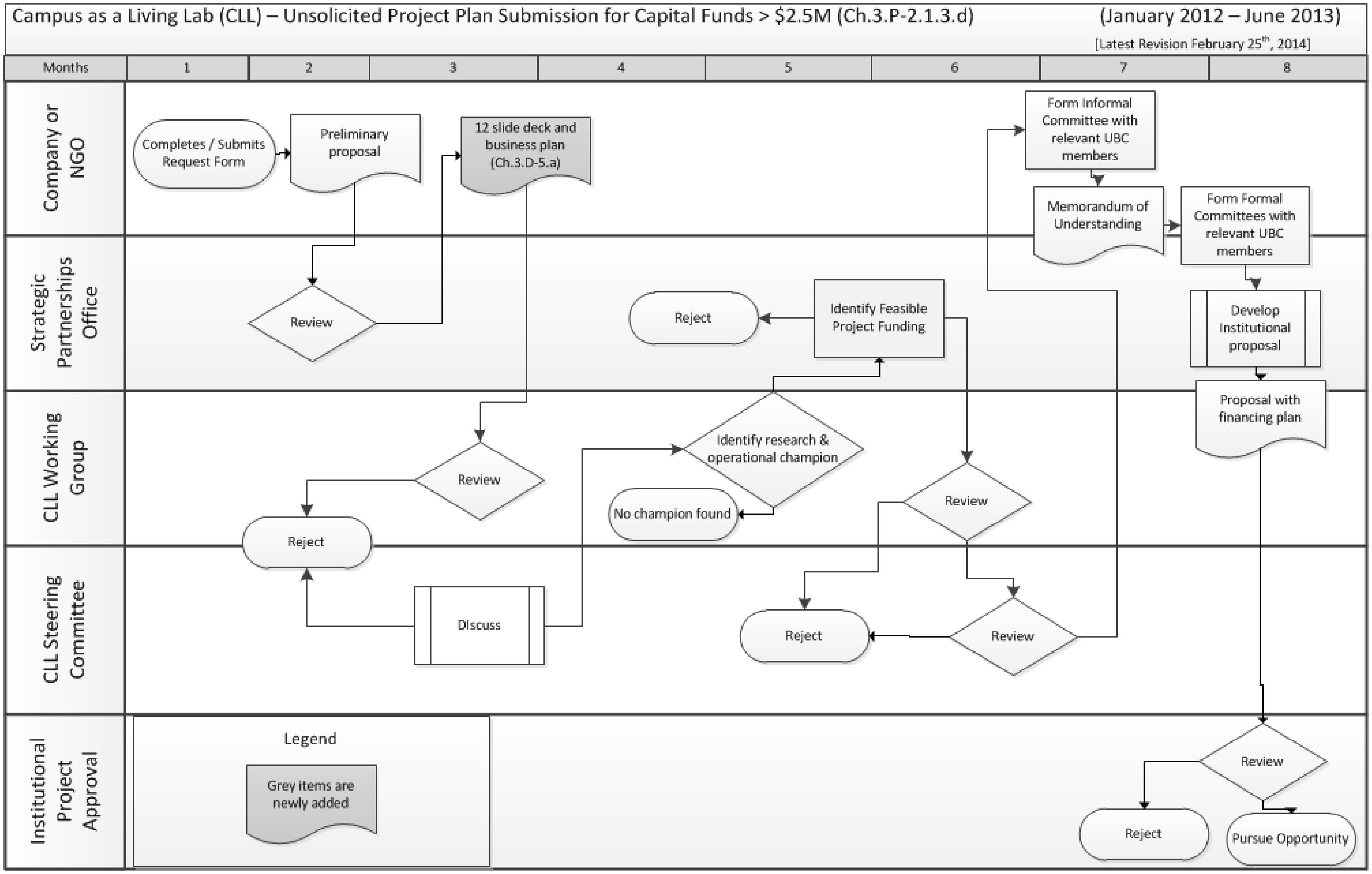

Figure 21: Campus as a Living Lab project plan submission for capital funds > 2.5M (January 2012 – June 2013)

After the 12 page slide deck was introduced, the Strategic Partnerships Office developed a Spider Chart to further analyse potential projects. This Spider Chart provided 5 categories and 24 sub-categories for analysis with the purpose of being able to strategically determine whether or not a potential project is worth exploring further. Each of the sub-categories are rated a point value of “-1”, “0”, or “1” and the higher the score, the better the project assessment. The threshold for a preliminary pass is approximately 7 points. A basic outline is provided in Table 3.2 and a full set of criteria is available in Appendix I Spider Chart Criteria.

Table 14: Spider chart criteria for selecting projects to pursue at UBC

Spider Chart Criteria (Ch.3.D-6.a)	
Category	**Item**
Operational Efficiency	Capital Expenditure (UBC Cash)
	Operational Expenditure (NPV over 10 year span based on operations budget.)
	Risks (Whether they can be identified and quantified)
	Identifiable Environmental Benefit
	Guidelines
	Leverage Dynamics (For every dollar UBC invests, how much would the company, government, and others contribute.)
Research Excellence	Publications (How long would it take to publish)
	Research Funding
	Leverageable Expertise within UBC
	Enhanced infrastructure to support leading edge research
	Engagement by research chair
	Number of departments engaged
	Knowledge Dynamics (M&A activity within technology field)
Student Learning	Undergraduate project work opportunities
	Graduate project work opportunities
	Recruit and retain top ranked graduate students and postdoctoral fellows
	Entrepreneurship at UBC opportunities
Community Engagement	Cross-campus collaboration
	Engagement with the University Neighborhood Association
	Engagement with local industry
	Engagement with other federal/provincial/municipal/not-for-profit
Sustainability	To be decided #1
	To be decided #2
	To be decided #3

Although the sustainability components for the spider chart are still under development, the economic and environmental aspects of projects are currently considered when evaluating projects. The development of the Spider Chart also made it possible to identify weaker categories and to investigate whether or not these areas could be strengthened. The Spider Chart comes after the 12 page slide deck review and is shown in Figure 3.10.

An illustration of how the spider chart could provide visual representation of strengths and weaknesses is provided on a sample project in Figure 3.11.

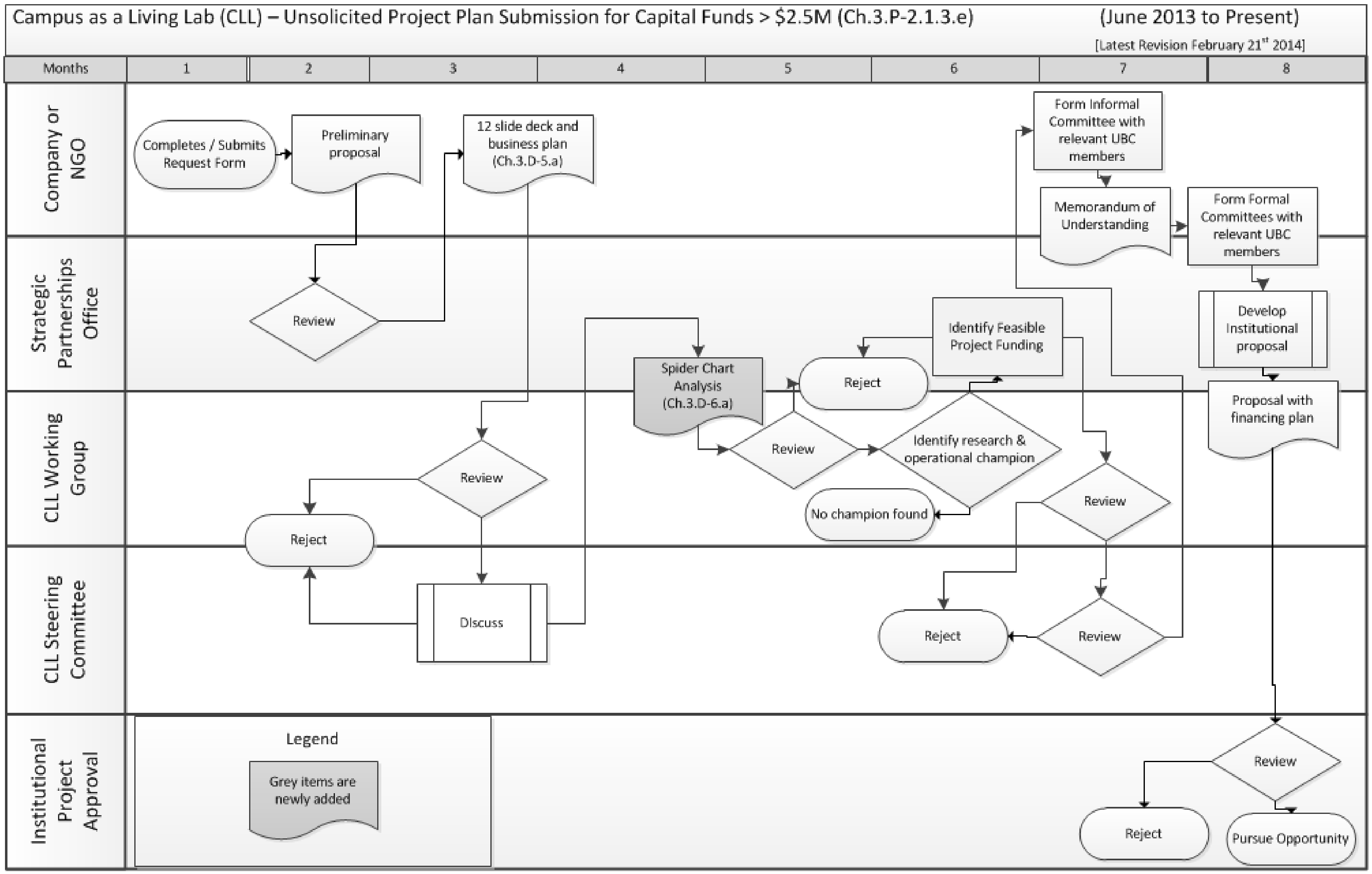

Figure 22: Campus as a Living Lab project plan submission for capital funds > 2.5M (June 2013 – Present)

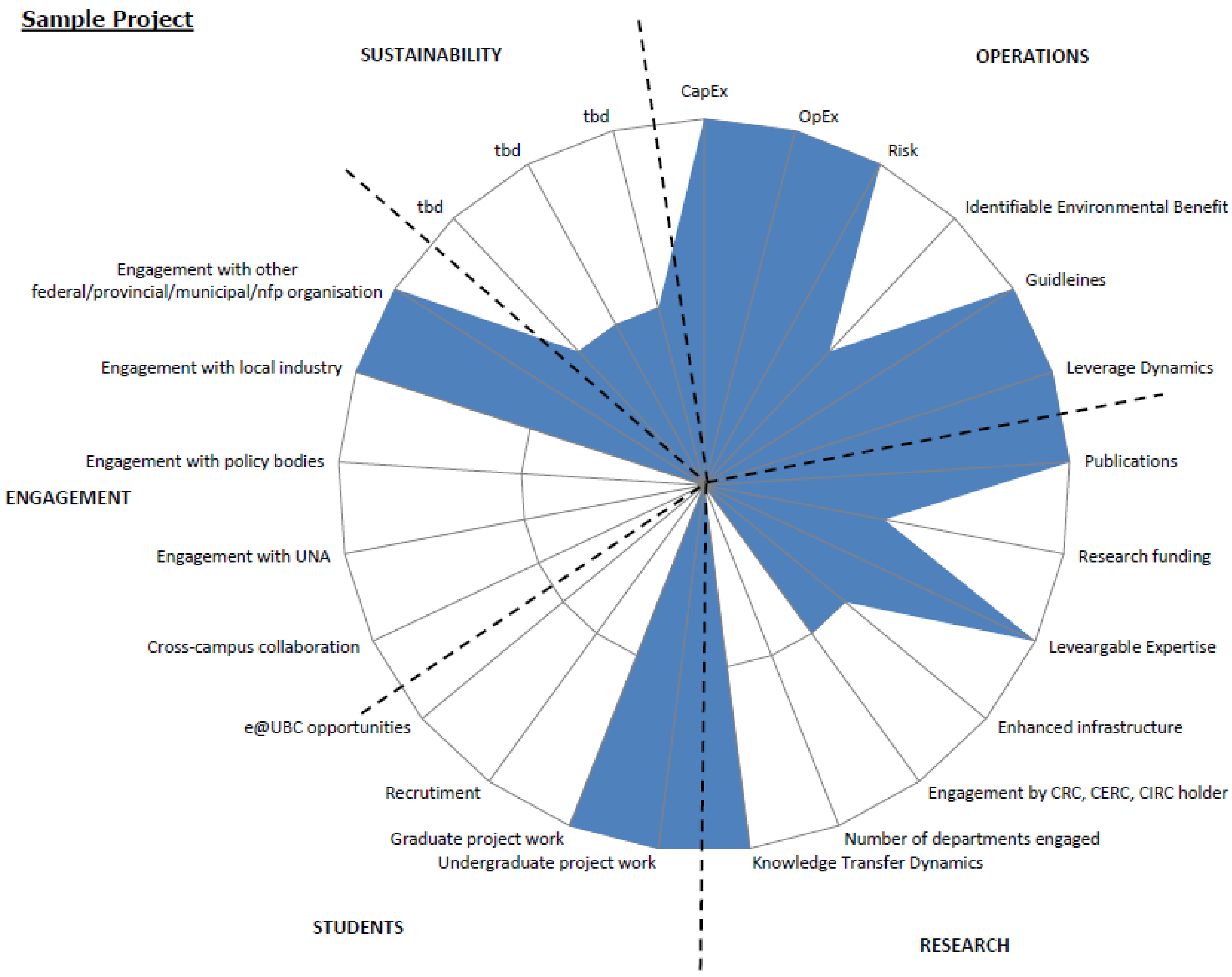

Figure 23: Visualization from spider chart analysis identifying potential project strengths and weaknesses

3.4.2.3 Unsolicited Project Plan Submissions Less than $2.5 Million – September 2010 through Current Practice

As previously mentioned in the "Unsolicited Project Plan Submissions Greater than $2.5 Million" section, for the first two years the CLL projects were delineated to either greater than $1.5 million or less than $1.5 million. For any project during this time period that fell below the threshold value, the CLL would not need the Board of Governors approval to pursue it. These projects follow the same rigour as the projects that are greater than $2.5 million in value. The only difference is that projects less than $50 thousand total project cost must be provided reviewed by the contracting out committee and allocated to unionized workers on campus through a first right of refusal process. This process is shown in the Figure 3.12.

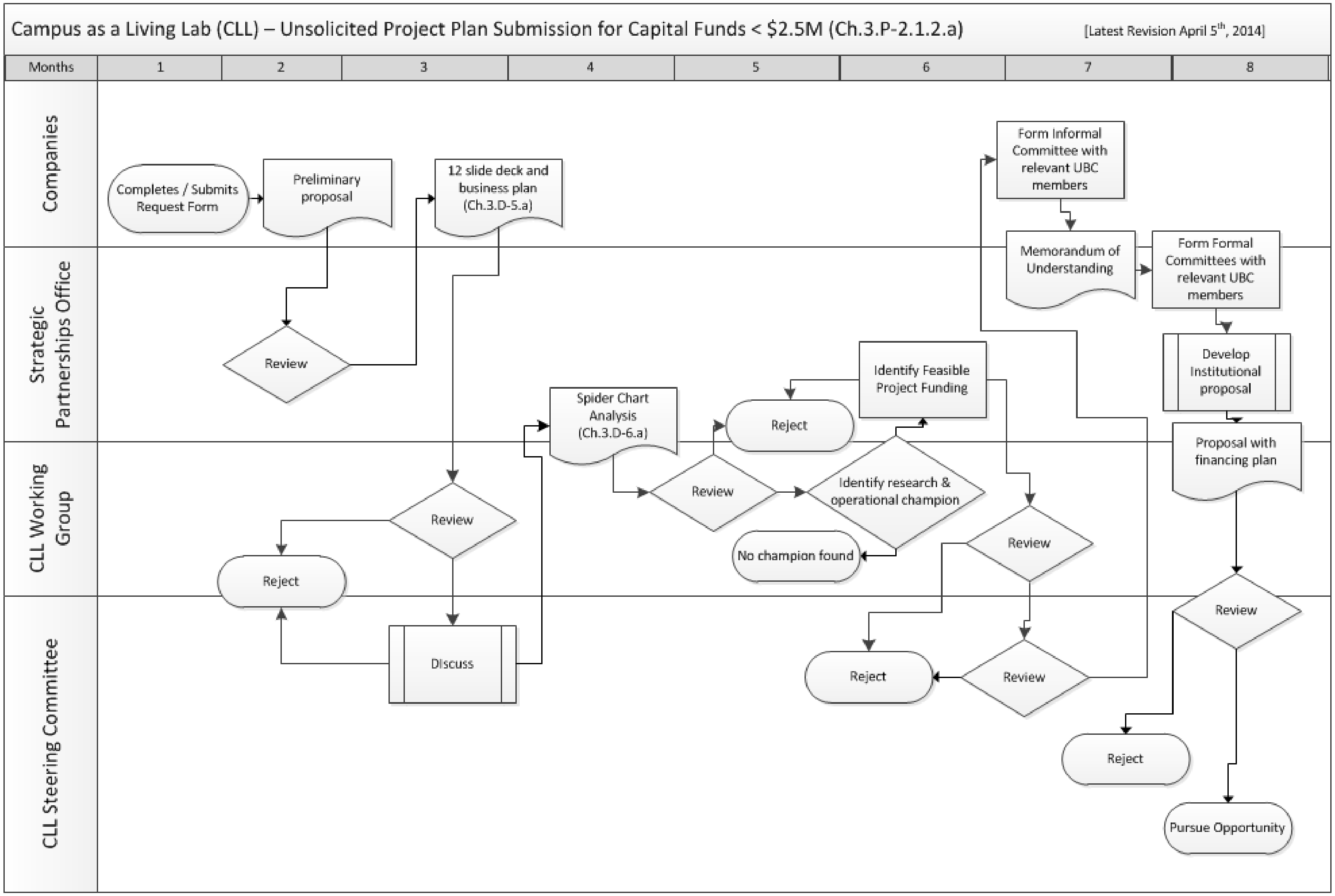

Figure 24: Unsolicited project plan submission for capital projects < $2.5M

3.4.3 Summary

The CLL underwent a number of changes from September 2010 through to the present in order to adapt to a more proactive, rather than reactive, model of governance. This included developing assessment tools for varying levels of analysis for project fit within the UBC campus. Additionally, a project steering committee and three sub committees (research, operations, and emissions) were devised to provide support for projects that require it.

3.5 Current Business Process Models for Campus as a Living Lab Solicited Proposal Requests

As with any large institution, there can be some regulation in regards to what opportunities should be solicited and what can be unsolicited. There is clearly a benefit to having both of these avenues open. Solicited requests allow for targeted proposals to be issued in order to compare potential partners on key metrics for a specific project that the institution has decided to undertake. Unsolicited proposals provide a method to continually review proposals for items that may not have been identifies by the institution and allow for perpetual engagement with industry.

3.5.1 Campus as a Living Lab, Initial Partner Selection

Universities are constantly receiving requests for collaboration and demonstration of new technology. While the unsolicited request for proposal approach is helpful for a continuous intake of proposals, a request for information approach can be helpful to develop deep long term relationships with specific industry partners. Using a request for information is also valuable for maintaining fairness with selecting these long term relationships.

One of the first requests for information for the selection of strategic partners was conducted in 2011 (Sauder & Evans 2011). The BPM of this request for information is outlined in Figure 3.13. Criteria were determined at the beginning as to how finalists would be selected and there were a number of checks along this process.

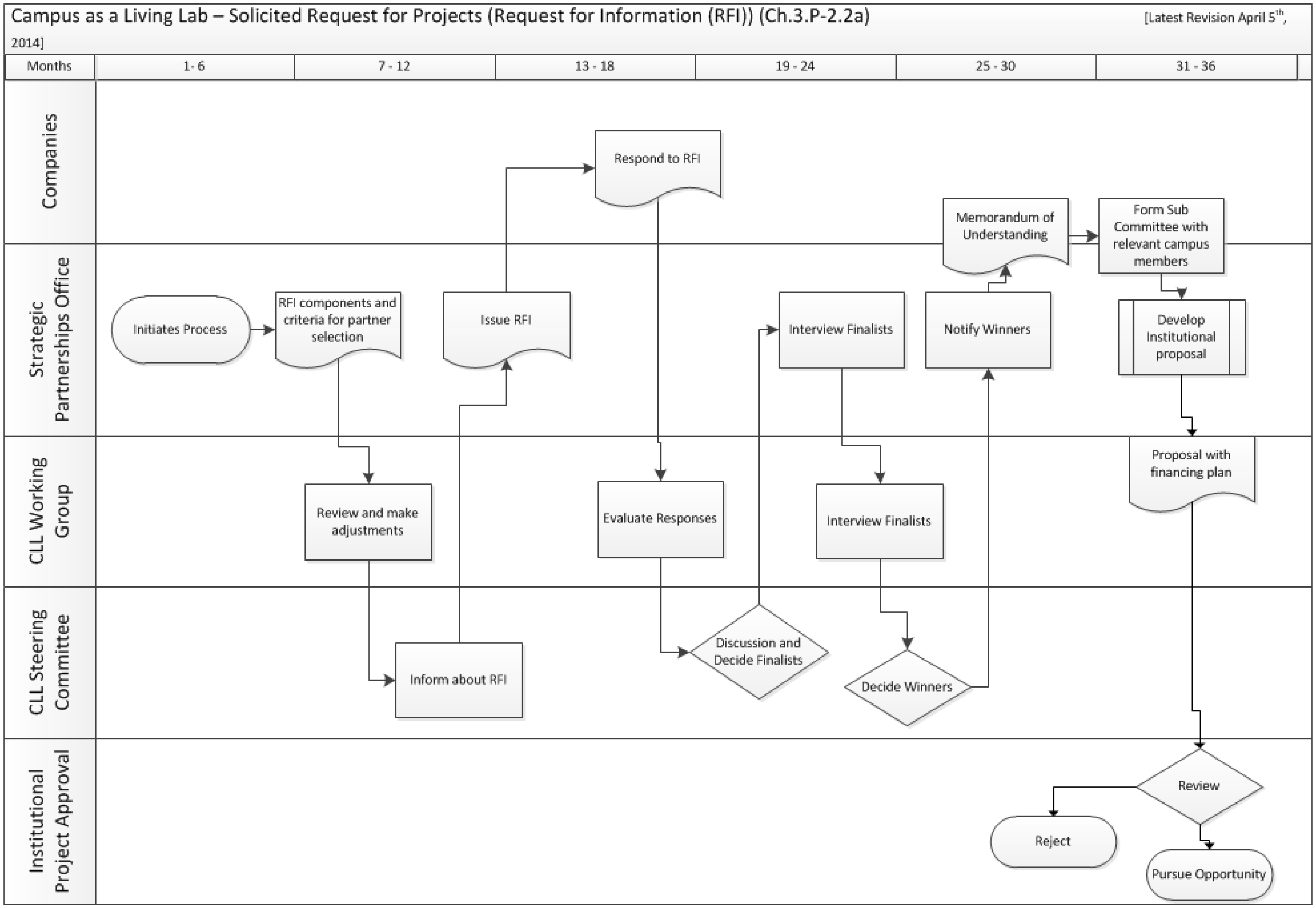

Figure 25: Campus as a Living Lab – initial strategic partner request for information

3.6 Project-Specific Business Process Models

The projects discussed in this section follow a chronological order according to when the projects were first initiated in order to provide a clearer view of the development of the CLL. The first project to be initiated was the Centre for Interactive Research on Sustainability (CIRS), followed by the Academic District Energy System conversion, and then the Bioenergy Research and Demonstration Facility. These are three of the four signature CLL projects currently completed on UBC campus. The other project (actually a number of smaller projects) involves continuous optimization of campus buildings to improve energy efficiency (UBC 2013a)—this project was not selected as the three projects selected already span the important CLL time periods and project types.

This section provides insight into the challenges that institutions face in trying to incorporate sustainability objectives into operational planning, as well as the solutions developed to overcome them. The work presented in this section represents the beginnings of a roadmap for leveraging institutional operations to help drive systemic change towards more sustainable technologies and practices.

3.6.1 Centre for Interactive Research on Sustainability

CIRS was one of the first projects to be completed as part of the CLL and was the earliest one to commence. This project provides a high level overview of the challenges facing inter-institutional collaboration for projects and it is an artifact of how projects can benefit from having aggressive sustainability goals set early on. Lessons from this also provide a framework for adopting other high performance sustainability buildings.

3.6.1.1 Introduction

CIRS symbolizes the fruition of a vision of Dr. John Robinson who first thought of the concept in 1999. Although CIRS was a $36.9 million dollar capital project, it is more than a typical research building (UBC 2009a). The building was designed to meet four net positive goals (that is, the building creates net benefits to its surroundings in these areas rather than net detriments): “energy, embodied carbon emissions, operational carbon emissions, and water quality” (UBC 2011a). Additionally, CIRS was to go beyond having a laboratory in the building, and instead to have the building itself become a “living laboratory”. This started from the design of the building and carried through construction and operations. During design, a number of charettes (relating to design, water, day lighting, and energy) and following research (including an integrated design process) were used to aid with designing a high performing building with the latest off-the-shelf sustainable technologies. In addition, a charette was held in 2004 that solidified 22 design goals for the project (Fedoruk & Save 2012). This provided an impetus for CIRS to have three net positive performance goals encompassing water , energy, and carbon sequestration. The construction phase carried through with the development of a building information model (BIM) to help with the construction. (Even though this model proved to be underutilized, it did provide a valuable learning experience.) The operating phase of the building allows opportunities for researchers to learn from the building through the aid of over 3,000 sensors integrated into the building for this purpose. Some of the other technology encompassed in the building to form a living laboratory are the following: heat capture from a neighboring building, a geo-exchange system, a reclaimed water system for sewage, a rainwater harvesting system for potable water and fire suppression, a green roof and living wall, natural ventilation, solar hot water and photovoltaic cells. Although some of the items designed have not been operating as effectively as planned (or in some cases, almost not at all), they do serve as part of a learning experience for high performance buildings.[11] A significant amount of work was required to reach this point.

3.6.1.2 Business Process Models

The BPM provided for CIRS in Figure 3.14 represents the actual process that occurred from the initial conception through to the implementation phase. Along CIRS’ 13 year journey from original conception through to occupancy, there were numerous leasons learned. One of the goals of CIRS was to bring together a number of institutions for greater cross-pollination of ideas on sustainability. The challenges involved with multi-stakeholder projects involving multiple universities with equal authority caused delays to the project, which resulted in CIRS being relocated back to the UBC Vancouver

[11] For more details on the operational efficiency of CIRS, refer to Laura Fedoruk’s 2013 UBC Master of Science thesis titled “'Smart' energy systems and networked buildings : examining the integrations, controls, and experience of design through operation”

campus.[12] Also apparent in Figure 3.14 is that the charettes held to aid with the design and systems of the building occurred after the second schematic design was already created for CIRS. This reduced the potential for any significant changes to the design of the building. Additionally, funding was obtained and tied to specific sustainable building components before these charettes, which predetermines some of the elements of the building. The benefit of this was that these components were not "value engineered" out of the building later on. The actual timing of these events is illustrated in Figure 3.14.

The definitions for the swim lanes presented in Figure 3.14 are presented below.

- ***Leadership Team:*** This began as a smaller group of people committed to sustainability at UBC, and then developed into a steering committee in 2003. The steering committee included "representatives from local academic institutions, government agencies, academic researchers and industry" (Fedoruk et al. 2012).
- ***Administration:*** Vice Presidents of the university and the Board of Governors.
- ***Architect:*** The architect on the project.
- ***Faculty / Researcher:*** The faculty member or researcher who develops and leads the idea. In CIRS case this was Dr. John Robinson.
- ***External Partners:*** These are groups with whom strategic alliances were made.[13]
- ***External Project Funding:*** External funding sources who contributed financially to CIRS. These sources were all applied for by the leadership team.

[12] During this time the building design also changed from a square meter high of 10,000 to the current 5,675 (Fedoruk et al. 2012, UBC n.d.).
[13] Modern Green is listed in the "External Project Funding" swim lane instead of the "External Partner" swim lane due to becoming a partner while construction had begun and providing the final investment in CIRS.

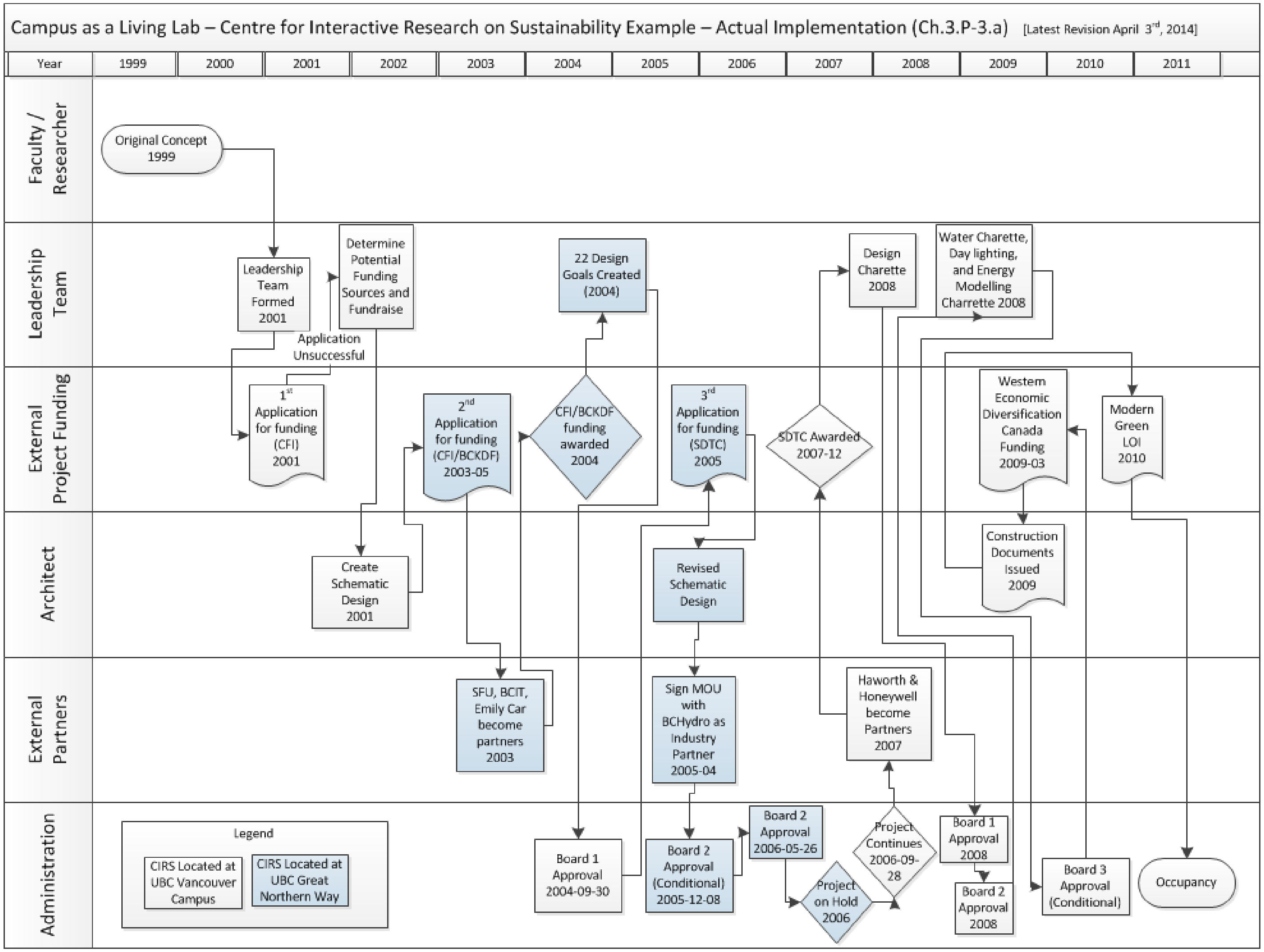

Figure 26: Campus as a Living Lab Centre for Interactive Research on Sustainability example – actual implementation

A full list of the chronological order of events for CIRS is provided in Appendix J Chronological Order of Implementation for the Centre for Interactive Research on Sustainability.

3.6.1.3 Summary

CIRS was a challenging building for a number of reasons. It was developed to integrate the sustainable technologies available; for three years it had numerous stakeholders with equal input for the design; it was relocated twice; and it drastically changed size. Through this process, it provided a number of lessons learned for those interested in developing other high performance buildings: it is helpful to have charettes informing the project early on to aid with technology decisions; linking funding with specific building components can reduce the potential for them to be value engineered away; and having one decision maker can streamline a project.

3.6.2 Academic District Energy System

The Academic District Energy System emerged from a larger initiative to review alternative energy sources at UBC. In addition to hiring a consultant to assist with producing the feasibility study, a local “Energy X Contest” was also created for people at UBC to pitch their ideas for additional options for UBC to pursue. This case study serves as a model of analysis of infrastructure options as well as a model for implementing a campus wide infrastructure system.

3.6.2.1 Introduction

The Academic District Energy System is an $88 million project to convert the campus from steam to hot water. It started in June 2011 and is scheduled to complete the ninth and final phase in January 2016. (UBC 2014a) (UBC 2011d) (Engineers 2014) The project entails the conversion of 131 buildings from steam to hot water, 14 kilometers of hot water distribution piping and a new 60 MW hot water Thermal Energy Centre. This will result in “$5.5 million in annual savings including the cost investment for not reinvesting the aging steam system”, and a reduction of GHG emissions by 22 percent. (Giffin 2014, UBC 2011d)

The catalyst that led to the implementation to the Academic District Energy System was a combination of ageing infrastructure, sky rocketing natural gas prices, newly implemented carbon taxes, public sector offset requirements and the campus looking for ways to reduce the carbon footprint. David Woodson (Director of Utilities at the time) then developed the Alternative Energy Committee and issued an RFI for alternative energy systems. This produced a lot of proposals some of which recommend a feasibility study." (Giffin 2014) This formed the basis for issuing a request for proposal being for a feasibility study. This compiling of the complex request for proposals was a "project in itself" due to the level of detail required (Collins 2014). Proponents were evaluated and then Stantec Consulting was hired and completing this feasibility study in March 2010 with the last revision in June 2010. This feasibility study culminated with several recommendations including: installing biomass (which was already underway), retro-commissioning buildings, continuous optimization, and converting the steam system to hot water.

During the time that the feasibility study was being conducted, the Alternative Energy Committee also wanted to engage the greater campus community to take advantage of local expertise to explore options for improvements on campus and opened up the "Alternative Energy X Contest" for this purpose. The Alternative Energy Committee received 75 two page proposals, and ended up selecting 4 winners because of the breadth, completeness and practical feasibility of their idea's. (UBC 2011b)

After the feasibility study and the contest were completed, a specialist in district energy was consulted and eventually hired to assist with the specifications.

3.6.2.2 Business Process Models

The BPMs provided for the Academic District Energy System project in Figure 3.15 is the original process that was used and is still currently used for the request for proposal process. There was one unique attribute to this process, which is that it concurrently ran an Alternative Energy X contest. The BPM for the Alternative Energy X contest is illustrated in Figure 3.16.

The definitions of the swim lanes for the models in Figure 3.15 and Figure 3.16 are listed below.

- ***Administration:*** Vice Presidents of the university and the Board of Governors.
- ***Alternative Energy Committee:*** 15 people were on this committee, including representatives from operations, campus utilities, campus and community planning Clean Energy Research Centre, the Campus Sustainability Office, mining and engineering, and Dr. John Robinson (who would later become the Associate Provost, Sustainability at UBC).
- ***Industry:*** Companies that responded to the request for proposal and the candidate who was selected to implement the feasibility study.
- ***UBC Community:*** Everyone at UBC, including students, faculty, administration, and the larger community.

As shown in the first BPM presented in Figure 3.15, the process spanned 23 months from initial inception to Board 1 approval. This included six months to develop the committee and design the request for proposals, and approximately twelve months to complete the feasibility study. The feasibility study was also developed with ongoing consultation with the Alternative Energy Committee as illustrated in Figure 3.15.

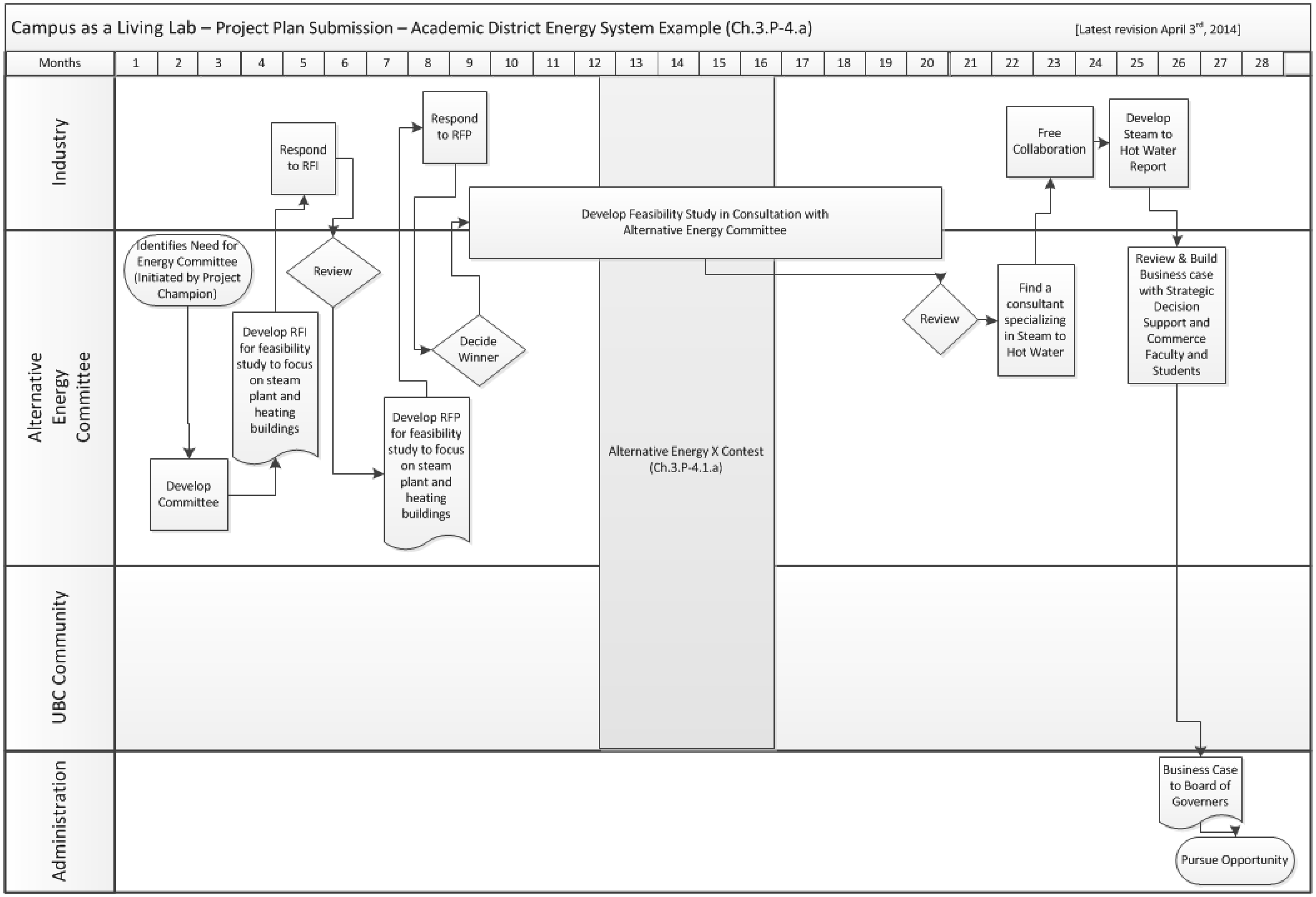

Figure 27: Campus as a Living Lab – project plan submission - Academic District Energy System example

As mentioned, the Alternative Energy X contest was also initiated during the feasibility study to discover more opportunities for energy savings. The contest was designed so that the Alternative Energy Committee would be able to efficiently solicit ideas from the larger community in order to integrate these ideas into the campus operations plan. The contest had a $10,000 prize for the best idea to be implemented on campus and, in the end, four winners shared this prize (Giffin 2014). All of these teams "except one recommended converting from steam to hot water" (Giffin 2014). As illustrated in Figure 3.16, the Alternative Energy X contest was able to be initiated and completed during the time that the feasibility study was being conducted. The Alternative Energy X results were then integrated into Stantec's feasibility study, which included biomass steam to hot water, and continuous optimization.

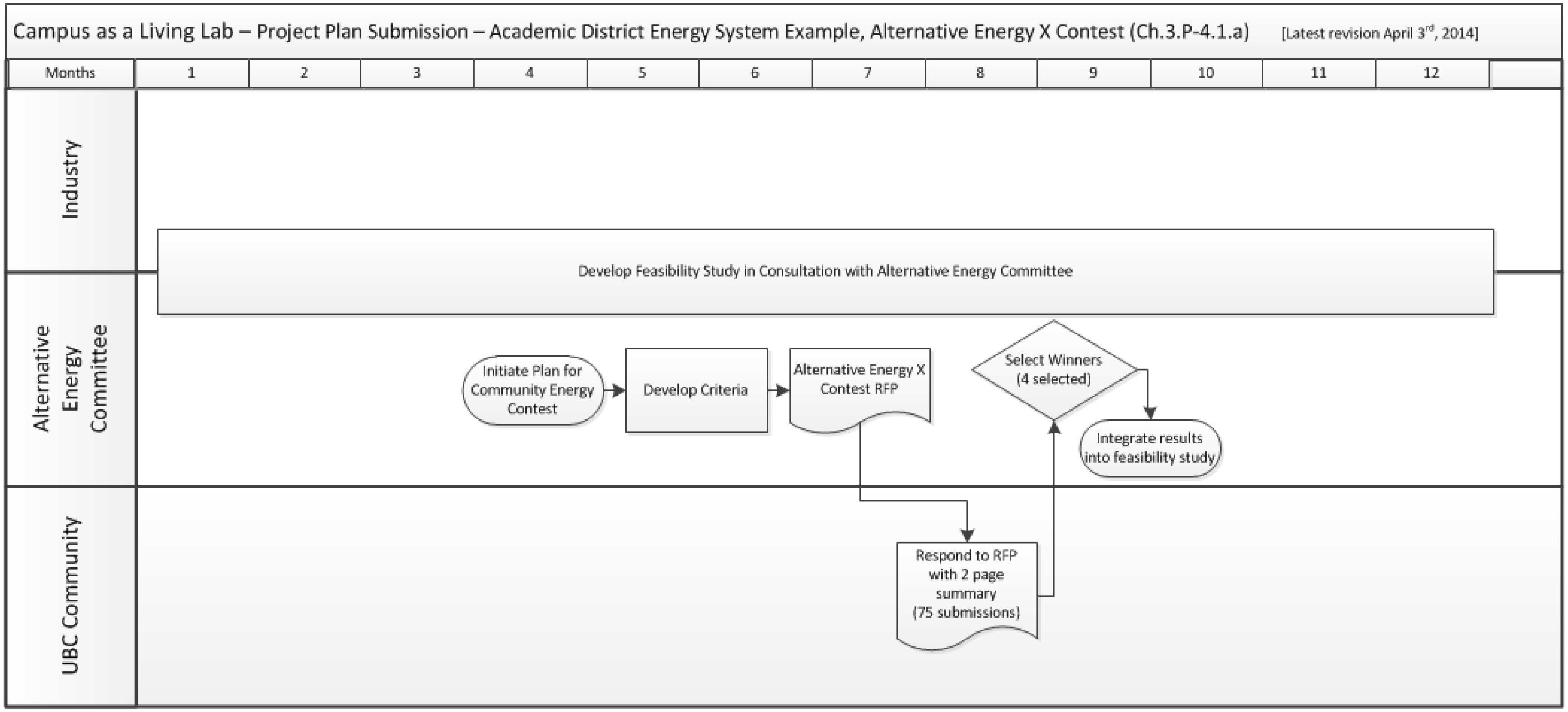

Figure 28: Campus as a Living Lab – project plan submission – Academic District Energy System example, Energy X Contest

3.6.2.3 Summary

In order to determine the optimum energy strategy for a campus, it is helpful to understand all the options available through a feasibility study and then narrow down the best options. This can be achieved by referring to experts on campus, but can be even more useful to combine these experts with third party consultation. Additionally, allowing an avenue for the larger campus community to provide ideas can render meaningful results for the campus.

3.6.3 Bioenergy Research and Demonstration Facility

The Bioenergy Research and Demonstration Facility project represents a unique opportunity to apply the proposed modelling methodology, as it was initiated before the CLL processes had been formally established. This case study provides insight on lessons from implementing a project before a structured process was in place. It also was a starting point from which UBC would build for analyzing future projects.

3.6.3.1 Introduction

The processes presented in this section focuses on the Bioenergy Research and Demonstration Facility, which is a signature CLL project, but is just one of many projects that have been undertaken within the CLL program. The Bioenergy Research and Demonstration Facility represents a $27 million investment in using a renewable resource for fuel and reducing the demand for imported power on campus (UBC, 2012b). The Bioenergy Research and Demonstration Facility was designed to operate in two modes: Thermal Mode and Demonstration Mode. Thermal Mode was designed to produce heat in the form of steam at the rate of 20,000 pounds per hour. This would reduce UBC’s base requirement on natural gas heating, and reduce UBC’s GHGs by 9,000 tonnes per year (UBC 2014b). Demonstration Mode was designed to generate “approximately two megawatts of electricity and 9,600 pounds per hour of steam”, which would reduce “UBCs GHGs by 5,000 tonnes per year” (UBC 2014b). Although the plant is not currently running at full capacity, a significant amount of work was required just to reach this point.

Conversations regarding a Bioenergy Research and Demonstration Facility had begun in 2008 between UBC's Clean Energy Research Center and Nexterra Corporation, with a decision to proceed with the project in 2009 (UBC, 2010c). This was all at a time when UBC was evaluating the best measures to pursue as part of an alternative energy feasibility report. Due to an opportunity to create the Bioenergy Research and Demonstration Facility at potentially zero cost to UBC, this project was chosen to proceed before the feasibility study was completed. Since this was one of the first projects to go through the CLL, the lessons learned would serve as a framework for all future projects.

3.6.3.2 Business Process Models

The BPMs provided for this project include the original process that was used, as well as a comparison to what is currently being administered at the CLL. The original process in Figure 3.17 illustrates how few checks and balances were in place before the adoption of more recent CLL practices beginning in September 2010. The comparison of processes in Figure 3.18 shows what new processes were included as a result of the learnings from the Bioenergy Research and Demonstration Facility.

The definitions of the swim lanes for the original model are listed below.

- ***Administration:*** Vice Presidents of the university and the Board of Governors.
- ***Campus & Community Planning:*** "The urban planners, designers, engineers, public consultation professionals, building inspectors and sustainability experts dedicated to creating a vibrant, sustainable, live-work-learn community at UBC" (UBC 2014c).
- ***Faculty / Research:*** The faculty or research member involved.
- ***Industry Partner:*** Company contracted to implement the Bioenergy Research and Demonstration Facility
- ***Institutional Project Approval:*** In UBC's case, this is the Board of Governors.
- ***Legal / Contract:*** The legal department.

- ***Operations:*** The building operations department.

It should be noted that the current models only extend up to the first “institutional project approval” phase, which the equivalent is “Board 1” on the Bio-energy Research and Diversification Facility example shown in Figure 3.17. It can also be seen that there is no governing group that oversees the project and that Operations has only been included to assign resources rather than act as a collaborator. More of the differences are easier to view in the comparison example in Figure 3.18.

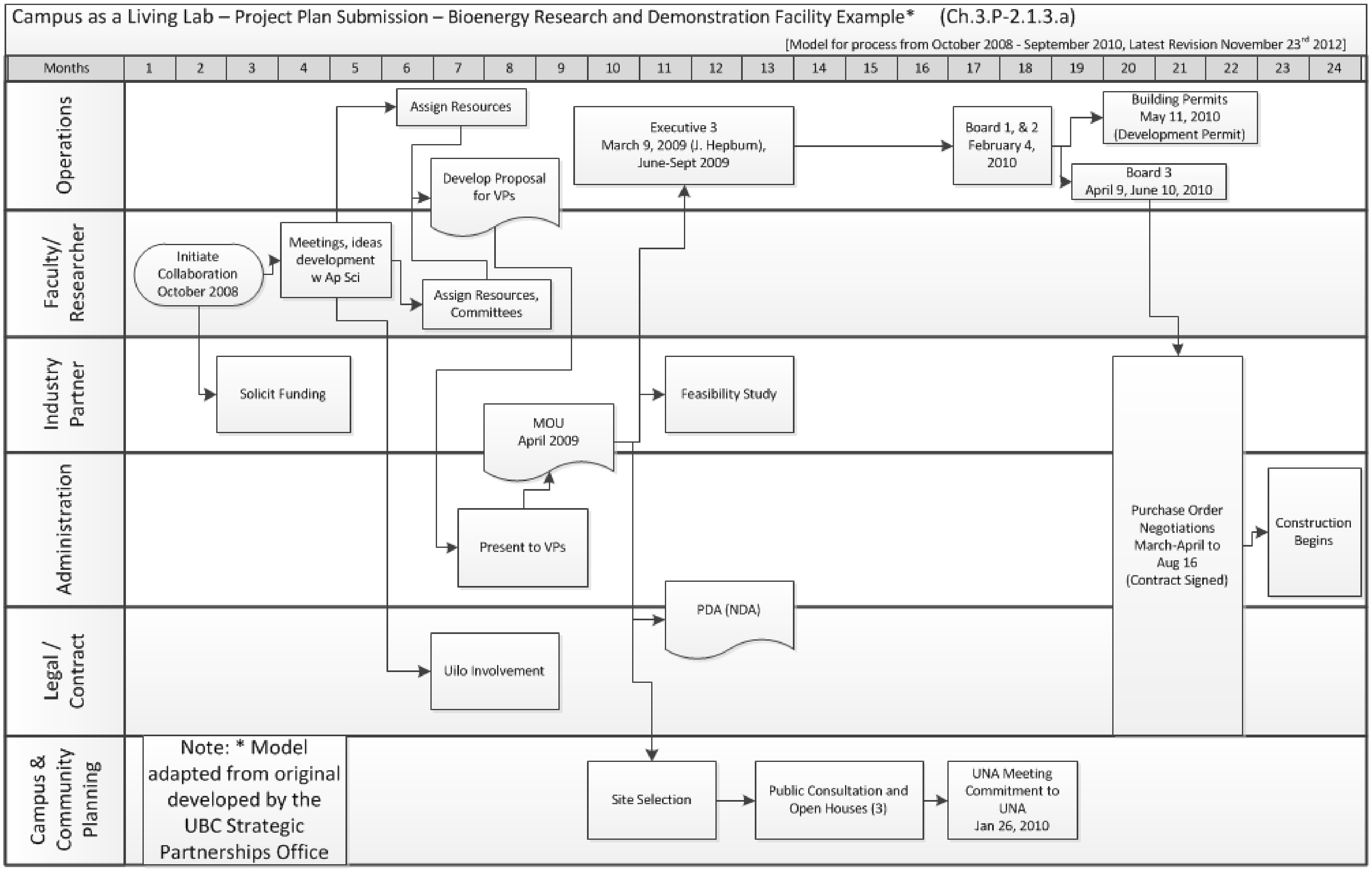

Figure 29: Campus as a Living Lab – project plan submission – Bioenergy Research and Demonstration Facility example

Shortly after construction began on the Bioenergy Research and Demonstration Facility, a meeting was held on February 4th, 2011 to debrief on the process undertaken (UBC 2011c). This meeting documented the following eight emergent themes:

1. stakeholder engagement,
2. funding,
3. managing expectations,
4. legal, risk assessments,
5. champions and project managers,
6. due diligence,
7. information sharing,
8. communications

From these themes, 12 recommendations emerged:

1. "Expand public consultations process to include other elements of community engagement (resources on engagement here: http://tamarackcommunity.ca/). Proactive consultation is required early and often.
2. Provide sufficient funding and/or resources for prefeasibility and feasibility resources, project management, and due diligence and evaluation.
3. Identify secure project funding earlier in the project life cycle to prevent a 'moving target' when approaching the UBC [Board of Governors]
4. Inform all stakeholders of process steps, key decisions, milestones, and all UBC expectations at the outset.
5. Identify and share expectations and needs of all stakeholder groups at the project outset.
6. Host project kick-off with all players.

7. Share broad vision, knowledge, context, and objectives of project, creating a consistent message and understanding of the project for all stakeholders.

8. Identify and adequately resource project managers and key champions within the organizations.

9. Assess all potential projects using technical and sustainable criteria, as well as against alternative possibilities to ensure adequate due diligence. Ask the right questions.

10. Coordinate communications with all stakeholders; ensure announcements are timely and have been approved by all stakeholders.

11. Develop risk assessment and evaluation document to guide/frame various interactive or negotiated steps in the development of the Project

12. Need a Process road map that lays out the Action Steps required to Action a Project" (UBC 2011c)

From these recommendations, the current models were developed. Figure 3.18 illustrates the improvements made on the processes. It can be seen that there were significantly fewer checks in place throughout this process, as noted by the grey highlighted items that were not in place for the Bio-energy Research and Demonstration Facility project.

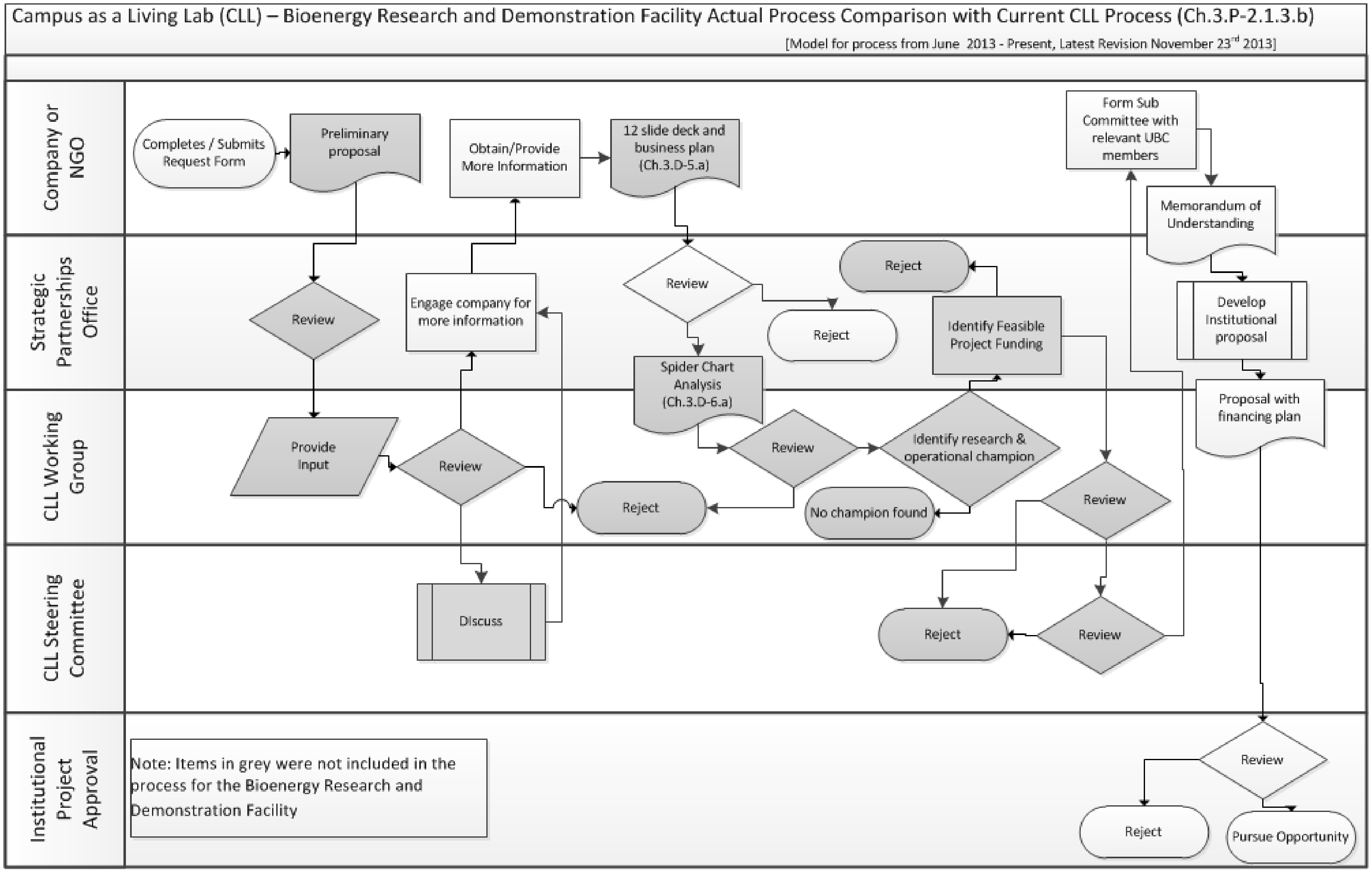

Figure 30: Bioenergy Research and Demonstration Facility actual process comparison with current CLL process

3.6.3.3 Summary

In summary, the Bioenergy Research and Demonstration Facility project represents a unique opportunity for exploring the development of the CLL and early lessons. Immediately following the implementation of the Bioenergy Research and Demonstration Facility, eight themes for improvement emerged with 12 specific recommendations. These have since been implemented along with a significant increase of other checks and balances, including a preliminary review of the company and proposed technology via a slide deck and additional review using a spider chart analysis. These have all contributed to better understanding of potential projects and the risks involved.

3.6.4 Summary

CIRS was a challenging building for a number of reasons. However, it does demonstrate that it is helpful to have charettes informing the project early to aid with technology decisions; that linking funding with specific building components can reduce the potential for them to be value engineered away; and that having one decision-maker can streamline a project. The Academic District Energy System showed how long of a process it can be to evaluate campus energy options and how both third party consulting and the campus community can collaborate. From the Bioenergy Research and Demonstration Facility emerged the foundation for current CLL processes. This was provided by a post-project review with all participants who determined the need for frequent checks and balances and greater stakeholder engagement. This also leads to a better understanding of potential projects and the risks involved.

3.7 Organizational Transformation

3.7.1 Introduction

The CLL was an institutional change in the way that UBC had previously thought about both operations and sustainability. The ability to tie these two together—along with an opportunity to leverage campus infrastructure as a test bed for sustainable technologies to be proven for commercialization—could be challenging for people to accept and implement. In order to overcome this, an organizational transformation is required to develop the foundation for a successful CLL experience. In order to aid with this transition, key transferable characteristics, recommendations for improvement, and a model for self-evaluation are provided.

3.7.2 Important Attributes

There are a number of important attributes that could potentially be useful in implementing a CLL in other institutions:

1. Bottom up and top down support for the program is needed to be truly effective.
2. Vision, mission, and objectives specific for the CLL need to tie into larger university objectives.
3. Process maps to illustrate the flow of a project from initial contact to acceptance can help with knowledge transfer, analysis of what is occurring, and improvements.
4. Multi-stakeholder committees can provide a depth of expertise and expand potential connections for research projects.
5. Tools to analyze opportunities for alignment with campus objectives aid with strategic decision making and can shift the project focus from being reactive to proactive

This can be viewed as a constant cycle of improvement for the CLL, illustrated in Figure 3.19.

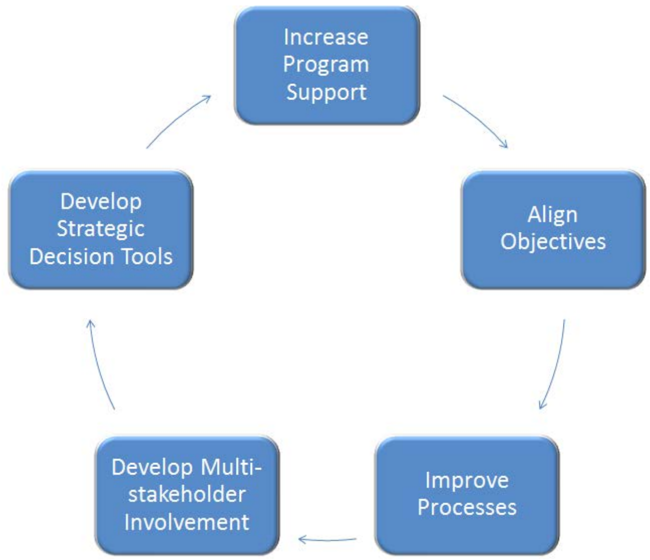

Figure 31: Model for self-reflection

3.7.3 Recommendations for Improvement

Although there are a number of positive attributes to the CLL, there are some items that could be improved. The current items for improvement and suggestions for improvement are listed below.

1. Due to time constraints of committee members and the limited number of people involved, only “obvious” connections or people who the committee members already know are contacted for engagement in projects. This is partly due to it being very difficult to know what everyone on the campus is working on or has expertise in.

    a. Have a more diverse range of people present at meetings and/or a website with listings of opportunities could increase engagement.

    b. Involve someone with knowledge about how to include the social context of sustainability in projects. This could generate more inter-disciplinary learning.

2. Industry partners can be more interested in the development and commissioning of projects, but there can still be quite a bit of learning to be completed during the operation phase.

    a. Engage industry for involvement deeper into the operational phase.

3. Sustainability indicators for the Spider Chart tool to analyze projects are not yet completed.
    a. These are important for more rigorously analyzing CLL projects through a sustainability lens
4. There have been some projects that have not performed as well as originally anticipated.
    a. Include performance as part of the contract to reduce risk.

3.7.4 Key Transferable Characteristics

There are a number of key transferable characteristics that can be extracted from this chapter. These will also be later utilized in Chapter 5 in the creation of generic BPMs. A list of these characteristics is as follows:

1. organizational structure for the USI and the CLL,
2. diverse multi-stakeholder committee membership structure,
3. process of categorizing projects based on size (high-level view),
4. process of project evaluation (due diligence) and approval (mid-level view),
5. tools for project evaluation: slide deck and spider chart,
6. selection of a research champion,
7. process for selecting strategic partners,
8. design goals and charettes for high performance buildings,
9. linking funding to sustainable technologies so that they are not value engineered out the equation,
10. contests to solicit ideas for alternative energy or otherwise,
11. linking feasibility studies to contests for the wider community to contribute ideas.

3.7.5 Summary

There are a number of important attributes that emerged, including increasing support for the CLL, aligning CLL goals with larger university objectives, improving processes, developing multi-stakeholder involvement, and developing strategic decision making tools. It was also found that there could be improvement in the current UBC CLL practices. Some of these improvements include increasing the diversity of the people in the multi-stakeholder meetings, having industry partners stay involved longer into the project life cycle, developing sustainability indicators for projects, and linking performance to project contracts to potentially reduce risk. A number of key transferable characteristics were also extracted from this Chapter in order to be utilized later in Chapter 5.

3.8 Conclusion

The CLL has developed over a long course of time that stretches back to 1990. In 2009, the advancement of the CLL was accelerated due to a number of strategies and efforts. The CLL Working Group and Steering Committee is part of a broader University Sustainability Initiative (USI) that encompasses many stakeholders. The focus of the CLL Working Group is largely on identifying and pursuing opportunities and on the pre-planning phase of projects' life-cycle. The concentration on this phase places the CLL in the best position to accelerate sustainable technology commercialization by positioning the UBC campus as a test bed.

The CLL projects fall into two main categories: unsolicited and solicited. Due to an influx of unsolicited requests, the CLL needed to adapt to a more proactive, rather than reactive, model of governance. In order to achieve this, assessment tools for varying levels of analysis were developed to evaluate project fit within the UBC campus. Additionally, a project steering committee and three sub committees (research, operations, and emissions) were devised to provide support for projects that require it. There was also a rigorous approach for selecting partners through a solicited approach.

In deciding how to potentially improve on future projects, three case studies were used: CIRS, the Academic District Energy System, and the Bioenergy Research and Demonstration Facility. These case studies were chosen as they gave a reference case to a building, an analysis of campus wide infrastructure options and a project. They also represent energy consumption, transmission, and generation.

CIRS demonstrated how it is helpful to have charettes informing the project early to aid with technology decisions. Additionally, linking funding with specific building components can reduce the potential for specific items to be value engineered away, and having one decision maker can streamline a project. The Academic District Energy System showed how long of a process it can be to evaluate campus energy options and how both third party consulting and the campus community can collaborate. From the Bioenergy Research and Demonstration Facility emerged the foundation for current CLL processes.

There are a number of important attributes that emerged, including increasing support, aligning goals, improving processes, developing multi-stakeholder involvement, and developing strategic decision making tools. Improvements to current CLL practices were also touched upon and key transferable characteristics were provided for use later in Chapter 5.

Chapter 4. Analysis of Campus as a Living Lab Activities

4.1 Introduction

This chapter describes the application of an ethnographic study to analyze the CLL. This was achieved by collecting 517 aggregated meeting items (topics discussed) from 36 CLL Working Group meetings across eight categories and 40 processes. These processes were either adapted from the frameworks developed by the Project Management Institute and the American Productivity and Quality Center, or created specifically to capture issues relating to the CLL. From the key findings of this study emerged proposed processes to be implemented in the generic BPMs in Chapter 5.

4.1.1 Objectives

The main objectives of this chapter are to identify themes from CLL Working Group meetings, and to review these themes for key transferable characteristics.

4.1.2 Research Questions

As there was little literature about the CLL, hands-on experience was needed to understand and collect data about the program. To provide this foundation, the author requested permission to attend the CLL Working Group, the CLL Steering Committee, and the USI Steering Committee. This was to understand how they achieve the overall sustainability, operational, and research goals of UBC. In order to answer this, the research questions that the author posed were the following:

- What occurs in the CLL Working Group and Steering committee meetings?
- How does this translate into future action?
- When do these follow-up actions occur?
- How does the CLL Working Group interact with other committees?
- What aspects of these meetings can be captured in BPMs?

- What other forms of tacit or explicit knowledge helpful to the implementation of living labs can be acquired?

Answering these questions is important to the objectives of this thesis, which are to document and model the processes, reconcile the models with emerging processes, and suggest improvements.

4.1.3 Methodology Selection

After reviewing various research methodologies for analyzing CLL meetings in order to answer the research questions posed, an ethnographic research methodology was selected. It was found that an ethnographic approach would best facilitate a concrete understanding of the subject matter. In the case of the CLL meetings, the subject matter was the development of processes; methods to decide which projects to pursue; and the development of collaborative relationships between industry, operations and researchers. Examples of this subject matter include the following:

1. Flow charts developed by Brent Sauder to visually capture the process for unsolicited proposals as they flow through the CLL.

2. Spider chart developed by Iain Evans to assess individual characteristics that are important to the CLL so as to decide whether a project should be further investigated and potentially pursued.

3. Contracts with industry as they develop from lessons learned and from feedback from operations and researchers.

The Campus as a Living Lab is constantly evolving and improving. Members are questioning current practices in order to make strides forward. Thus, the CLL can be viewed as a learning system; all parts of the system involve some form of learning.

At the heart of this system is the CLL Working Group. Consisting of academic members, UBC administrators, students, external partners, meetings among these and a succession of town hall meetings, the Working Group emerged from the "Sustainability Academic Strategy" as a mechanism for learning, clarifying existing knowledge, and conceiving of new ideas. Although the goal of this group may not be to "learn" as much as it is to "do" as in the form of achieving campus sustainability goals, there is constant learning occurring.

In order to further develop already existing documents and processes created by and available for the CLL internally, it is important to understand what types of interactions are occurring. After attending the first CLL Working Group meeting on December 6th, 2012, it was observed that there was a high degree of tacit knowledge that could be difficult to capture without attending regular meetings. Additionally, it seemed as though the research questions would not be able to be answerable with any type of questionnaire or from only a couple interviews with individuals. Therefore, an ethnographic research methodology (introduced in Section 2.6) was chosen.

4.1.4 Ethnographic Study of Campus as a Living Lab Activities

4.1.4.1 Introduction

This section discusses the author's participation role in the meetings, the data collection, and the field note coding.

4.1.4.2 Observer as Participant

As described in Section 2.6.2, there are a number of methods available for collecting ethnographic data. While participant observation may be a widely used method, there are also four types of this observation: complete participant, participant-as-observer, observer-as-participant, and complete observer. For purposes of this thesis, the author's role was originally a complete observer, but quickly morphed into an "observer-as-participant" role since there were a number of times that the committee welcomed the author's suggestions and opinions. About halfway through obtaining these observations, the author gave a presentation to the committee on research that addressed the comparison of modelled energy consumption versus actual energy consumption on five UBC buildings. For the purposes of this meeting, the author briefly became a participant-as-observer. As this research extended over 16 months, the group became increasingly familiar with the author. Nevertheless, it is important to note that the processes were the subject of observation, not the people participating in the meetings. In this way, there was potential for group members to be more open than if the individuals themselves were being studied.

As noted in Section 2.6.2, having some activity in a meeting while also observing that meeting can increase the researcher's "identification with the observed" and can help the researcher to be "better able to become aware of the subtleties of communication and interaction" (Schwartz & Schwartz 1995).

4.1.4.3 Data Collection

Before writing any field notes, 98 weekly CLL Working Group and 20 monthly Steering Committee meeting minutes and associated documentation were reviewed. This facilitated an understanding of the evolution of the CLL, and provided a foundation for developing a method of writing notes. There were notes on project updates, project assessment, project funding, recruitment of researchers for projects, and finding projects for researchers and students.

The period of data collection in the form of field notes stretched over 16 months from December 6th, 2012 through March 27th 2014. During this period, 36 CLL Working Group meetings and four Steering Committee meetings were attended by the author. As the meeting notes themselves must remain confidential, they are not provided in this thesis; however, information about these meetings, such as the high-level topics of conversation and the periodicity with which they occurred was synthesized in a dataset and analyzed as discussed in the following sections. The dates of the CLL Working Group meetings attended and the corresponding number of data points are also included in Appendix E CLL Meetings Attended. Audio or video recordings were never requested due to the potentially sensitive nature of some of the meeting content. Additionally, even if they were allowed, it would change the tone of the meetings, which would skew the results of the research on what processes naturally occur.

For the purposes of consistency in the data collection where the meetings were attended by the researcher, every attempt was made to capture the content of the conversation during regular intervals (i.e., every five minutes). However, sometimes an "in-camera" session occurred, or topics changed rapidly within the intervals, so this was not always possible. At other times, it seemed as though there were more items of importance that arose within short periods of time, so more notes were taken. The meetings ranged from 45 to 90 minutes in length with the majority of meetings taking longer than 60 minutes.

As the CLL Working Group had been first organized in April of 2010, the 16 months of meeting attendance spanned over one third of the group's existence. In the hopes of gaining a deeper understanding about the development of the social entities under consideration (in this case, living labs), the theory of expansive learning developed by Engoström (2001) was reviewed. This theory indicates that "a full cycle of expansive transformation may be understood as a collective journey through the zone of proximal development of the activity" (Engeström 2001). Engoström elaborates, "activity systems take shape and get transformed over lengthy periods of time. Their problems and potentials can only be understood against their own history." An objective of this thesis is to explain what is occurring within the CLL and to evaluate its past and current trajectory. As the CLL developed over a long period of time, the Engoström theory was helpful to understanding this social entity.

In addition to collecting data in the form of field notes, meeting minutes were collected from past meetings of the CLL Working Group, CLL Steering Committee, and USI Steering Committee. BPMs were already developed and tools for strategic decision-making, including the spider chart and slides for assessing projects, are detailed in Section 3.4.2.2.

4.1.4.4 Coding Field notes

Notes taken from the meetings were formatted to allow for easier reference later; this involved coding the notes taken from each interval (approximately five-minutes) into discrete "data points". Collected together in an Excel spreadsheet, each data point refers to the date a meeting occurred and whether or not a particular issue was covered in that meeting, which is marked as an "x" to affirm coverage. An example of a covered issue would be an update on a project or information about students looking for research projects. An illustration of this formatting is provided in Figure 4.1.

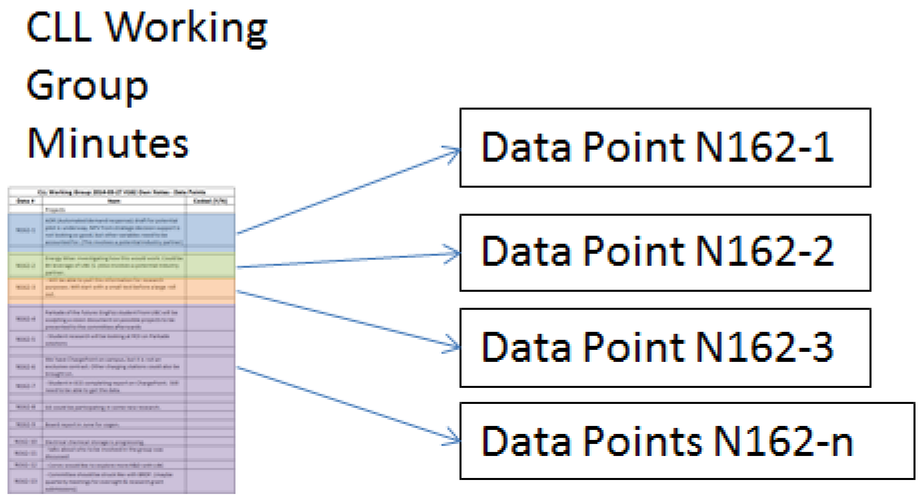

Figure 32: CLL Working Group field note example

The original plan was to plot each data point against a classification system comprised of a combination of the American Productivity and Quality Center's (APQC) cross industry process classification framework and the Project Management Institute's (PMI) Project Management Body of Knowledge. Although these frameworks were found to be useful, an initial trial of plotting of 67 data points from five random meetings showed that these frameworks did not adequately capture all of the data point categories, and a number of additional sections were added to facilitate coding. Further, it was found that approach of plotting data points in 517 columns across more than 573 rows of category headings, processes and sub-processes lead to more detail and was more cumbersome than was originally envisioned.

To simplify the analysis, the field notes, the two frameworks from APQC and PMI, as well as the 67 data points plotted from five random meetings were reviewed in order to utilize a thematic network approach as explained in Section 2.6.4. Figure 4.2 illustrates how these were originally plotted and how new items were also added in a green italic font when they emerged. These new items represent a new process that was not listed with the APQC or PMI frameworks.

	N162-1	N162-2	N162-3	TOTAL
APQC				
Define the business concept and long term vision (1.1)				
Assess the external environment (1.1.1)	x			1
Survey market and determine customer needs and wants (1.1.2)		x		1
Perform Internal Analysis (1.1.3)				
Establish Strategic Vision (1.1.4)				
PMI				
Initiating Process Group (P3.3)				
Develop Project Charter (P3.3.1)				
Identify Stakeholders (P3.3.2)	x	x		2
Identify Key Components of MOU				
Planning Process Group (P3.4)				
Develop Project Management Plan (P3.4.1)				
Collect Requirements (P3.4.2)			x	1
Define Scope (P3.4.3)	x			1
Create WBS (3.4.4)		x		1
Define Activities (3.4.6)				

Figure 33: Original plotting of data points across the APQC and PMI frameworks

Using this spreadsheet approach, a simplified eight-category, 40-process, CLL Process Framework was developed to plot all the 517 data points from the field notes. This process was iterative, as each time a data point did not seem to fit in a sub-process, a new sub-process was created. Consequently, all data points previously plotted were reviewed to ensure that the new process received the appropriate number of entries in the spreadsheet. This occurred 7 times throughout this process. Additionally, once items were plotted, data points in each process were checked for consistency.

The resulting framework is listed in Table 4.1. The framework from which each process was adapted is listed, along with the category from which it was copied or adapted. For example, process "(3.2) Evaluate risk, determine and implement risk mitigation strategies" was adapted from the APQC process 10.0 and PMI's process 11.0. Additionally, it changed sufficiently enough that it was also determined to be a new item. On the other hand, category "(2.0) Develop and Manage Business Capabilities" is the exact wording listed in the APQC framework category 12.0, so this is noted with the letter "A" for exact match. This framework represents a thematic network with a global theme (CLL Process Framework), organizing themes (categories), and basic themes (processes).

Table 15: The derivation of the Campus as a Living Lab-Specific Classification Framework

Campus as a Living Lab Process Framework Creation

[Legend: "A" = Exact Match, "B" = Adapted From, "C" = New / Substantive Changes Made]

Category / Process	APQC	Section	PMI	Section	New
(1.0) Develop Vision, Strategy and Assessment Tools	B	1.0			C
(1.1) Develop, evaluate, establish, and re-evaluate vision and mission	B	1.0			
(1.2) Develop, evaluate, establish, and re-evaluate high level goals	B	1.0			
(1.3) Develop, evaluate, establish, and re-evaluate objectives	B	1.0			
(1.4) Develop, evaluate, establish and re-evaluate organizational structure, reporting, and governance	B	1.2.5			
(1.5) Develop, evaluate, establish and re-evaluate tools for assessing projects					C
(1.6) Learn from others and develop ideas for improvement					C
(2.0) Develop and Manage Business Capabilities	A	12.0			
(2.1) Develop, evaluate, establish, and re-evaluate human resource management, planning, policies, and strategies	B	6.1	B	9.0	
(2.2) Manage financial resources	A	8.0			
(2.3) Develop, evaluate, establish, publish, and re-evaluate process management	B	12.0			
(2.4) Develop, evaluate, establish, and re-evaluate knowledge management practices	B	12.5			
(2.5) Develop, evaluate, establish and re-evaluate metrics for post-implementation of projects					C
(2.6) Plan meetings					C
(3.0) Develop Opportunities					C

Campus as a Living Lab Process Framework Creation

[Legend: "A" = Exact Match, "B" = Adapted From, "C" = New / Substantive Changes Made]

Category / Process	APQC	Section	PMI	Section	New
(3.1) Develop, and evaluate opportunities	B	2.0			C
(3.2) Evaluate risk, determine and implement risk mitigation strategies	B	10.0	B	11.0	C
(3.3) Evaluate opportunity alignment with vision, mission, goals, and objectives	B	2.1.4			
(3.4) Identify requirements, objectives and resources for opportunities			B	3.4	C
(3.5) Develop, and evaluate, and present business case(s)	B	12.2.3.1.5	B	3.4	
(3.6) Develop requests for information/proposals; negotiate, establish, and manage contracts	B	4.2			C
(3.7) Develop, evaluate, and obtain funding	B	12.2.3.1.5			
(4.0) Assess the Environment					C
(4.1) Assess internal needs, capabilities, and opportunities					C
(4.2) Evaluate the internal economic, environmental, and social landscape					C
(4.3) Assess external needs, capabilities, and opportunities	B	3.0			
(4.4) Evaluate the external economic, environmental, and social landscape					C
(5.0) Manage Researcher Opportunities					C
(5.1) Identify projects for researchers / students looking for collaboration opportunities					C
(5.2) Identify research champion					C
(5.3) Identify potential candidates for research opportunity available					C
(5.4) Engage researchers already working on projects external to Living Lab for information / updates					C
(5.5) Engage researchers already working on projects internal to Living Lab for information /					C

Campus as a Living Lab Process Framework Creation

[Legend: “A” = Exact Match, “B” = Adapted From, “C” = New / Substantive Changes Made]

Category / Process	APQC	Section	PMI	Section	New
updates					
(6.0) Relationship Management	B	11.0			
(6.1) Develop, evaluate, and manage external Campus relationships	B	11.0			C
(6.2) Develop, evaluate, and manage internal Campus relationships	B	11.0			C
(6.3) Develop, evaluate, establish, and re-evaluate internal and external relationship service	B	5.0			C
(7.0) Marketing and Communications	B	3.4			
(7.1) Develop, evaluate, establish, and re-evaluate marketing and communications strategy					C
(7.2) Implement marketing and communications strategy			B	10.0	C
(7.3) Share information about upcoming and past events/meetings within committee					C
(8.0) Project Management			B	3.0	
(8.1) Receive updates and provide feedback on project scope			B	5.0	C
(8.2) Receive updates and provide feedback on project schedule			B	6.0	C
(8.3) Receive updates and provide feedback on project cost			B	7.0	C
(8.4) Receive updates and provide feedback on project human resources			B	9.0	C
(8.5) Receive updates and provide feedback on project risk			B	11.0	C
(8.6) Receive updates and provide feedback on project procurement			B	12.0	C

All of the data points were then plotted across these processes. An illustration of this is provided in Figure 4.3.

	N162-14	N162-15	N162-16	TOTALS
Develop Vision, Strategy and Assessment Tools (1.0)				**148**
Develop, evaluate, establish, and re-evaluate vision and mission				**5**
Develop, evaluate, establish, and re-evaluate high level goals				**13**
Develop, evaluate, establish, and re-evaluate objectives				**14**
Develop, evaluate, establish and re-evaluate organizational structure, reporting, and governance				**21**
Develop, evaluate, establish and re-evaluate methods and tools for assessing projects				**41**
Learn from others and develop ideas for improvement				**54**
Develop and Manage Business Capabilities (2.0)				**61**
Develop, evaluate, establish, and re-evaluate human resource management, planning, policies, and strategies				**7**
Manage departments financial resources				**1**
Develop, evaluate, establish, publish, and re-evaluate process management				**10**
Develop, evaluate, establish, and re-evaluate knowledge management practices				**8**
Develop, evaluate, establish and re-evaluate metrics for post-implementation of projects				**4**
Plan meetings				**31**
Develop Opportunities (3.0)				**257**
Develop, and evaluate opportunities			1	**63**
Evaluate risk, determine and implement risk mitigation strategies	1	1		**32**
Evaluate opportunity allignment with vision, mission, goals, and objectives				**28**
Identify requirements, objectives and resources for opportunities	1	1	1	**54**
Develop, and evaluate, and present business case(s)				**18**
Develop requests for information/proposals; negotiate, establish, and manage contracts				**26**
Develop, evaluate, and obtain funding				**36**
Assess the Environment (4.0)				**161**
Assess internal needs, capabilities, and opportunities				**89**
Evaluate the internal economic, environmental, and social landscape				**26**
Assess external needs, capabilities, and opportunities				**29**
Evaluate the external economic, environmental, and social landscape				**17**

Figure 34: Example of plotting data Points across Campus as a Living Lab Process Framework

4.1.4.5 Summary

In summary, data collection occurred over the span of 16 months beginning on December 6th, 2012 and lasting through to March 27th, 2014. A total of 36 meetings were attended, which resulted in 517 data points. A CLL-specific framework for coding the field notes was developed from an amalgamation of categories, processes, and sub-processes from the APQC and PMI frameworks. Upon analyzing this dataset, a number of key findings emerged.

4.2 Key Findings

4.2.1 Introduction

In order to distill the data after plotting of data points across the CLL Process Framework, quantitative and qualitative methods were used.

4.2.2 Quantitative Analysis

For the qualitative portion, an examination of the location of the data points was carried out.

Perhaps not surprisingly, the category with the most data points was category "(3.0) Develop Opportunities" followed by "(4.0) Assess the Environment", then "(1.0) Develop Vision, Strategy, and Assessment Tools". These meetings generally tended to juggle priorities, from reviewing opportunities to developing assessment tools and ways to improve. As of recently, the meetings have prioritized the need to assess energy on campus, so category (4.0) has taken the second largest portion.

These results are provided in Figure 4.4.

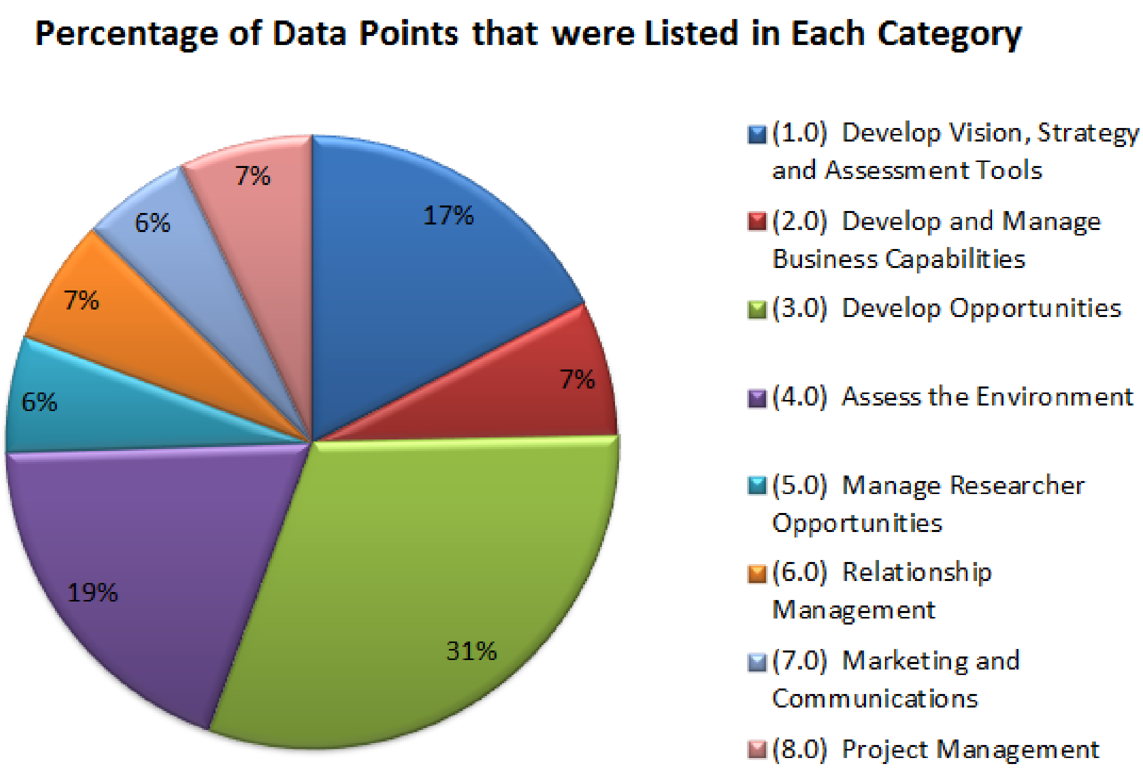

Figure 35: Percentage of data points that were listed in each category

A full breakdown of the number of data points listed is provided in Appendix K.

A review of how priorities shift over time was completed to understand how the CLL Working Group balances their workload (Figure 4.5). All categories were first graphed together to identify any interesting relationships. Patterns for three categories in particular emerged. For the first 260 data points, it would appear that the categories “(3.0) Develop Opportunities” and “(1.0) Develop Vision, Strategy, and Assessment Tools” are in constant flux. This fluctuation indicates movement between conducting the work itself and trying to improve strategies for the work that is conducted. From data points 261 onwards “(4.0) Assess the Environment”, and “(3.0) Develop Opportunities” are in flux. This is due to the current urgency to develop a comprehensive energy plan for UBC campus.

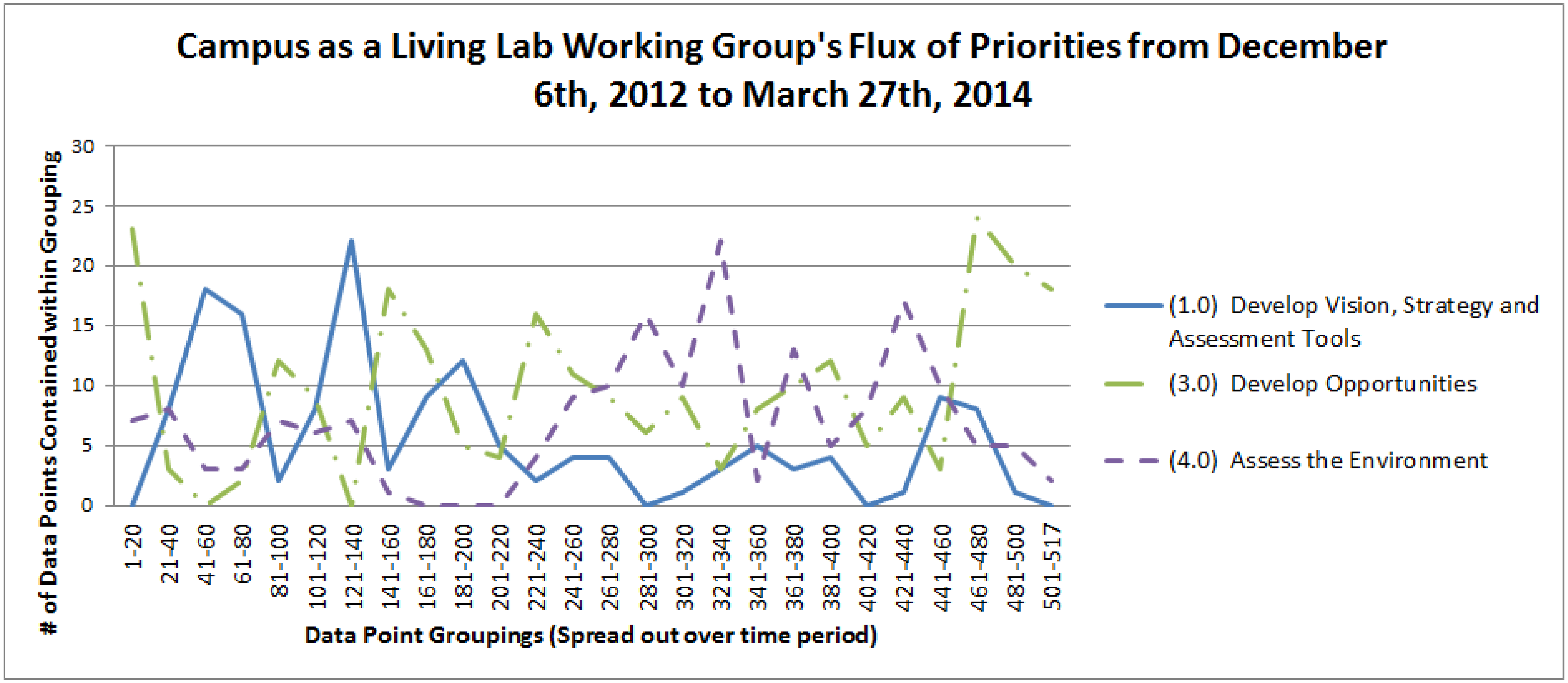

Figure 36: Campus as a Living Lab Working Group's flux of priorities from December 6th, 2012 to March 27th, 2014

A simpler representation of the flux in priorities described above is shown in Figure 4.6. This is meant to extract the flow between "Develop Opportunities" and "Develop Vision, Strategy, and Assessment Tools" for the first 260 data points listed in the previous Figure 4.5.

Figure 37: Campus as a Living Lab Working Group flux of priorities

Figure 4.6 demonstrates how the CLL Working Group has been in a state of "catch-up" and that the shift from reactive to proactive has taken longer than may have been anticipated. This could also be partly due to the fluctuating workload of each member of the CLL Working Group and the lack of consistent time available to the group, undeterred by outside pressures. One opportunity would be to budget and plan for a CLL Working Group strategic retreat.

4.2.3 Qualitative Analysis

This section provides a qualitative analysis based on the following method:

1. development of a thematic network and,
2. development of sub-themes based on categories in the thematic network.

As previously mentioned in Section 2.6.4, there is a lack of tools available for systematically, and methodically analyzing the data and that using a method of developing a thematic network helps to overcome this (Attride-Stirling 2001). Thematic networks begin by aligning every data point with a basic theme, then every basic theme with an organizing theme, and finally a global theme. An illustration of this structure is provided in Figure 4.7. It also makes using a thematic-themed approach an option for integrating field notes into already established frameworks of themes.

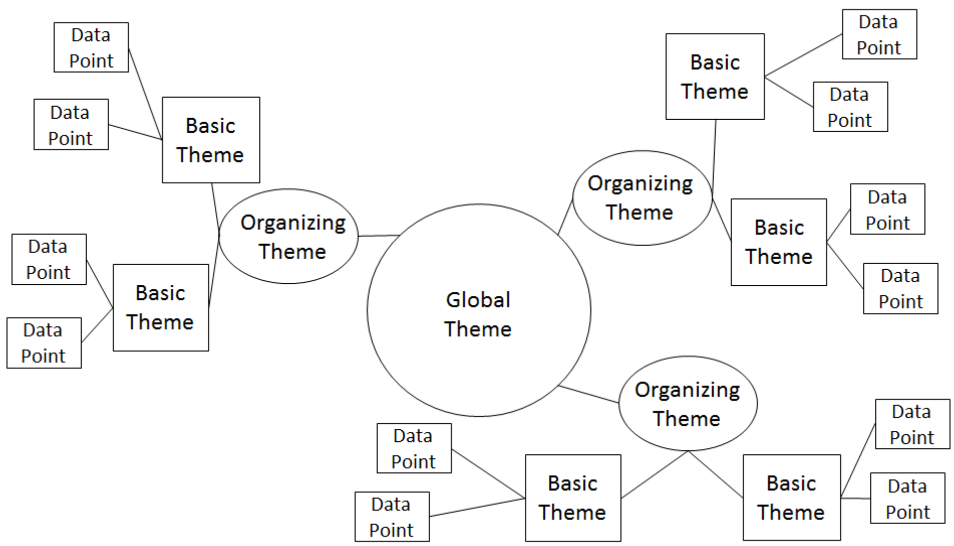

Figure 38: Organization of a thematic network. Image adapted from (Attride-Stirling 2001)

The thematic network that emerged is the CLL Process Framework, which is provided in Table 4.1. In this framework, the basic themes and organizing themes are respectively referred to as processes and categories. In order to potentially uncover sub-themes, field notes were reviewed relative to the categories organizing themes. This was accomplished by scanning the category in the Excel document for data points and then reviewing each respective data point and taking brief notes. An illustration of this cyclic process of discovering themes and reviewing organizing themes is provided in Figure 4.8.

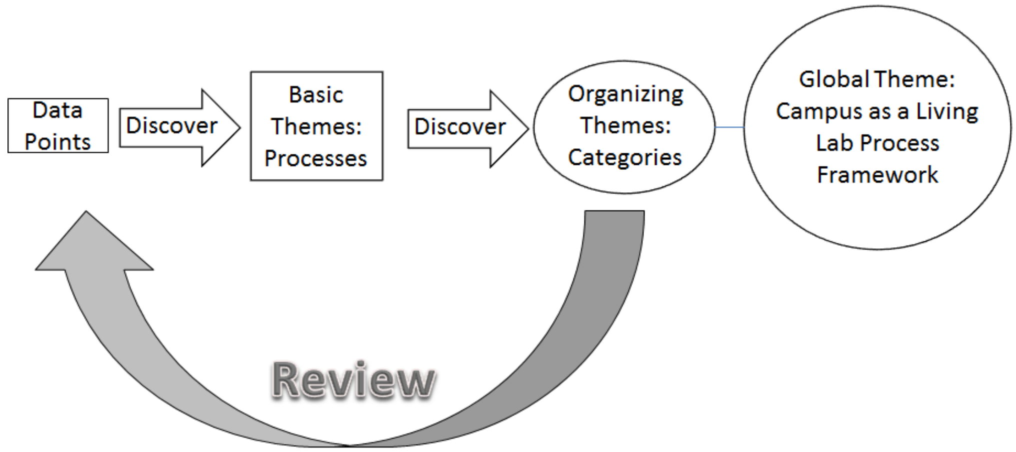

Figure 39: Discovery and review process for themes

As each organizing theme was reviewed a number of sub-themes emerged. Interestingly, some of these sub-themes also overlapped. A representation of this is provided in Figure 4.9.

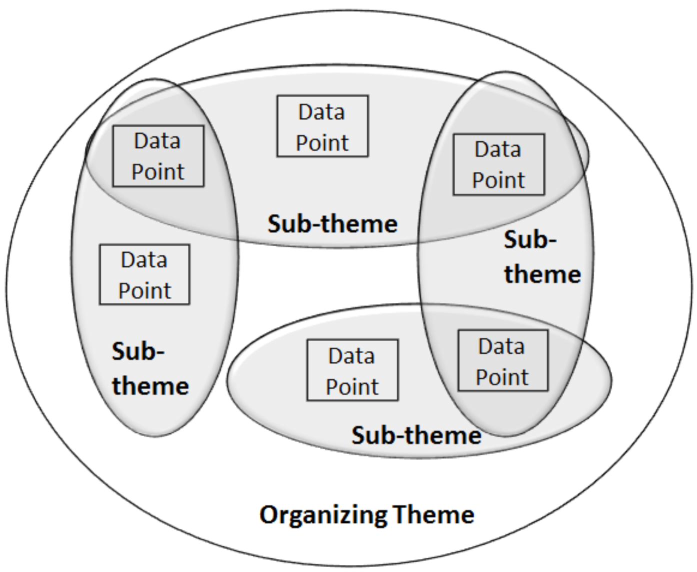

Figure 40: Emergence of sub-themes from reviewing data points

These emergent sub-themes are listed below according to each of their respective CLL Process Framework category. Reasons why each sub-theme may present a potential problem and suggestions for improvement are also provided. Although some of the improvements are underway, they could be developed further. Additionally, the suggestions for improvement are not meant to be exhaustive, but merely a starting point for future analysis.

3. Develop Vision, Strategy and Assessment Tools

    a. Terms of reference. These have been developed and serve as a helpful guide for group activities.

    b. Reactive to proactive. Projects are continuously arising and deciding priorities can be difficult. It is helpful to allocate more time to the development of assessment tools and of project selection principles in order to get a step ahead. It could prove beneficial to share these with potential partners as well as the wider UBC community. A similar strategy, as listed in “Side-by-side opportunity review” in “Developing Opportunities,” could also be useful.

    c. Key challenges. There are a number of occasions where the need to identify all key challenges was mentioned, a task which some of the meetings addressed. There could be potential to develop a shared list with the campus community.

    d. Technical guideline integration. Even though UBC has its own entity for administering projects, namely UBC Properties Trust, it can be difficult to align ideas with the technical guidelines. A transparent and seamless process for integrating defensible guidelines could be helpful. This would also help integrate the “step ladder” approach for ensuring that every building constructed is more efficient than the one built before it.

    e. CLL governance. There are other projects on campus being administered that are not part of the CLL Working Group. It would be beneficial to have an overarching governance model so as to provide an opportunity for collaboration.

4. Develop and Manage Business Capabilities

    a. Process development. There currently is no formal structure in place for continuous optimization of CLL processes. Any improvements are completed through the Strategic Partnerships Office. It is not helpful to have so many processes that the committee becomes overburdened, so some additional processes could prove worthwhile. This is also the case for improving process for engaging students

b. Knowledge transfer. There is potential to lose information when projects change hands from pre-design, design, construction, and operation. The development of a system to capture this information could be helpful. There are often major delays with publications as well, not only for the CLL. It would be helpful to manage the flow of information from the CLL and integrate a more expedient publication process.

c. Metrics for success. It is currently difficult to determine success when it is achieved as an overarching guideline for doing so does not exist. Perhaps a general set of metrics with baselines could be useful.

d. Human resource management. The capacity of people on the committee has reached its limit and there is still more work that can be accomplished. Additional human resources could aid with further development of the CLL.

5. Develop Opportunities

   a. Side-by-side opportunity review. Opportunities are generally reviewed one at a time as opposed to side by side. There could be an opportunity to reduce the spread of time across projects if they can be reviewed side by side.

   b. Inter-disciplinary business case review. As reviewing a business case requires technical as well as business acumen, there could be a method to have an inter-disciplinary team of researchers ready to develop business cases – perhaps via a website.

   c. Myriad of opportunities. There is always potential to integrate some new technology before projects such as buildings reach the design stage. It could be helpful to have a list of items to be integrated ready, waiting, and already approved.

   d. Integrated presentations. Presentations are currently provided as needed and somewhat *ad hoc*. It might be helpful to structure a series of linking presentations in sequence to develop a better committee-wide understanding on technologies and how they can fit into the economic, environmental, and social landscape.

e. Technical project evaluation. Much of the evaluation of projects involves assessing the technical aspects of projects, so it is helpful to have an expert on CLL Working Group. There usually is one present, and if the expertise is not directly available, it is sought out.

f. Construction and operation cost linkage. Operational cost does not appear to be accounted for when a building is placed for tender. It could be beneficial to link these in order to develop the "step ladder" approach to continual building improvement as already suggested. This can be achieved by determining baseline operating cost according to building type and then charging the department for any overages and reimbursing for any underage. This would be a similar strategy to what the City of Vancouver is using to promote retrofits in older buildings and energy efficiency in new buildings. (Vancouver 2013)

g. Full building energy analysis. It is not currently possible to understand where all the energy during building operation is being consumed. This makes it more difficult to implement an automated demand response system. Perhaps through expanding UBC's network, a solution could be found, or maybe one could be developed in-house.

6. Assess the Environment

a. Scalable human capital. There are times when the workload suddenly increases and this can be taxing on the committee members. An on-demand system for generating a sudden influx of researcher capacity could be beneficial. This could be achieved through a web portal job board that is dedicated for research. Such a system could also be linked to government researcher funding like MITACS and NSERC.

b. Deferred maintenance. There is currently an estimated $500 million of deferred maintenance that is being spent for building operations. Implementing part of the operational cost into the initial building budget could help mitigate further increases.

c. Incentivise Deans. The rationale is the same as for “Construction and operation cost linkage” under “Develop Opportunities”.

d. Rising energy demand. UBC is quickly reaching maximum capacity on BC Hydro lines to campus. Although, solutions are currently being proposed, it is mentioned here since it has been on the agenda for a number of CLL Working Group meetings.

e. Building sensors. Sensors for buildings are not always connected to the monitoring system. There is an opportunity to find a solution to this.

7. Manage Researcher Opportunities

   a. Researcher engagement. There is fortunately a pipeline of potential projects and other opportunities for researchers to collaborate on. However, the timing with which these opportunities flow does not always align. The solution to this may be the same as for “Scalable human capital” in “Assess the Environment”.

   b. Research champions. There is often a search for someone to become a research champion. It could be useful to identify researchers who are already willing and ready to participate in projects. This way, not only can researchers be selected by project availability, but projects can be developed according to researcher availability.

8. Relationship Management

   a. Inter-institutional collaboration. There is expertise around the globe in various areas that we could leverage knowledge from. It could be helpful to develop a network of knowledge leaders in various areas that the CLL can rely upon for advice. Automated demand response (automatically adjusting energy flow by regulating energy demand through systems such as a smart grid and integrated building energy management) would be one such area for further exploration.

b. UBC internal collaboration. There are a number of initiatives within campus that have opportunities for CLL collaborations available, but they are not being leveraged. The only recent start of collaboration with UBC Social Ecological Economic Development Studies (SEEDS) is an example of this. Having a roundtable discussion with all the groups on campus could allow everyone to better appreciate the opportunities for collaboration.

9. Marketing and Communications

   a. Bridging the gap. There are questions about how to report the successes and failures of the CLL to the larger community. Having a strategic communications plan, and budget in place to execute this plan could assist. Additionally, regular sustainability updates on UBC homepage could be implemented.

   b. CLL identity. There is not currently a definitive CLL brand that fits within the larger sustainability brand. The CLL could benefit from having its own 'brand' identity, connecting other groups working on CLL initiatives with cohesive marketing.

   c. Marketing budget. The CLL does not always have sufficient marketing and communications support. This could be resolved by allocating funding to a specific CLL marketing budget line.

10. Project Management14

    a. Project issues. There are a number of projects issues that are not being captured to provide points of learning for others. This links to "Bridging the gap" in "Marketing and Communications".

In summary, the CLL Process Framework developed in Section 0 was utilized to review for sub-themes. This was accomplished by scanning the every CLL Process Framework category in the Excel document for data points and then reviewing each respective data

[14] "Project management" occurs more or less in the form of updates to the CLL Working Group. Although brainstorming does occur for potential solutions, it is the function of UBC Project Services to carry out the project management itself, and UBC Operations to oversee the operating of buildings and projects. There are members representing both groups on the CLL Working Group, so progress updates are provided.

point and taking brief notes. From this emerged the sub-themes, which provide a basis of recommendations and is further fleshed out to provide a number of key transferable characteristics in the next section.

4.2.4 Key Transferable Characteristics from Key Findings

The proposed transferable characteristics from this section are items that can be combined with key transferable characteristics in Section 3.7.4 in order to develop generic BPMs for Chapter 5. Key transferable characteristics were identified from Section 4.2.3 and are listed below with a reference to which item in the extensive numbered list from which they were obtained.

- Develop strategic documents
    - Continually optimise strategic documents (2a)
    - Terms of reference (1a)
    - Project selection principals (1b)
    - Metrics for success (2c)
    - Processes to follow
        - Continual optimization of CLL processes (2a)
        - Integration of new technical guidelines for campus (1d)
- Administration
    - Implement a governance model to capture all groups who may potentially work on CLL projects (1e)
    - Ensure adequate human resources are available (2d)
    - Develop a database of researchers ready to work on projects, and projects ready for researchers (4a & 5a)
    - Ensure the committee has technologically savvy members (3e)
    - Create a strategic marketing and communications plan (7a)

  - Establish a CLL identity (7b)
  - Have a marketing and communications budget (7c)
  - Identify research potential research champions early (5b)
  - Create relationships with other groups within the campus who are interested in CLL projects (6b)
- Knowledge transfer
  - Share general challenges (1c)
  - Share successes and failures (7a & 8a)
  - Cultivate relationships with other institutions to share information about new technologies (6a)
- Be strategic
  - Review proposals side-by-side to reduce stretching of resources and select most viable options (3a)
  - Have an inter-disciplinary business case review team on hand (3b)
  - Develop a list of technology items ready to be integrated (3c)
  - Develop a presentation schedule for committee learning (3d)
  - Forecast potentially major campus issues and work on a plan early (4d)
- Integration with campus
  - Link construction and operating cost into building budget (3f & 4b)
  - Incentivise deans to improve operational efficiency of buildings (4c)
  - Monitor energy usage of buildings and ensure equipment installed to monitor energy usage is installed and connected (3g & 4e)

4.2.5 Summary

The quantitative analysis showed that the majority of the CLL Working Group's time is absorbed by tasks related to the development of opportunities, assessing the environment, and developing a vision, strategy, and assessment tools. It is a delicate balance to juggle these items while trying to remain on-course. To assist with strategizing, likely recommendations would be a dedicated budget line CLL Working Group and time allocated for a strategic retreat.

The qualitative analysis provided a number of sub-themes, challenges, and partial solutions for further exploration. These are all meant to be a starting point for a rigorous analysis and business case development, but they also include ideas for proposed processes.

4.3 Conclusion

To conclude, over the span of 16 months beginning on December 6th, 2012, a total of 36 meetings were attended. After taking field notes from these meetings and coding them, a thematic network emerged in the form of a CLL Process Framework. This framework was partly derived from an amalgamation of categories, processes, and sub-processes from the APQC and PMI frameworks. A quantitative and qualitative analysis was then completed based on the data obtained. The quantitative analysis showed that the majority of the CLL Working Group's time is absorbed by developing opportunities, assessing the environment, and developing a vision, strategy, and assessment tools. The qualitative analysis revealed a number of sub-themes, challenges, and partial solutions for further exploration. These results were then categorized into key transferable characteristics to be integrated in Chapter 5.

Chapter 5. Proposed Generic Living Lab Processes

5.1 Introduction

The focus of this chapter is to extract lessons learned and key transferable characteristics from the University of British Columbia's (UBC's) "Campus as a Living Lab" (CLL) program and to propose replicable processes for other universities and municipalities to expand their sustainable practices in similar ways. This chapter provides a summary of the thesis in the form of Business Process Models (BPMs). As there was a learning curve with implementing a living lab program at UBC, the goal of this summary is to potentially shorten this learning curve for others and accelerate the adoption of a CLL strategy. As this chapter is intended to be suitable for reading as a stand-alone section, some content already presented has been repeated.

CLL is the focus of this research because it is believed by the author to be a practical and effective way to advance the development of new sustainable technologies. The CLL concept assists with the need to develop innovative technologies in order to become more sustainable. There are many steps along this process, including idea creation, implementation, and alteration of mainstream processes. One of these development steps is to pilot new technologies for widespread adoption. Although there are barriers to this, one way to alleviate them is to provide companies with an avenue to test their technologies within the UBC environment—using the University's campus and community itself as a testing ground. This UBC "testing ground" also happens to be at the size of a small municipality, which provides a scale that could be useful for wide applicability of tested technology. Through this process, barriers to the implementation of these technologies can be identified and solutions can be developed. It is through these innovative technologies that greater energy conservation, sustainable energy production, water conservation, and larger overall greenhouse gas (GHG) reductions can be realized. An example of one UBC CLL project is the district energy system implementation, which changes the current system from steam to hot water and will potentially reduce GHG emissions by 22 percent while saving $4 million per year (UBC 2012c).

The BPMs presented in this chapter culminate the research provided in Chapter 2 to Chapter 4:

- ***Chapter 2*** provided a basis for selecting flow charts as the BPMs of choice to illustrate processes. The chapter additionally developed a foundation for the methodology on data collection and analysis in the form of ethnographic research.
- ***Chapter 3*** delivered a general overview of the BPMs utilized at UBC as well as reasons why improvements have been integrated into these models.
- ***Chapter 4*** presented an ethnographic study carried out over 16 months, where the author observed and participated in 36 CLL Working Group meetings to learn about the CLL processes being employed and to culture ideas for improvement.

5.1.1 Objectives

The main purpose of this chapter is to create the foundation of a generic "roadmap" for other institutions to be able to adopt a CLL strategy. This "roadmap" is provided in the form of a series of BPMs.

5.1.2 Methodology

The methodology for this chapter was to create generic BPMs by integrating key transferable characteristics identified from previous chapters.

5.2 Key Transferable Characteristics from Previous Chapters

5.2.1 Introduction

This section provides a number of key transferable characteristics to support the development of the generic models for this chapter. They have been extracted from actual process improvements developed in Chapter 3 and findings from an ethnographic study in Chapter 4.

5.2.2 Key Transferable Characteristics from Chapter 3

The key transferable characteristics extracted from Chapter 3, Section 3.7.4, were based on a general overview of processes being utilized and three case studies from various stages of CLL development; namely the following:

- The Centre for Interactive Research in Sustainability (CIRS) – provided a case study for a high performance building,
- The Academic District Energy System – provided a case study for infrastructure analysis,
- The Bioenergy Research and Demonstration Facility – provided a case study for a project

Characteristics were borrowed from the CIRS example by reviewing past documentation, and by consulting with project participants. The Academic District Energy System information was provided by people directly involved in the project, and the Bioenergy Research and Demonstration Facility material was obtained from a debrief on the lessons learned by all the project participants.

A list of the key transferable characteristics is as follows:

1. organizational structure for the USI and the CLL,
2. diverse multi-stakeholder committee membership structure,
3. process of categorizing projects based on size (high-level view),
4. process of project evaluation (due diligence) and approval (mid-level view),
5. tools for project evaluation: slide deck and spider chart,
6. selection of a research champion,
7. process for selecting strategic partners,
8. design goals and charettes for high performance buildings,
9. linking funding to sustainable technologies so that they are not value engineered out the equation,
10. contests to solicit ideas for alternative energy or otherwise,
11. linking feasibility studies to contests for the wider community to contribute ideas.

5.2.3 Key Transferable Characteristics from Chapter 4

The key transferable characteristics from Chapter 4 were obtained by ethnographic study carried out over 16 months that began on December 6th, 2012. During this period, field notes were written during 36 CLL Working Group meetings attended and quantitatively and qualitatively analyzed. This analysis consisted of developing a CLL Process Framework based on American Productivity and Quality Center's (APQC) cross industry process classification framework and the Project Management Institute's (PMI) Project Management Body of Knowledge frameworks and coding the notes taken at the meetings to identify themes. From these themes, a series of recommendations for improvements developed and key transferable characteristics were extracted. This list is provided below:

- Develop strategic documents
    - Continually optimise strategic documents
    - Terms of reference
    - Project selection principals
    - Metrics for success
    - Processes to follow
        - Continual optimization of CLL processes
        - Integration of new technical guidelines for campus
- Administration
    - Implement a governance model to capture all groups who may potentially work on CLL projects
    - Ensure adequate human resources are available
    - Develop a database of researchers ready to work on projects, and projects ready for researchers
    - Ensure the committee has technologically savvy members
    - Create a strategic marketing and communications plan

    - Establish a CLL identity
    - Have a marketing and communications budget
    - Identify research potential research champions early
    - Create relationships with other groups within the campus who are interested in CLL projects
- Knowledge transfer
    - Share general challenges
    - Share successes and failures
    - Cultivate relationships with other institutions to share information about new technologies
- Be strategic
    - Review proposals side-by-side to reduce stretching of resources and select most viable options
    - Have an inter-disciplinary business case review team on hand
    - Develop list of technology items ready to be integrated
    - Develop a presentation schedule for committee learning
    - Forecast potentially major campus issues and work on a plan early
- Integration with campus
    - Link construction and operating cost into building budget
    - Incentivise deans to improve operational efficiency of buildings
    - Monitor energy usage of buildings and ensure equipment installed to monitor energy usage is installed and connected

5.2.4 Summary

An extensive amount of research was conducted to provide these key transferable characteristics which will be utilized throughout this chapter.

5.3 Campus as a Living Lab Business Process Models

5.3.1 Introduction

This section was designed to be a summary of the thesis in the form of BPMs. As there was a learning curve with implementing a living lab at UBC, the goal of this summary was to potentially shorten this learning curve for others and accelerate the adoption of a CLL strategy. As this was designed to be a stand-alone section for distribution, some content already presented has been repeated from earlier sections of this thesis.

This section provides the bare essentials of a roadmap developing and operating a CLL. The items provided are either documents (represented by a "D") or processes (represented by a "P"). The specific items provided in this chapter are as follows:

- Documents
    - Model Overview (D-1)
    - Organizational Chart (D-2)
    - Terms of Reference (D-3)
    - Slide Deck for Preliminary Project Evaluation (D-4)
    - Spider Chart for In-depth Project Evaluation (D-5)
- CLL Processes
    - CLL Committee Evolution (P-1.0)
        - CLL Committee Development Phase (P-1.2)
            - Infrastructure Analysis (P-1.2.1)
                - Infrastructure Analysis Contest (P-1.2.1.1)
            - CLL Project Selection and Development (P-1.2.2)

            - Unsolicited Request Evaluation (P-1.2.2.1)
                - Initial Review (P-1.2.2.1.1)
                - Request < $2.5M (P-1.2.2.1.2)
                - Request > $2.5M (P-1.2.2.1.3)
            - Solicited Request (P-1.2.2.2)
        - CLL Improvement (P-1.2.3)
            - Continuous Improvement of Buildings (P-1.2.3.1)

- High Performance Buildings
    - High Performance Buildings (P-2)
            - Continuous Improvement of Buildings (P-1.2.3.1)

As all the BPMs presented in this Chapter follow the same standard flowchart shapes, a legend applicable for all of the BPMs presented in this Chapter is provided in Figure 5.1. The modelling of all the processes follows a flow chart and swimlane configuration. Some notable differences between this legend and the legend presented in Chapter 3 are the removal of the model version and chapter number. The reason for this is that all models in this chapter are the same chapter, and they were made as generic models to be utilized by others, so the chapter reference has also been removed.

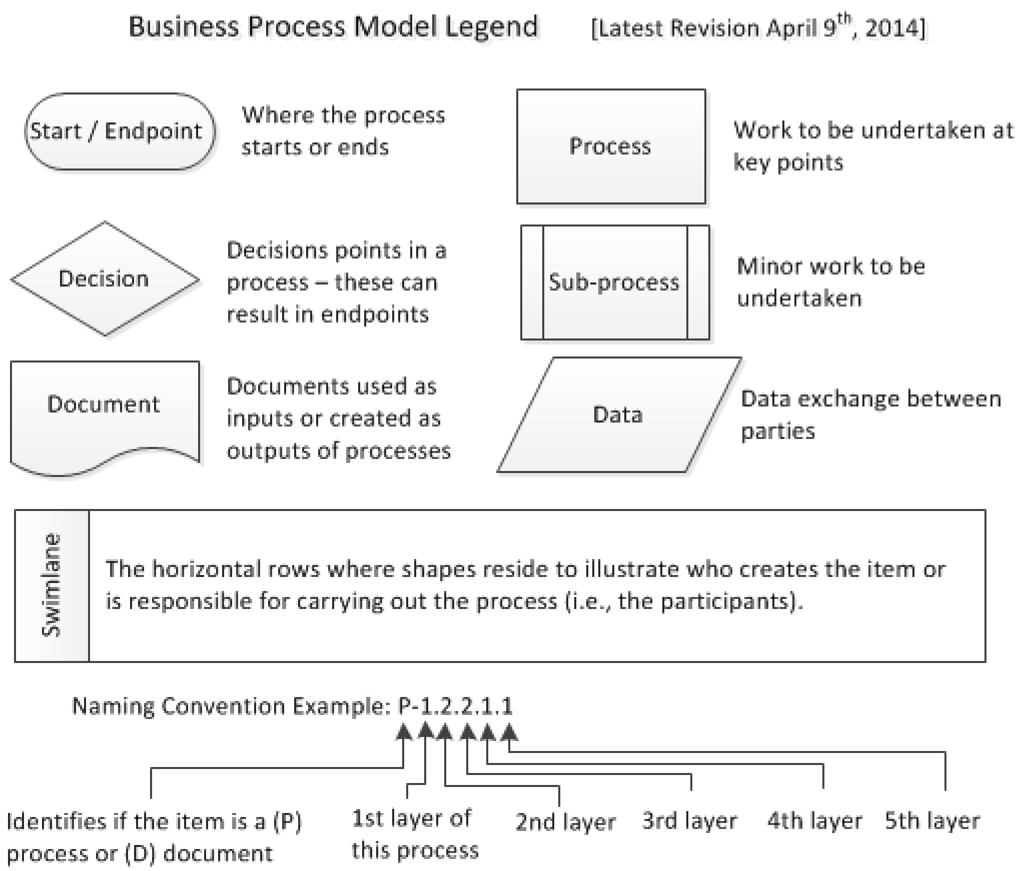

Figure 41: Business process model legend

As the legend in Figure 5.1 shows, there are a number of layers to the models. How these models are imbedded is provided in the “Model Overview” in Figure 5.2. This imbedding of models has been significantly extended from the current UBC CLL processes and the items that occur most often also have the most processes imbedded; this is the case for the “CLL Project Selection and Development”. An illustration of how all of these combine together is provided in Figure 5.2. The idea behind the structuring of these models is to provide assistance in developing a CLL structure and operating once the structure is in place. The main activities to support the operation are the “Infrastructure Analysis”, “Project Selection and Development”, and “CLL Improvement”. Another model for “High Performance Buildings” is also included. This is to develop lessons learned from CIRS about how to continually improve buildings on campus. The main reason for this is that operating buildings and the equipment inside of them consume the vast majority of resources; namely, energy and water. This provides an opportunity for optimizing building design for efficiency through continuous improvement. The following sections in this chapter will detail each of these processes and how they interconnect

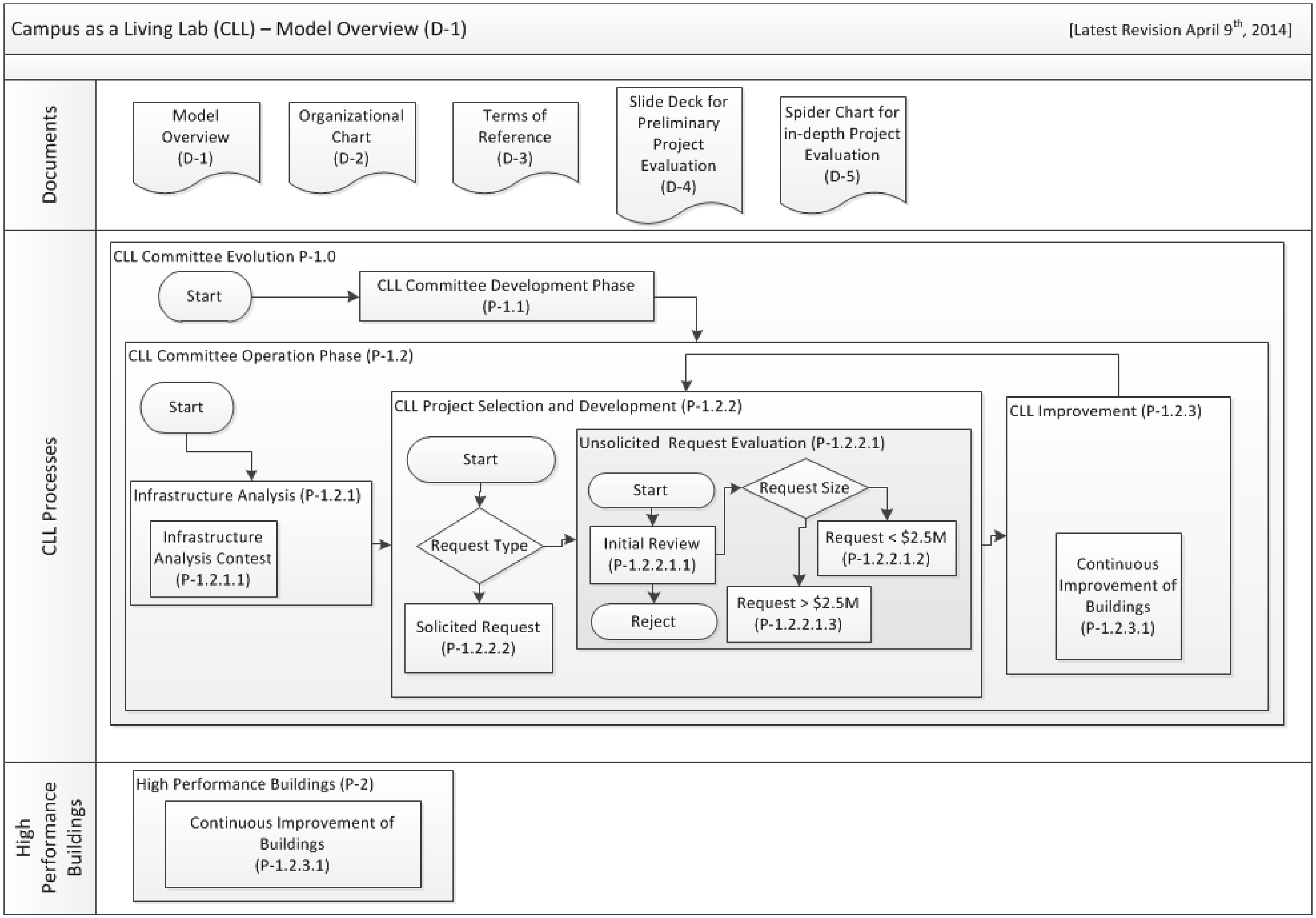

Figure 42: Campus as a Living Lab - model overview

5.3.2 Campus as a Living Lab Committee Evolution (P-1.0)

Based on viewing the development of the CLL Working Group over 16 months, and reviewing the history of the committee before this, the evolution of the committee can be considered to have two distinct phases: a development phase, and an operation phase. During the development phase, the committee structure is developed, as well as a number of key documents.

The operation phase then executes the work while continually optimizing. An illustration is provided in Figure 5.3 with more detail in the following sections.

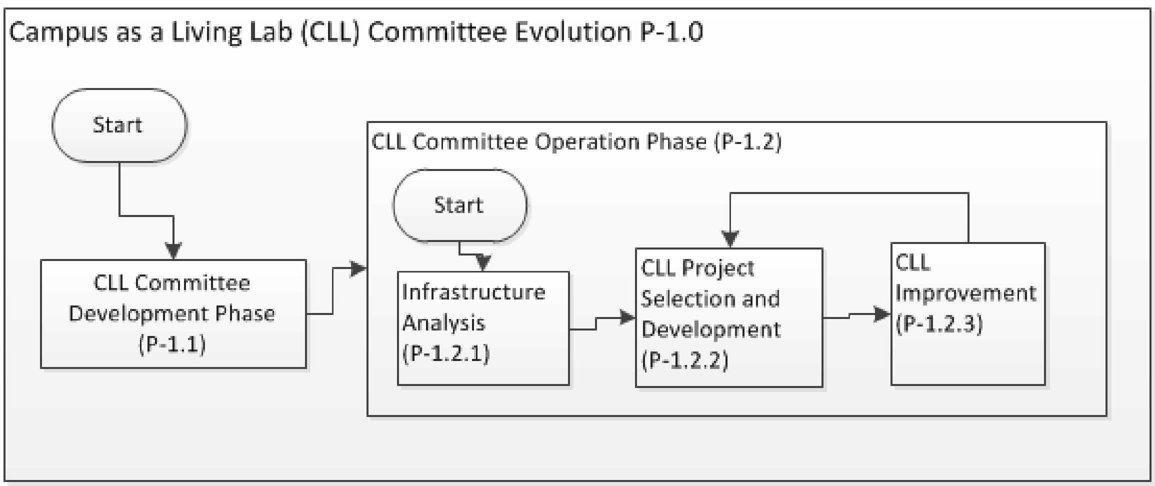

Figure 43: Campus as a Living Lab committee evolution

5.3.2.1 Campus as a Living Lab Development Phase (P-1.1)

The CLL development phase begins with gaining support for the development of the CLL, and then creates the overarching committee structure as well as a number of key documents. This process also captures a number of important attributes as noted in Section 3.7.2 and listed below:

- Bottom up and top down support for the program is needed to be truly effective.
- Vision, mission, and objectives specific for the CLL need to tie into larger university objectives.

- Tools to analyze opportunities for alignment with campus objectives aid with strategic decision making and can shift the project focus from being reactive to proactive.

It is important to have bottom-up and top-down support in order to ensure that there are people on the ground ready to act and that there is alignment with university goals and budgets. The key documents created during this process are an organizational chart, terms of reference, a slide deck for preliminary project evaluation, and a spider chart for in-depth project evaluation. This process is shown in Figure 5.4.

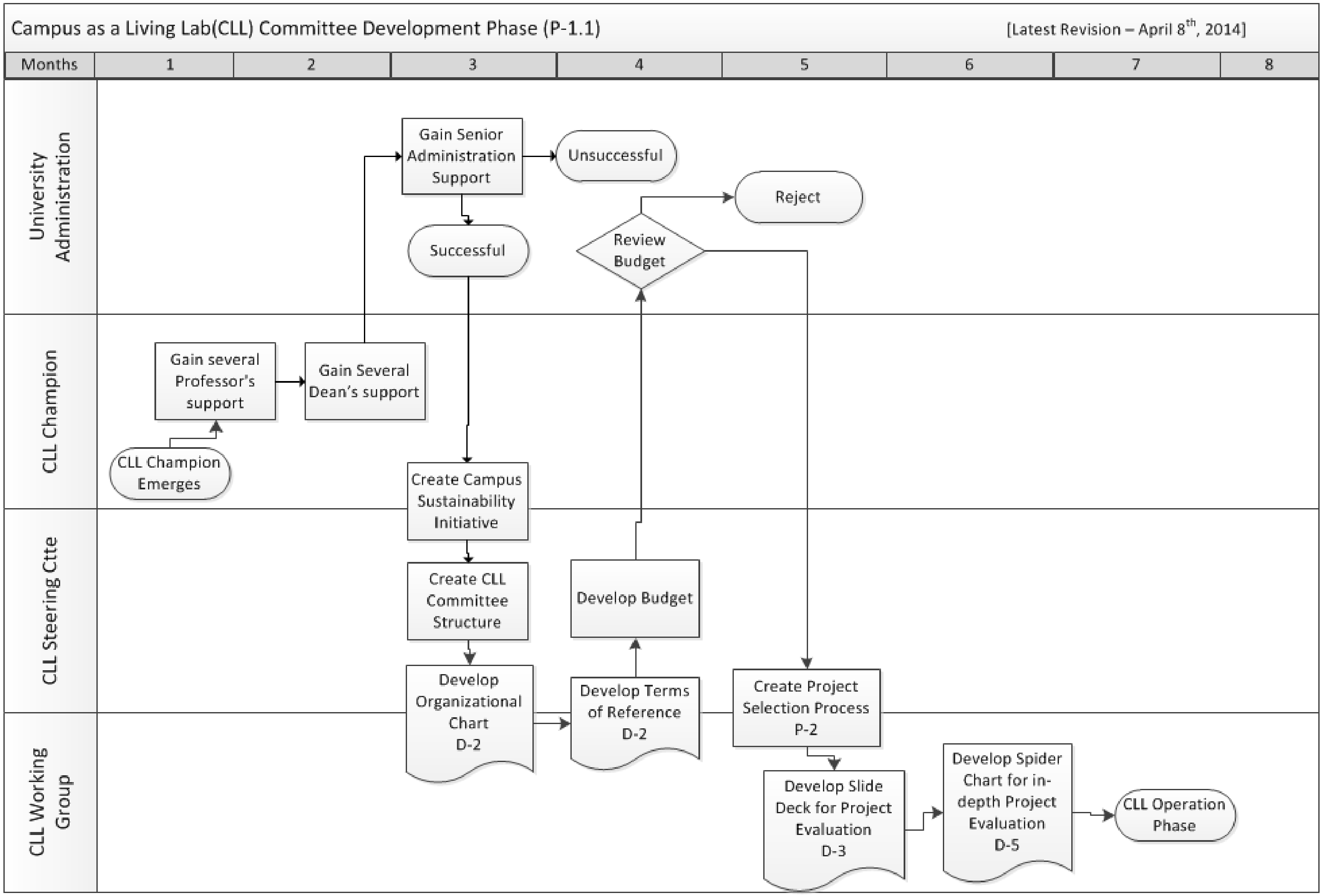

Figure 44: Campus as a Living Lab committee development phase

5.3.2.2 Organizational Chart (D-2)

The organizational chart in Figure 5.5 was modified from an original version to reflect the integration of the Project Steering Committee and the three committees reporting to it, as well as a connection between Marketing and Communications and the CLL Working Group. This last connection was added from information obtained in the ethnographic study indicating that stronger ties could facilitate knowledge transfer and the sharing of successes and failures with others. The definitions of each of the groups are also provided below. The committee structure described below recognizes the importance of having multi-stakeholder engagement. This was realized after the implementation of the Bioenergy Research and Demonstration Facility at UBC, during the lessons learned debriefing, when it was realized that members of the community were not adequately consulted in a method where they could provide meaningful input. This led the extension of this idea and inclusion of multi-stakeholders in the various meetings and is noted in Section 5.2.2.

- ***President:*** The University President.
- ***Campus Sustainability Steering Committee:*** A group consisting of senior Vice-Presidents, Deans, planning and operations, and a representative from the Student Sustainability Advisory Council.
- ***International Advisory Board on Sustainability:*** A group of international advisors who provide macroeconomic advice on international initiatives.
- ***Regional Sustainability Council:*** A local group of sustainability leaders who guide the local direction and regional influence of the Campus Sustainability initiatives.
- ***Student Advisory Council:*** An elected group of students representing the student societies on campus, sustainability student groups, student housing, and other interested students. Their role is to provide advice to the Campus Sustainability Steering Committee.

- ***Campus as a Living Lab Steering Committee:*** A group of "representatives from the key stakeholder groups (academic, operational, community)" (Sauder et al. 2013)

- ***Campus as a Living Lab Working Group:*** A group of representatives from key project participant groups who are responsible for project evaluation and development. (Sauder et al. 2013) There should be a high level of project management experience to assist with the planning and execution of the projects.

- ***Associate Director:*** The person who is in charge of overseeing day-to-day operations of campus sustainability.

- ***Marketing and Communications:*** The group who integrates the marketing and communications of the sustainability group with the campuses larger marketing group.

- ***Executive Assistant:*** Provides assistance to the Associate Director

- ***Administration Coordinator:*** Provides assistance to the Executive Assistant and the Associate Director.

- ***Strategic Partnerships Office:*** Responsible for developing partnerships and securing funding for projects.

- ***Teaching and Learning Office:*** Responsible for the integration of sustainability curriculum.

- ***Project Steering Committee:*** Provides overarching support to the three sub-committees of research, operations, and emissions. It can encompass the leaders in operations, project services, and professors with specific expertise.

- ***Research Committee:*** This committee may be led by a full professor and other colleagues knowledgeable in the research area. The primary responsibility is to assist with research development.

- ***Operations Committee:*** The group has members from project services with heavy engagement from operations.

- ***Emissions Committee:*** Led by operations with stakeholders from the local neighborhood community.

The organizational chart was developed this way in order to provide additional oversight and support to the CLL committees and to the Campus Sustainability Steering Committee.

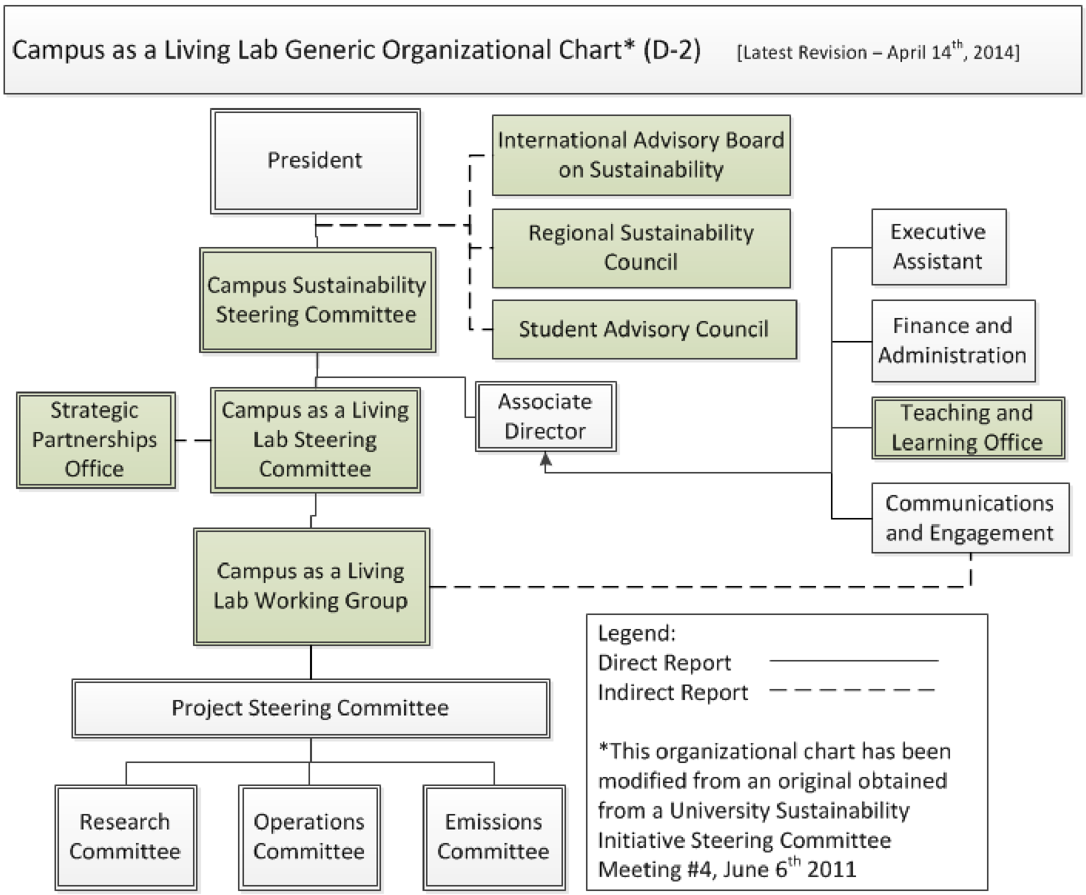

Figure 45: Campus as a Living Lab generic organizational chart

5.3.2.3 Terms of Reference (D-3)

The terms of reference help to guide the committee in its mission to ensure that it remains on track and aligned with the larger campus objectives. The following terms of reference in Table 5.1 is a draft developed at UBC in February of 2013. These example terms of reference is divided into 8 categories: Foundational Elements, High-Priority Objectives, Principles, Governance, Project Selection Principles, Partner Selection Principles, Sustainability Lens, and Key Success Factors.

Table 16: University of British Columbia's Campus as a Living Lab draft terms of reference (Verbatim) (Sauder et al. 2013)

University of British Columbia Campus as a Living Lab Terms of Reference (D-3)	
Category	**Item**
Foundational Elements	Integrates core learning and research mission with campus operations
	Involves partnerships between UBC and public, private and NGO organizations
	Involves sound financial use of UBC infrastructure for demonstration of and research on leading edge solutions (technical and social)
	Engages researchers, students, operations staff and external partners
	Has potential for knowledge transfer beyond UBC
High-Priority Objectives	Be a leader in sustainability – meet UBC GHG reduction targets using techniques that can be applied by other organizations
	Develop research, innovation, and collaboration opportunities – develop new technologies, techniques and solutions in partnership with others
	Reduce our energy consumption – find innovative ways to reduce energy use and maximize energy efficiency
	Look for integrated solutions – employ campus-wide perspective, focusing on connections between physical (energy, water, material, food) and social systems
	Provide learning opportunities for students and faculty – involve campus community members from a broad range of disciplines in the innovation process
Principles	Create sustainable solutions: Innovations selected for implementation must be financially self-sufficient and long-term supportable by campus operations
	Deploy operable Technology: Implement reliable solutions that support the needs of daily campus life
	Align with broader UBC objectives: Focus on UBC Vision and Commitments for guidance
	Build with a long-term vision of more than 20 years: Select creative, innovative solutions that will be of value for decades
	Be Inclusive and Contributory: Work for mutual benefit with a broad range of UBC community members and outside partners, focusing on support for the BC clean technology industry where appropriate
Governance	Steering Committee – Responsible for overall direction and decision-making. Includes representatives from the key stakeholder groups (academic, operational, community).
	Working Committee – Responsible for project evaluation and development. Includes reps from key project participant groups.
	Project Management – Individual projects managed by Infrastructure Development Project Services team.

University of British Columbia Campus as a Living Lab Terms of Reference (D-3)

Category	Item
Project Selection Principles	Evaluate potential projects using multiple tools • Cost benefit analysis & net present value • Life Cycle Assessment (cradle to grave) • Multi-criteria Analysis (for measuring against objectives and principles Ask the right questions (due diligence) • Do we need it? Enable or hinder future choices? Barriers to overcome?
Partner Selection Principles	Solicit using multiple channels • Request for proposals, Request for interests, Competitions, Direct engagement Structure • Transparency, Intellectual Property, Mutual benefits, Aligned objectives, Long-term, Competition & Collaboration Selection • Understand needs, Research and due diligence, Shared values/objectives, Risk versus Reward
Sustainability Lens	Consistent, comprehensive sustainability evaluation framework incorporating LCA and LCC in regenerative context Extends beyond individual buildings or infrastructure systems to integrated neighbourhood/campus scale When considering the impacts of decision-making, the scope must be broadened to include all environmental and social impacts beyond UBC's physical boundaries, as well as consider the broader economic impacts, particularly to the BC economy
Key Success Factors	Strong research, teaching & learning interest Identified operational needs Committed/motivated partners Dedicated project management Frank and open communications Access to 3rd party funding (e.g. research grants)

5.3.2.4 Slide Deck for Preliminary Project Evaluation (D-4)

As time passed in the development of the CLL at UBC, the Strategic Partnerships Office noticed that the business plans being provided by companies wanting to pursue projects often did not provide a value proposition. This led to the CLL Working Group sometimes trying to extract information from the company to try to develop a value proposition for them. This led to an approach more in line with a venture-capital process to investigating potential projects that required a 12 page slide deck with a clear value proposition. This consisted of a template developed by Iain Evans in the Strategic Partnership Office that was generally agreed by the CLL Working Group to be provided to companies that passed the first step of the process. This slide deck became the terms of reference for companies interested in participating in CLL activities. The slide deck also helps guide the company to provide insight into the technology, show how well the company knows your university as a customer, and whether or not the company fundamentally understands what the university is trying to accomplish (Evans 2014). The goal of the following slide deck is to provide a format to easily relay the idea behind the project to multiple stakeholders in order to make an informed decision.

Table 17: Slide deck for preliminary project evaluation (Evans 2012)

Slide Deck for Preliminary Project Evaluation (D-4)	
Slide # & Item	**Contents**
1) Introduction slide	Project Name, Company Name, Company Location, Company Lead
2) Presentation Outline	Slide headings of 3-12 on this list
3) Executive Summary	How UBC helps achieve the company's corporate goals
4) Opportunity Positioning	The key problem they are solving and why it is unlike any other product
5) Solution Overview	Outlines the value proposition and core technology
6) Solution Example	Describes how problems will be overcome
7) Program Plan	Provides key resources, tasks and milestones
8) Program Partnerships	Partnerships that will develop within BC and beyond
9) Product Cost Assumptions	A detailed cost breakdown
10) Innovation Opportunities	Researcher involvement opportunities, risks and barriers to commercialization
12) Operations and Maintenance Support Plan	How support will be provided to UBC
12) Value-added Opportunities	Other potential synergistic opportunities for UBC

5.3.2.5 Spider Chart for In-depth Project Evaluation (D-5)

The following spider chart in Table 5.3 was created by Iain Evans of the UBC Strategic Partnerships Office to further the initial analysis by the slide deck, and is meant to be tailored to the individual needs of the campus. Only the sustainability indicators were provided by the author. This Spider Chart provides 5 categories and 24 sub-categories for analysis with the purpose of being able to strategically determine whether or not a potential project is worth exploring further. Each of the sub-categories are rated a point value of "-1", "0", or "1" and the higher the score the better. Details on the scoring, and further explanation are provided in Appendix I Spider Chart Criteria.

Table 18: Spider chart for in-depth project analysis (Evans 2013)

Spider Chart Criteria (D-5)	
Category	**Item**
Operational Efficiency	Capital Expenditure (UBC Cash)
	Operational Expenditure (NPV over 10 year span based on operations budget.)
	Risks (Whether they can be identified and quantified)
	Identifiable Environmental Benefit
	Guidelines
	Leverage Dynamics (For every dollar UBC invests, how much would the company, government, and others contribute.)
Research Excellence	Publications (How long would it take to publish)
	Research Funding
	Leverageable Expertise within UBC
	Enhanced infrastructure to support leading edge research
	Engagement by research chair
	Number of departments engaged
	Knowledge Dynamics (M&A activity within technology field)
Student Learning	Undergraduate project work opportunities
	Graduate project work opportunities
	Recruit and retain top ranked graduate students and postdoctoral fellows
	Entrepreneurship at UBC opportunities
Community Engagement	Cross-campus collaboration
	Engagement with the University Neighborhood Association
	Engagement with local industry
	Engagement with other federal/provincial/municipal/not-for-profit
Sustainability	Ability to provide be cost competitive with comparable technologies
	Ability to improve the surrounding environment
	Ability to provide social engagement and improve well being

To aid with evaluating all of these criteria, the actual “spider chart” component becomes a key feature. An example of this is provided in the following figure.

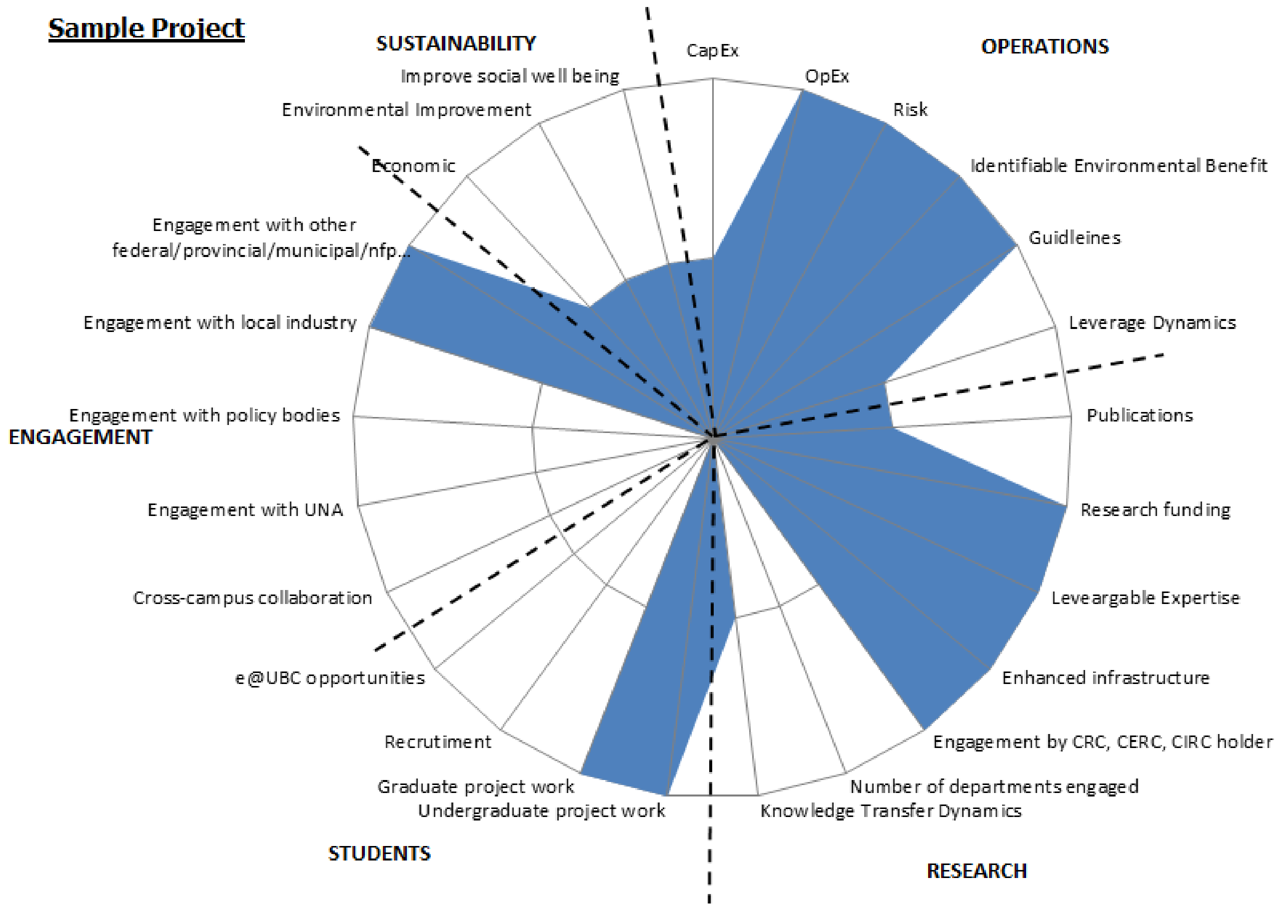

Figure 46: Visualization from spider chart analysis identifying potential project strengths and weaknesses

5.3.2.6 Campus as a Living Lab Operational Phase (P-1.2)

Branching from the development phase in Section 5.3.2.1, the operational phase of the CLL begins with an infrastructure analysis, then a continuous cycle of “project selection and development” and “CLL improvement”. It was noted by a past Associate Director of UBC Project Services and chair of the CLL Working Group (and a person who has been involved with nearly 1,500 projects for a total cost of approximately three quarters of a billion dollars) that this infrastructure analysis is the start of the development of a CLL. The underlying reason is that it enables a campus to become more strategic with decision making when it comes to project selection. Following the infrastructure analysis phase comes “project selection and development” as the idea behind the CLL is to have a continuous stream of projects available. Next is the “CLL Improvement” phase, which provides a method to refine and improve existing practices. This operational phase was developed with current UBC CLL practices as well as improvements from the ethnographic study conducted and is illustrated in Figure 5.7.

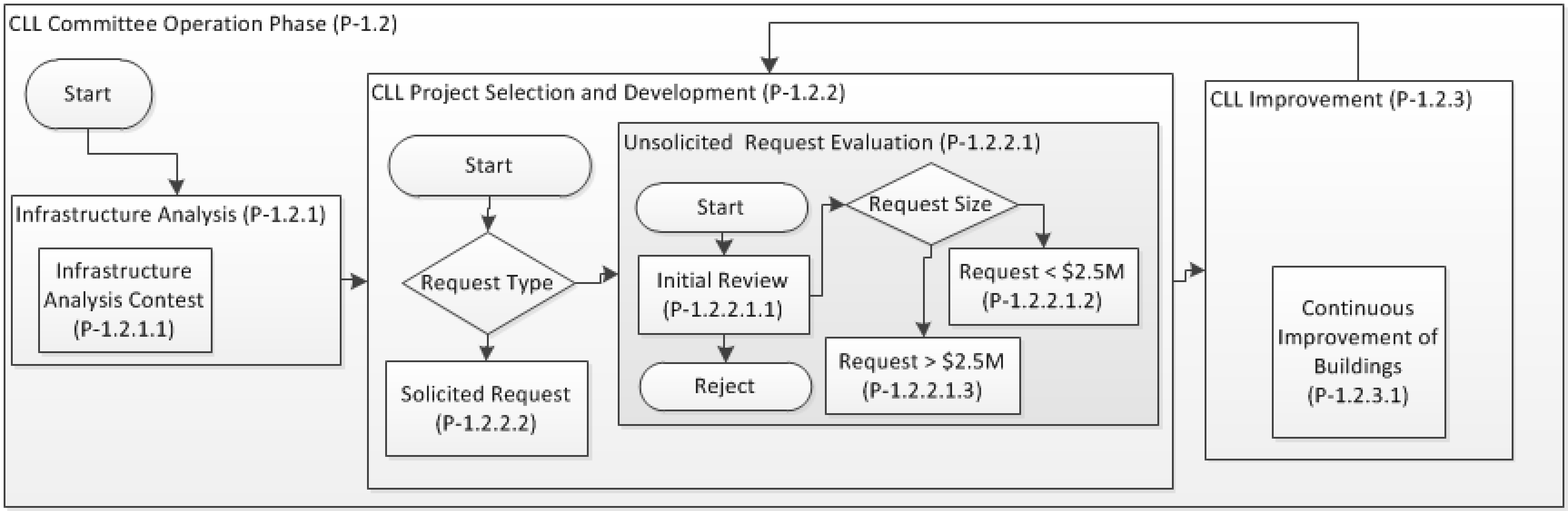

Figure 47: Campus as a Living Lab committee operation phase

5.3.3 Infrastructure Analysis Model (P-1.2.1)

The infrastructure analysis is composed of two parts: a request for information combined with a feasibility study, and an infrastructure analysis contest. Both of these are respectively provided in Figure 5.8 and Figure 5.9 and emerged from a process in which UBC conducted a feasibility study for an Academic District Energy System and they have since been generalized so that they could be applied to any institution for any infrastructure analysis. The process can open the door to focus on certain areas, and should be a first step to avoid “getting lost in the desert” (Collins 2014) The process involves a compiling a complex request for proposals which should be considered to be a “project in itself” (Collins 2014). It should be anticipated that providing the level of detail required in an adequate request for proposals of this type will be time consuming. Once a proponent is selected, the feasibility study is held concurrently to the contest identifying other possible opportunities. The results from the contest can be integrated into the feasibility study as well; as was the case with the Academic District Energy System at UBC.

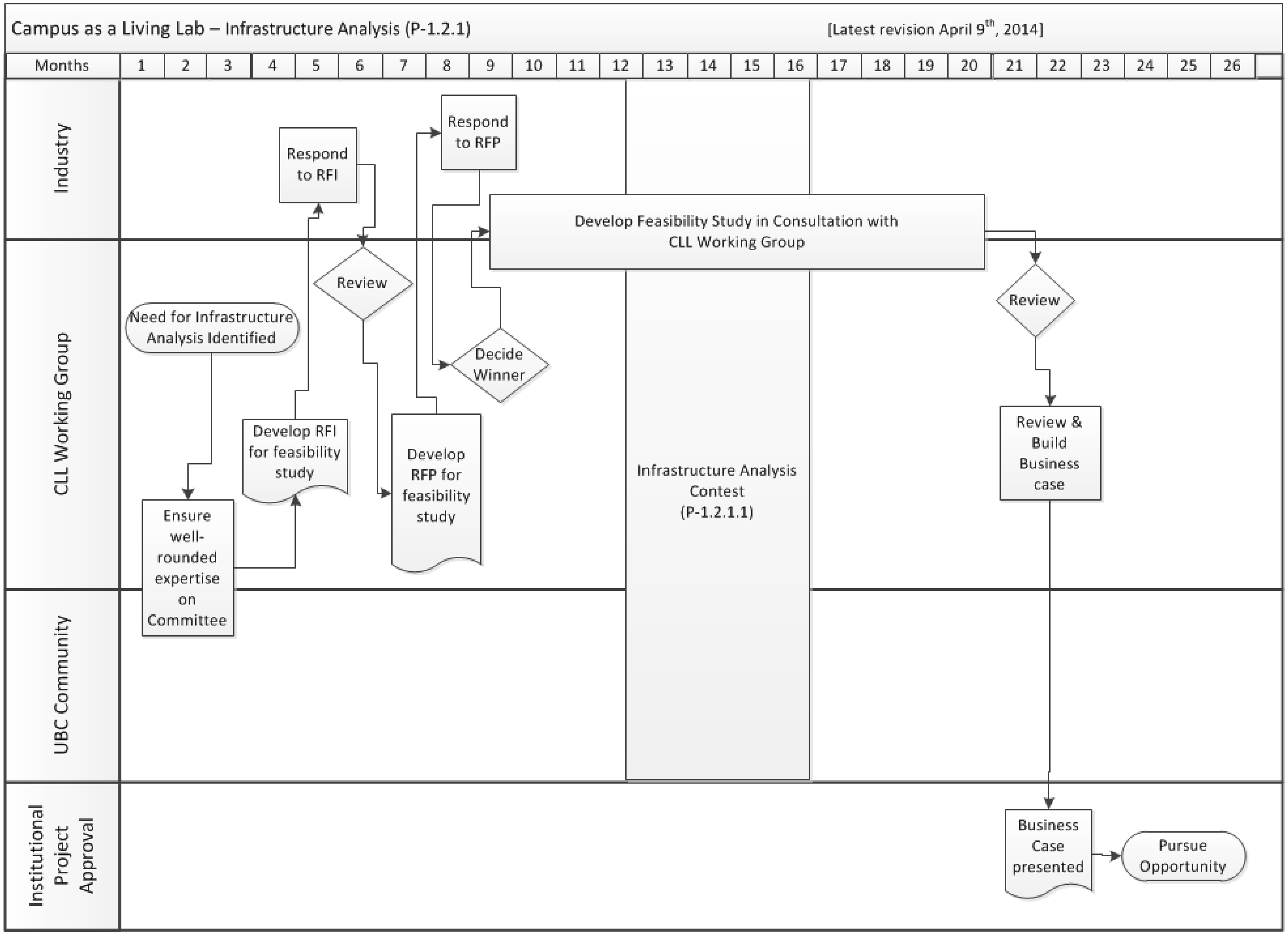

Figure 48: Campus as a Living Lab infrastructure analysis

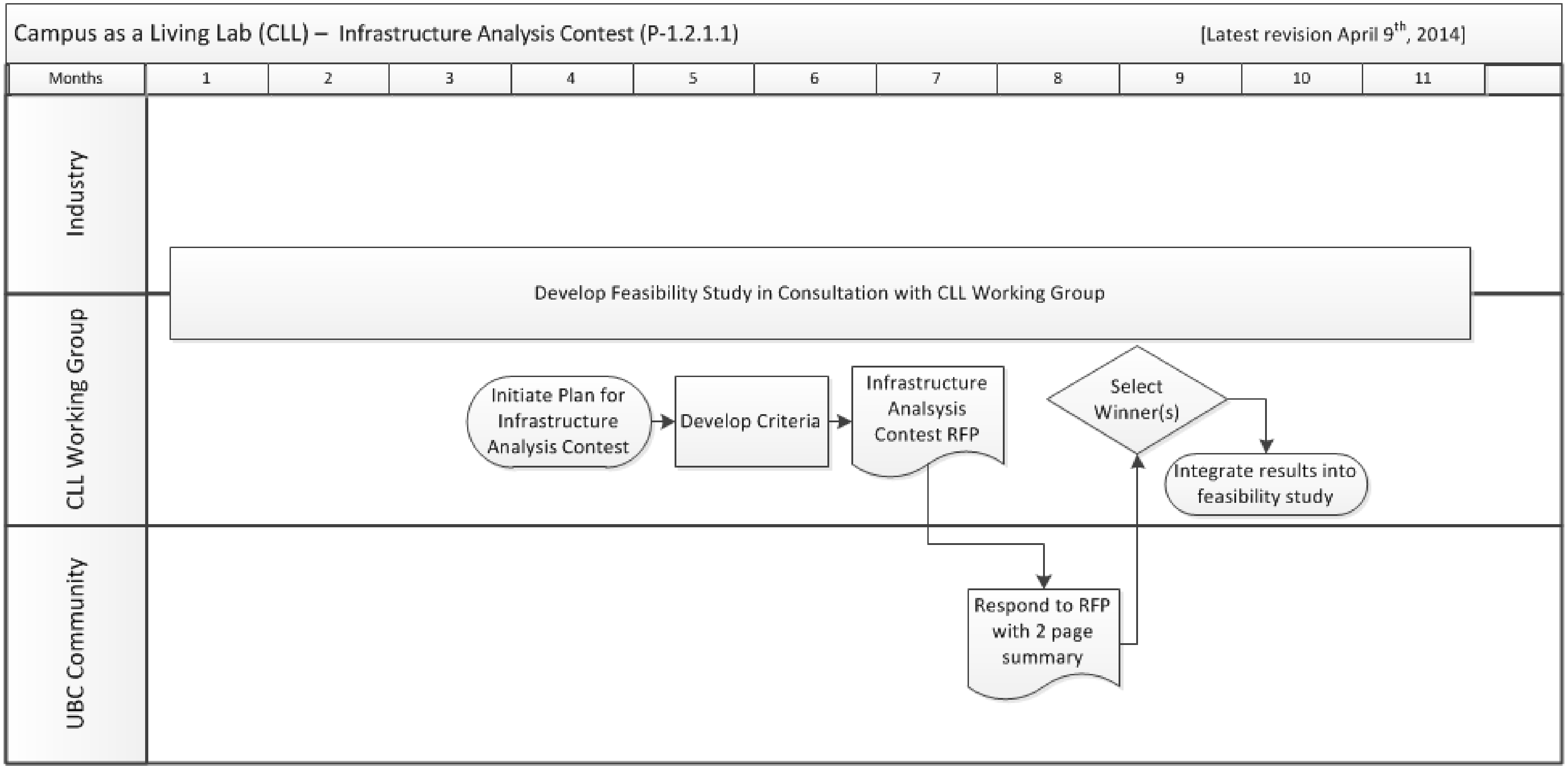

Figure 49: Campus as a Living Lab infrastructure analysis contest

5.3.4 Project Selection (P-1.2.2)

Project selection is divided into two categories: unsolicited requests and solicited requests. Historically at UBC, the unsolicited requests make up the bulk of the projects as they are initiated by either potential industry partners or by someone on campus. The solicited requests occur less frequently, but they tend to develop long relationships with the industry partners selected. Figure 5.10 provides a brief illustration.

In either category, the length of time required to complete a project can be longer than a company anticipates, so clearly expressing the process and a longer time frame at the start is important (Collins 2014).

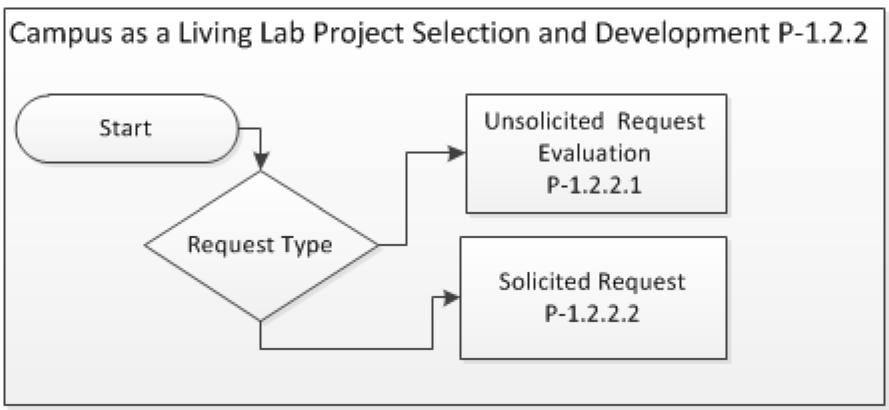

Figure 50: Campus as a Living Lab project selection and development

5.3.4.1 Campus as a Living Lab Unsolicited Request (P-1.2.2.1)

The following process in Figure 5.11 provides a high-level overview of the processes involved with unsolicited requests, as well as the time that it could take to pursue these projects. These estimated time frames were obtained by committee members of the UBC CLL, and provide a rough guide as to project duration. It takes substantially longer to pursue the larger projects as it does the smaller projects. The process is also based off of an existing UBC process with the addition of a time element. The project management process is also slightly more complex than the traditional project management process due to the iterations, budgeting, procurement and delivery, and commissioning being much more involved (Collins 2014).

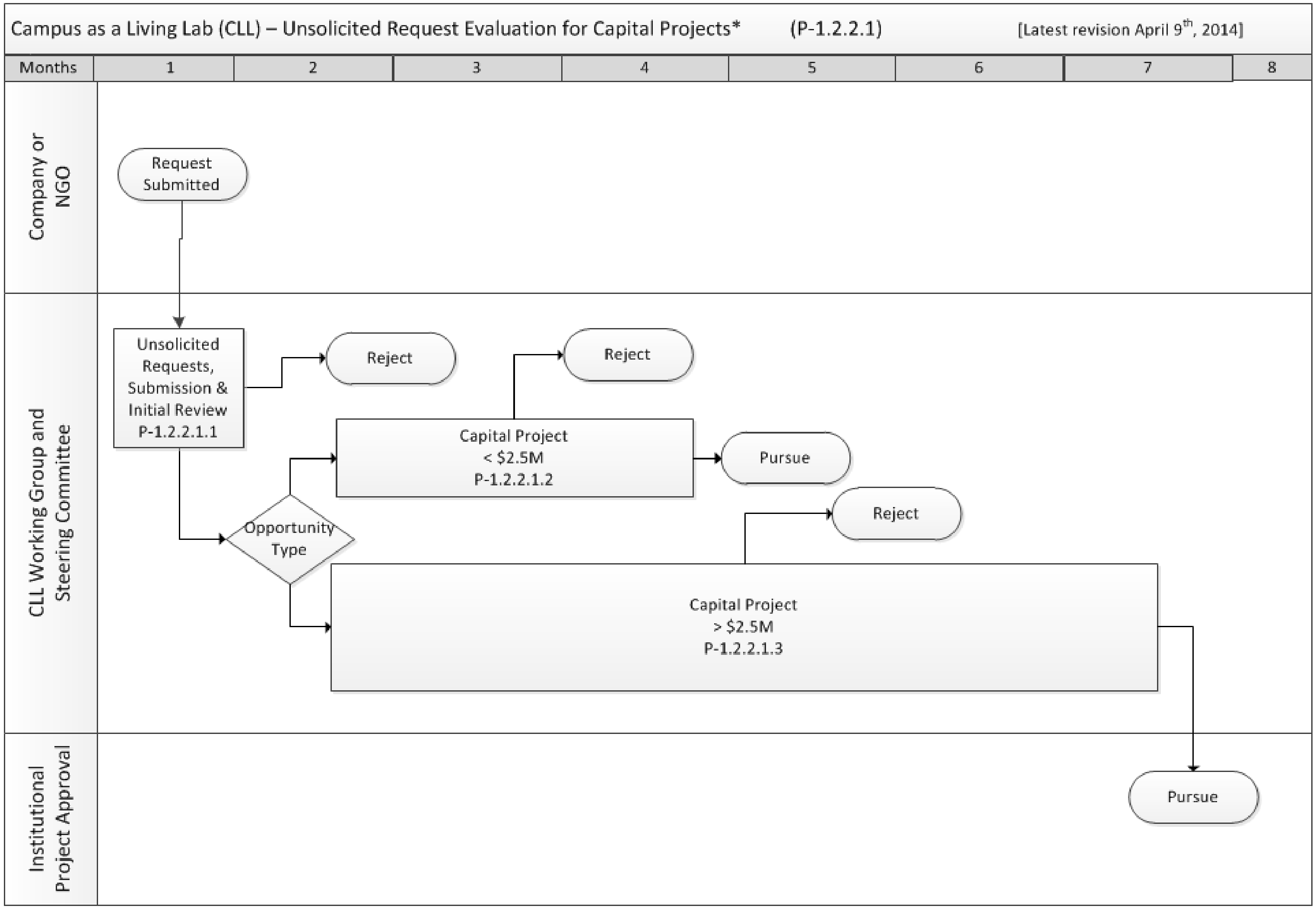

Figure 51: Campus as a Living Lab unsolicited request evaluation for capital projects

5.3.4.1.1 Campus as a Living Lab Unsolicited Requests Submission & Initial Review (P-1.2.2.1.1)

This initial review provides the initial phase of determining if a submission is qualified for a living lab opportunity, qualified for an operations-company or operations-researcher opportunity, or rejected. This initial preliminary determination is carried out by the Strategic Partnerships Office. If the opportunity does appear to qualify for the living lab, then a brief presentation is made at the weekly CLL Working Group meeting before a more thorough analysis is completed. This initial review also allows for a side-by-side review of a number of unsolicited requests before being forwarded to a committee as recommended in Section 5.2.3. This process is outlined in Figure 5.12.

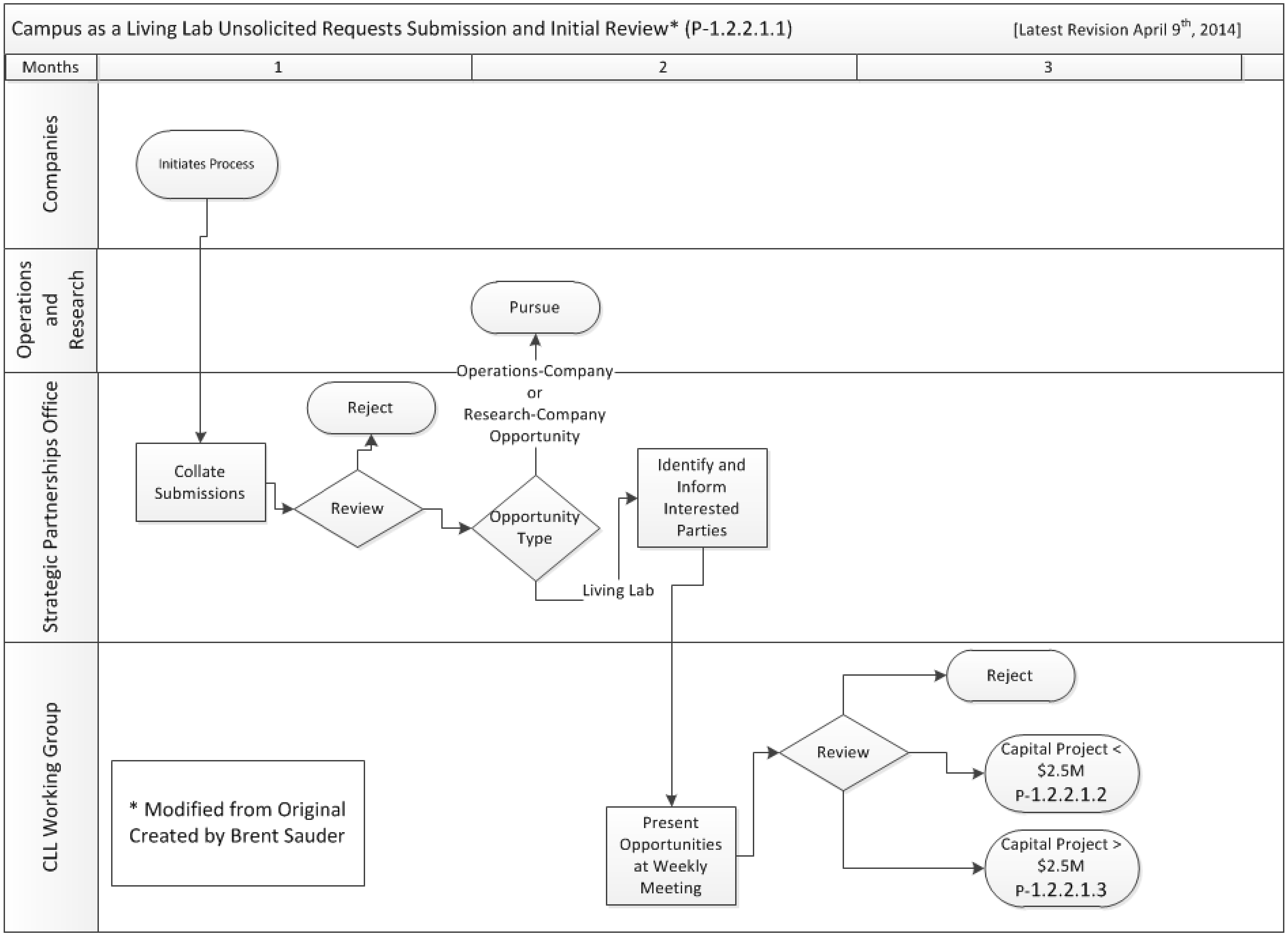

Figure 52: Campus as a Living Lab unsolicited requests submission and initial review

5.3.4.1.1.1 Campus as a Living Lab Unsolicited Requests < $2.5M (P-1.2.2.1.2)

The first stage of an unsolicited request requires completing an online form and submitting a two-page proposal. This first step is crucial in ensuring that UBC's interests align from the beginning of the project and it has been tailored to ensure that information gathered addresses specific questions. From here, the proposal is reviewed by the Strategic Partnerships Office who provides feedback to the CLL Working Group for review. If the company passes this section, the company then completes the slide deck template discussed in Section 5.3.2.4. This slide deck provides insight into the technology, how well the company knows the university as a customer and whether or not the company fundamentally understands what the university is trying to accomplish.

It has been found in the CLL Working Group that the presentation of this format of a slide deck prepared has helped to clearly outline where the potential benefit is to UBC and to industry as a whole. There have been occasions where the technology may be cutting edge, but if a company is not able to produce a benefit to UBC and to industry as a whole, then the project would not be pursued. The slide deck is first reviewed by the Strategic Partnerships Office and then by the CLL Working Group. After this step, a spider chart analysis is completed based on the framework developed by Iain Evans in the Strategic Partnerships Office. This Spider Chart provided 5 categories and 24 sub-categories for analysis with the purpose of being able to strategically determine whether or not a potential project is worth exploring further. Each of the sub-categories are rated a point value of "-1", "0", or "1" and the higher the score the better alignment between the technology to be tested and the university sustainability objectives. This is an important step to have, as these reviews are carefully done by a diverse team of individuals who contribute various areas of campus expertise and involves examining the project against the terms of reference. If the working group considers the project to have potential, then the Strategic Partnerships Office will request additional information to further review with the CLL Working Group. If the CLL Working Group agrees that there is a fit, then a champion for the project is identified. (Appointing a champion for a project can prove challenging at times when everyone already is balancing a full-time workload.) Once a project champion has been appointed, then a presentation is made to the CLL Steering

Committee for final vetting before an informal steering committee is created to develop a memorandum of understanding.

These projects follow the same rigour as the projects that are greater than $2.5 million in value. The only difference is that the projects do not require institutional project approval. The process is provided in Figure 5.13.

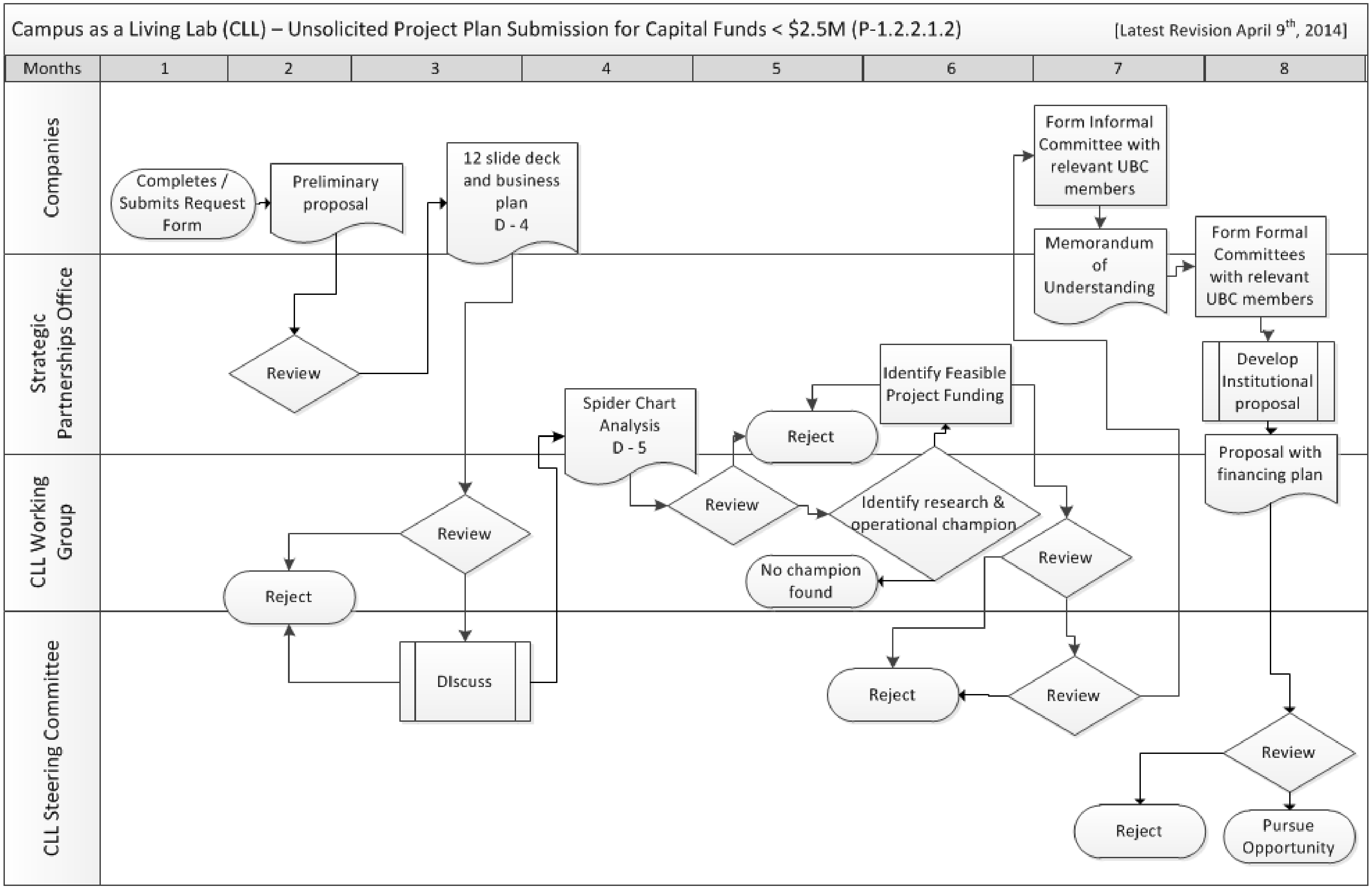

Figure 53: Campus as a Living Lab unsolicited project plan submission for capital funds < $2.5M

5.3.4.1.1.2 Campus as a Living Lab Unsolicited Requests > $2.5M (P-1.2.2.1.3)

The process for unsolicited requests greater than $2.5M is the same as the process for requests less than $2.5M in value with the exception that final approval would need to come from the institution. For detail on the steps, refer to Section 5.3.4.1.1.1. The illustration is provided in Figure 5.14.

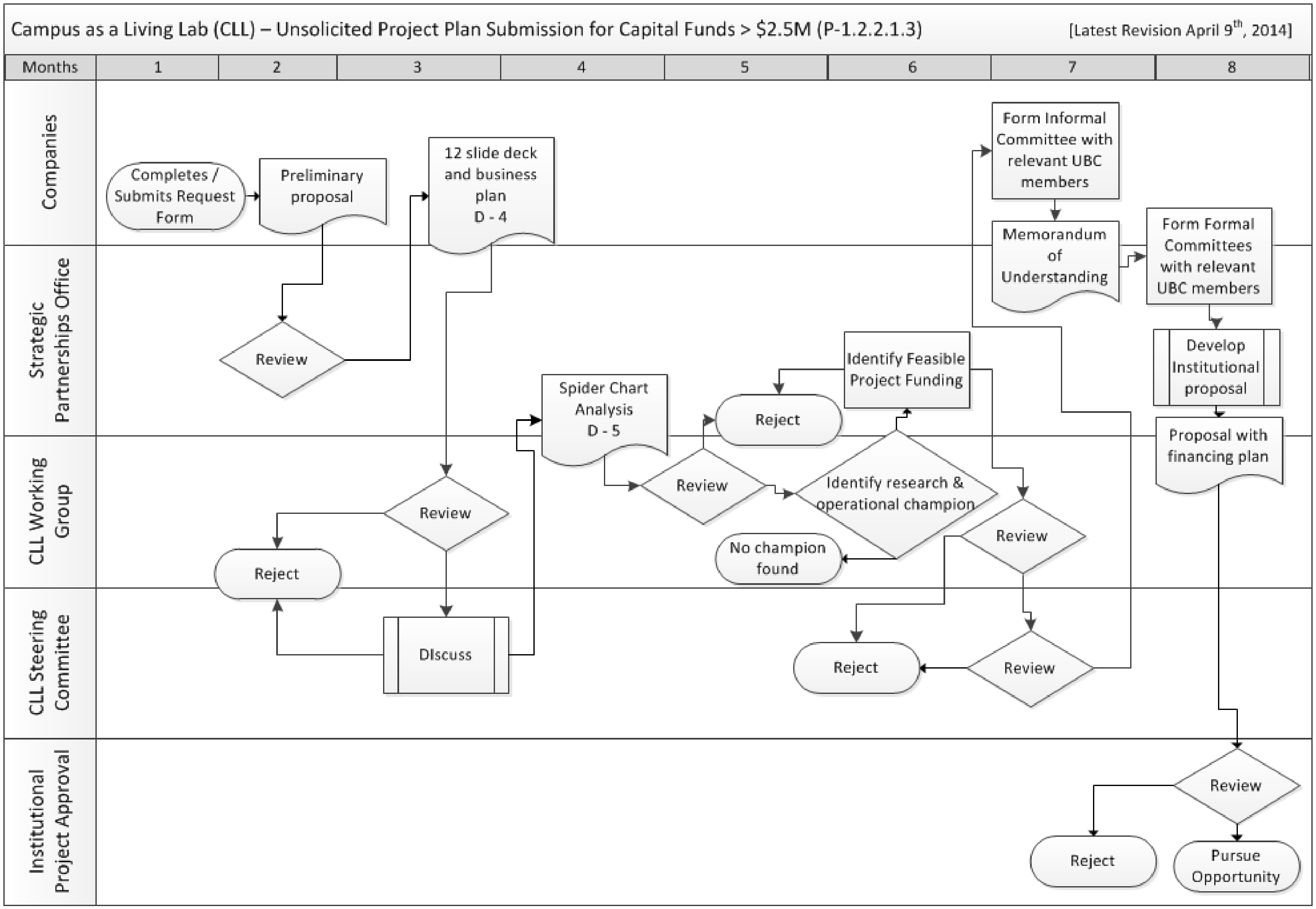

Figure 54: Campus as a Living Lab unsolicited project plan submission for capital funds > $2.5M

5.3.4.1.2 Solicited Request (P-1.2.2.2)

The solicited requests are completed through a request for information (RFI) approach in order to provide an initial vetting of potential partners. This vetting also flows through the relevant committees to provide a wide range of expertise for the review. It was developed based on UBC CLL processes in place and illustrated the need for a number of checkpoints as mentioned in Section 5.2.2. This process is shown in Figure 5.15.

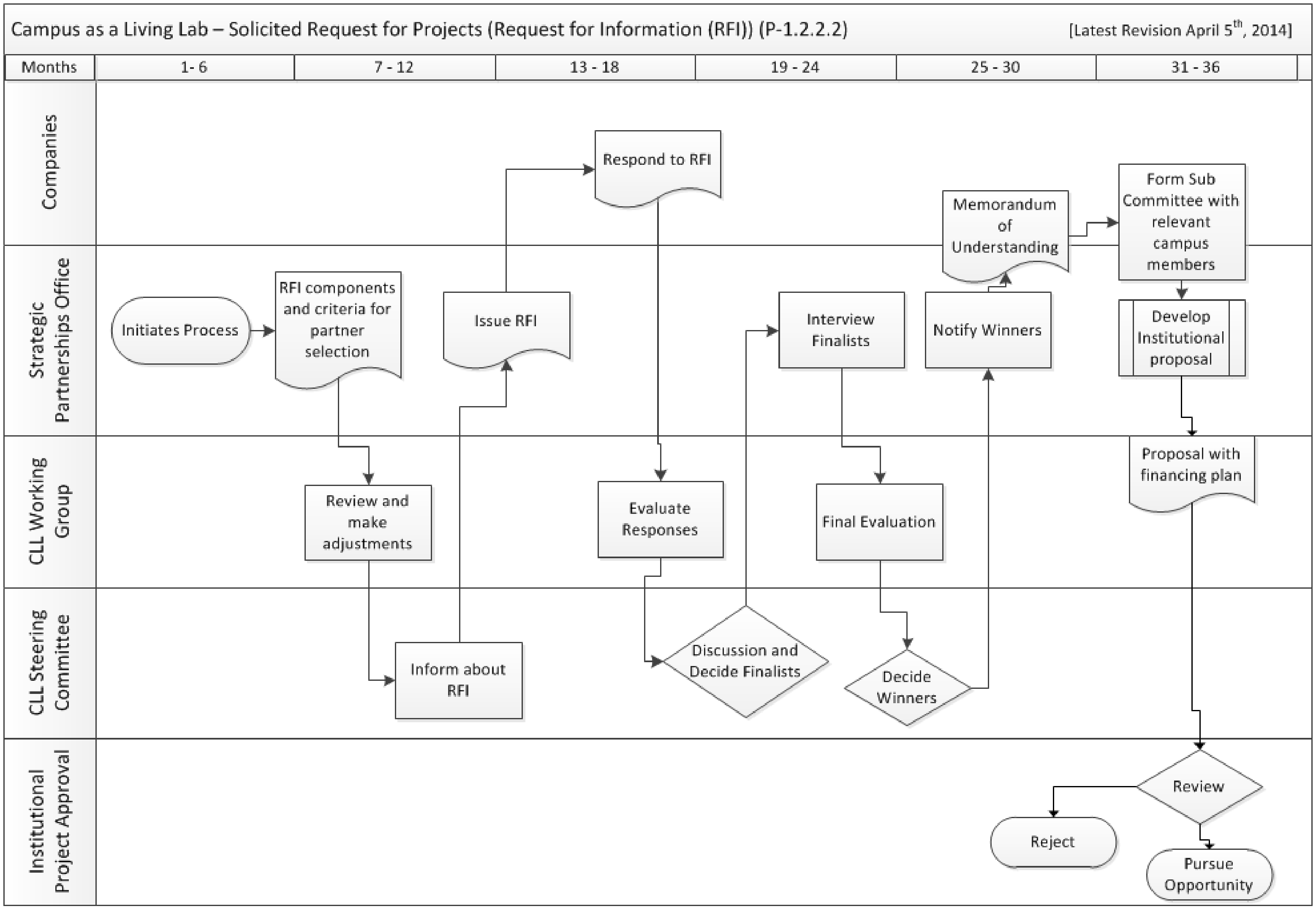

Figure 55: Campus as a Living Lab solicited request for projects

5.3.5 CLL Improvement

The operational phase of the CLL is best described as a cycle that rotates between strategizing and optimizing CLL processes, engaging other groups, developing and refining tools for decision making, evaluating metrics for success, and continually improving the technical guidelines for campus buildings. Explanations of each of these include the following:

Strategizing and optimizing CLL processes: This includes evaluating the terms of reference for the CLL and improving reporting procedures.

Engaging other groups: As there are a number of groups on campus where a synergistic relationship could develop, it is valuable to initiate dialogue to investigate potential opportunities for collaboration.

Developing and refining tools for decision making: The slide deck and spider chart mentioned previously are two examples of these.

Evaluating metrics for success: Since the only way of knowing if a CLL program is successful is to provide metrics to measure success, time spent refining these can assist in proving the value of a CLL program.

Continually improving the technical guidelines for campus buildings: The goal of this is to provide a platform to support having every building constructed be better than the building before it.

This operational phase was developed with current UBC CLL practices as well as improvements from the ethnographic study conducted (Figure 5.16).

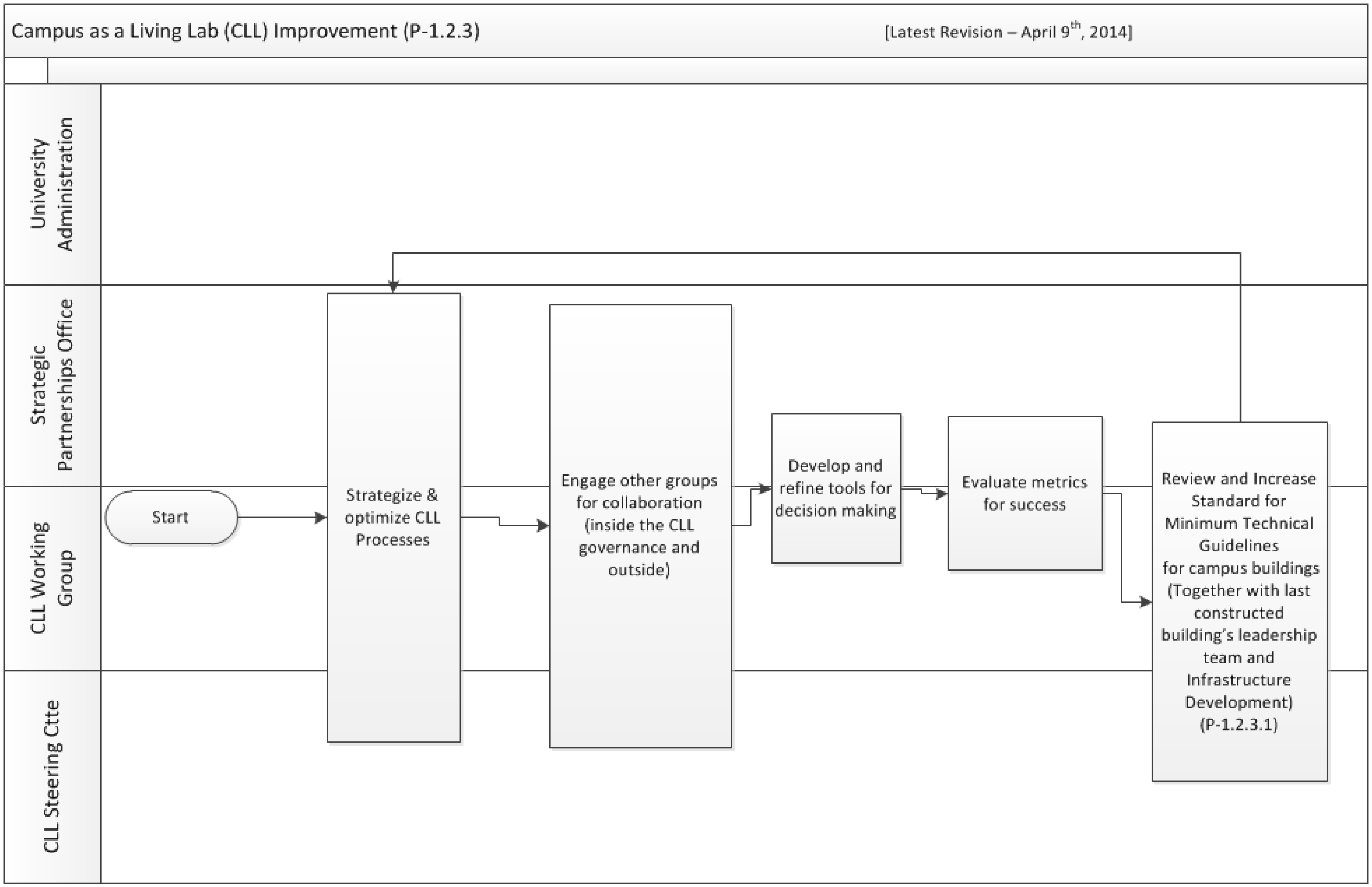

Figure 56: Campus as a Living Lab continual improvement

5.3.5.1 Continually Improve Technical Guidelines for Buildings (P-1.2.3.1)

Although this process has not been developed yet, it did warrant having a separate section as it has been something discussed numerous times during the UBC CLL Working Group meetings. The development of a method to continually increase the performance of buildings is an essential element to campus sustainability since buildings also consume the vast amount of energy and water on campuses. The improvements for these guidelines are also meant to go beyond technical aspects of the building, but also reach into processes and tools used throughout the planning, design, construction, commissioning, and operation phases. Additionally, if a campus is to set aggressive GHG reduction targets, a new paradigm of improving buildings would also need to be part of the solution.

5.3.6 High Performance Building Model (P-2)

Developing a high performance building can prove to be a challenging task. The process in Figure 5.17 provides an amalgamation of the key points that were used in the development of the Centre for Interactive Research on Sustainability (CIRS) as well as key transferable characteristics identified in the ethnographic study. The items integrated from the ethnographic study are the “improve technical guidelines” and the “determine construction and operating costs – fundraise to cover both costs” portions. A key item learned from the original CIRS process was to also link fundraising efforts to specific building components, so that they cannot be value engineered out afterwards. Another important point was to have design goals developed early on in order to develop consensus among the parties involved and to keep the project focus from continually shifting. The idea of integrating a review of technical guidelines after the building is constructed allows potential improvements to be integrated for reasons mentioned in the previous section.

This process is shown in Figure 5.17.

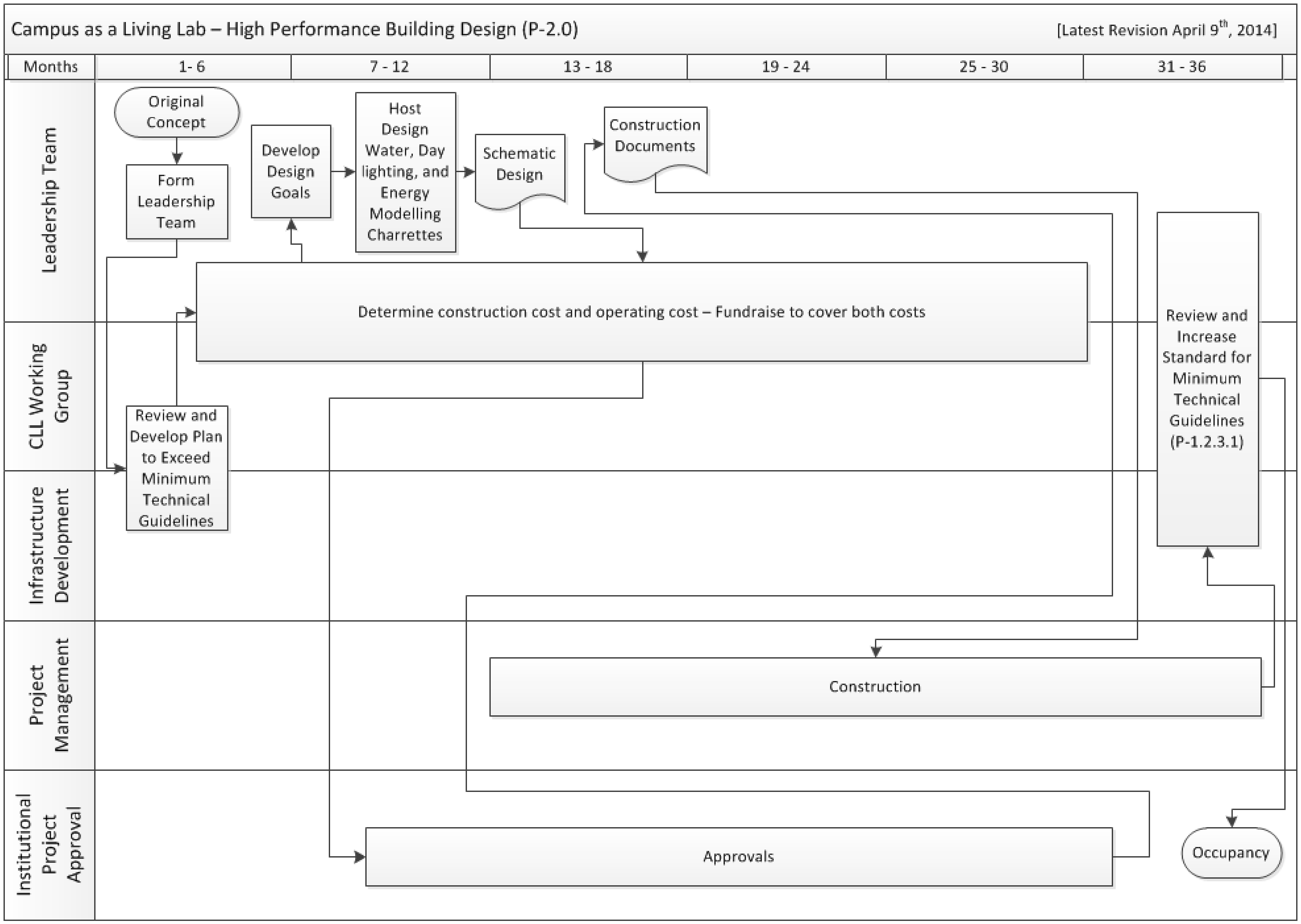

Figure 57: Campus as a Living Lab high performance building design

5.3.7 Summary

This section developed the foundation of a roadmap to help assist other campuses and municipalities to develop a CLL of their own. This roadmap consisted of replicable processes that were extracted from the lessons learned and the key transferable characteristics from UBC's CLL program. These key transferable characteristics, combined with the previously existing CLL BPMs, led to the creation of 22 BPMs to support the process of developing and operating a CLL. These included processes to assist in the development of a CLL, infrastructure analysis, project selection and development, CLL improvement, and high performance buildings.

The key transferable characteristics that formed the basis of these BPMs were provided in Chapter 3 and Chapter 4 of this thesis. Chapter 3 provided a general overview of the BPMs utilized at UBC, as well as reasons why improvements have been integrated into these models. Chapter 4 built upon an ethnographic study that was carried out over 16 months, where the author observed and participated in 36 CLL Working Group meetings to learn about the CLL processes being employed and to culture ideas for improvement.

In order to further support the transition into a CLL, five documents were also provided: a process model overview, an organizational chart, a sample terms of reference, a slide deck for preliminary project evaluation, and a spider chart for in-depth project evaluation.

5.4 Recommendations

The goal of this chapter was to develop a replicable roadmap to assist with implementing a CLL concept. It was meant provide insight into the practices at UBC and to assist in shortening the learning curve that is involved with developing a CLL. In order to apply these to a new organization, the generalized processes provided would need to be adapted to conform to various organizational structures and to the human and financial resources available. It is a long process to develop a CLL, as can be noted by the many changes that the author witnessed during a 16-month-long ethnographic study, but the process can be worthwhile as it provides another avenue for collaboration within a university and can assist with reducing the ever-present silos in institutions.

Chapter 6. Conclusions

The goal of this thesis was to do explore the contributions of the University of British Columbia's (UBC's) "Campus as a Living Lab" (CLL) program and to develop replicable processes for other universities and municipalities to expand their sustainable practices in similar ways. Since UBC is the size of a small municipality, it is an assumption of the author that the CLL process could potentially be replicated at similar scale entities. As there are a number of potential benefits associated with a CLL program including GHG reduction, more resilient infrastructure systems, and improved collaborations between industry, operations, and researchers, there is reason to believe that others could be interested in adopting a similar program.

The research on how to replicate a CLL program began in ***Chapter 2*** by discussing barriers to sustainable technology adoption in campus infrastructure systems, the increasing availability of technology, technology development and transfer, knowledge creation and diffusion, qualitative research methods, and business process modelling.

Some of the barriers to sustainable technology adoption in campus infrastructure systems discussed included risks that could hinder projects due to uncertainty associated with performance, schedule, and cost. This section also highlighted how UBC attempts to de-risk projects by leveraging UBC infrastructure investments with matching funds from industry and the government, by reducing potential liability on carbon taxes, and by using projects to contribute to research and teaching. The technology development and transfer section amalgamated technology readiness levels, the technology transfer process, economic clusters, the value chain, the technology adoption curve, and living labs.

The technology readiness levels showed how new technology moves through different stages of maturity and the ways that these stages can be used to assess the timing to introduce a new technology. The technology transfer process highlighted how science-based and development-based regimes differ, and presented the differences between the three stakeholders for university technology transfer. The description of economic clusters provided a description of how local regions could benefit and how a CLL environment would be able to assist with knowledge spillovers, labour pooling and input-output linkages. Additionally, firms within an economic cluster could improve their value chain to increase their competitiveness. The technology adoption curve illustrated the significant hurdle to overcome when crossing from the early adopters to early majority. University living labs were then introduced to show how they can bridge between the technology readiness levels, the technology transfer process, economic clusters, the value chain, and the technology adoption curve. They achieve this by providing a test bed for developing and demonstrating projects. This also provides an avenue for the financing of a demonstration project that can lead to commercialization of the technology to be adopted by others.

Knowledge creation and diffusion was explained, including the differences between tacit and explicit knowledge, and how knowledge modes and helices were introduced to offer a method of understanding knowledge creation systems. Barriers that prevent new knowledge from being created and diffused were introduced, which included personal barriers (personal accommodation, and threat to self-image), and organizational barriers (the need for a formalized language, organizational precedents, procedures, and company vision). Potential barrier reduction methods and enablers for knowledge transfer were also provided.

An overview of ethnographic research established the methods available for collecting data with a focus on participant observation as the most widely used method. Various formats to take written notes were also provided with field notes being the main form, and descriptive notes being main category used. Methods available to code the field notes were outlined along with the benefit of using thematic networks amongst already developed frameworks to organize themes. Two frameworks were also proposed for use: the Project Management Body of Knowledge and the cross industry process classification framework.

The current and future use of BPMs for the CLL was reviewed using perspectives, objectives, and characteristics. This aided in determining what attributes a model should possess. Once these were determined, the advantages and disadvantages of the main

BPMs and their respective ability to provide each of the four perspectives were reviewed, which resulted in the selection of a modified flow chart.

Chapter 3 introduced the history of the UBC CLL, and how the advancement was accelerated due to a number of strategies and efforts. It also illustrated how the CLL Working Group and Steering Committee is part of a broader University Sustainability Initiative (USI) that encompasses many stakeholders, and that the focus of the CLL Working Group is largely on identifying and pursuing opportunities and the pre-planning phase of a project's life-cycle. The concentration on this phase places the CLL in the best position to accelerate sustainable technology commercialization by positioning UBC campus to be a test bed. Additionally, CLL projects fall into two main categories: unsolicited and solicited. Due to an influx of unsolicited requests, the CLL needed to adapt to a more proactive, rather than reactive, model of governance. In order to achieve this, assessment tools for varying levels of analysis were developed to evaluate project fit within the UBC campus. These assessment tools were also provided in Chapter 5 for reference in the roadmap developed.

In deciding how to potentially improve on future CLL projects, three case studies were used: CIRS, the Academic District Energy System, and the Bioenergy Research and Demonstration Facility. These case studies were chosen as they gave a reference case to a building, an analysis of campus-wide infrastructure options, and a CLL project. They also represent energy consumption, transmission, and generation. All of the case studies have had varying degrees of positive impact on UBC campus. CIRS demonstrated how it is helpful to have charettes informing the project early-on to aid with technology decisions, to link funding with specific building components to reduce the potential for them to be value-engineered away, and to have one decision-maker to streamline a project. CIRS also illustrated how a building can be designed to meet four net positive goals (that is, the building creates net benefits to its surroundings in these areas rather than net detriments): "energy, embodied carbon emissions, operational carbon emissions, and water quality" (UBC 2011a). The Academic District Energy System showed how long of a process it can be to evaluate campus energy options and how both third-party consulting and the campus community can collaborate. The Academic District Energy System will potentially reduce GHG emissions by 22 percent while saving “$5.5 million in annual savings including the cost investment for not reinvesting an aging steam system”. (Giffin 2014, UBC 2011d) This aids with resiliency to campus infrastructure by reducing capital expenditures and reliance on external energy sources. From the Bioenergy Research and Demonstration Facility emerged the foundation for the current CLL processes; this facility also has the potential to reduce “UBCs GHGs by 5,000 tonnes per year” (UBC 2014b)

There are a number of important attributes that emerged in this chapter, including increasing support, aligning goals, improving processes, developing multi-stakeholder involvement, and developing strategic decision-making tools. This chapter also illustrated how researcher collaboration with industry and operations can be increased. Improvements to current CLL practices were also touched upon and key transferable characteristics were provided for use later in Chapter 5.

Chapter 4 introduced a 16-month-long ethnographic study that began on December 6th, 2012 and involved attending a total of 36 CLL Working Group meetings. After taking field notes from these meetings and coding them, a thematic network emerged in the form of a CLL Process Framework. This framework was partly derived from an amalgamation of categories, processes, and sub-processes from the American Productivity and Quality Center’s cross industry process classification framework and the Project Management Institute’s Project Management Body of Knowledge frameworks. A quantitative and qualitative analysis was then completed based on the data obtained. The quantitative analysis showed that the majority of the CLL Working Group’s time is absorbed by developing opportunities, assessing the environment, and developing a vision, strategy, and assessment tools. The qualitative analysis revealed a number of sub-themes, challenges, and partial solutions for further exploration. These results were then categorized into key transferable characteristics and integrated into Chapter 5.

Chapter 5 developed the foundation of a roadmap to help assist other campuses and potentially municipalities in developing a CLL of their own. This roadmap consisted of replicable processes that were extracted from lessons learned and key transferable characteristics from UBC’s CLL program. These key transferable characteristics combined with already existing CLL BPMs to provide 22 BPMs to support the process of developing and operating a CLL. These included processes to assist in the development of a CLL, infrastructure analysis, project selection and development, CLL improvement, and high performance buildings. The key transferable characteristics that formed the basis of these BPMs were provided from Chapter 3 and Chapter 4. In order to further support the transition into a CLL, five documents were also provided: a process model overview, an organizational chart, a sample terms of reference, a slide deck for preliminary project evaluation, and a spider chart for in-depth project evaluation

The goal of this thesis was to develop a replicable roadmap to assist with implementing a CLL concept. It was meant provide insight into the practices at UBC and to assist in shortening the learning curve that is involved with developing a CLL. In order to apply these to a new organization, the generalized processes provided would need to be adapted to conform to various organizational structures and to the human and financial resources available. It is a long process to develop a CLL, as can be noted by the many changes that the author witnessed during a 16 month long ethnographic study, but the process can be worthwhile as it provides another avenue for collaboration within a university and can assist with reducing the ever-present silos in institutions

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Appendices

Appendix A Kyoto Protocol GHG Emission Reduction Calculation

This appendix provides a methodology and steps to support the following sentence in Section 1.1:

"In 1997, 38 countries signed the Kyoto Protocol which bound them to reduce their GHG emissions to an average of 4.95 percent below 1990 emissions levels for the period of 2008 through 2012 (United Nations 1998), United Nations 2011b)."

The reason why the first 38 countries were used for the reference was two-fold: 1) to find out how well the initially pro-active countries for signing the Kyoto Protocol accomplished their goals, and 2) to utilize sources where their information is readily available.

In order to obtain the 4.95 percent, the following methodology and steps were used.

Methodology

1. Obtain list of countries who were the first signatories in 1997
2. verify how emissions are to be calculated under the Kyoto Protocol,
3. verify these countries emissions in 1990, 2008, 2009, 2010, and 2011,
4. calculate each country's percentage difference in emissions between 2011 and 1990,
5. calculate the total weighted average of the 38 countries' agreed upon emission reduction,

Steps

1. The list of countries who were the first signatories was obtained from "The Report of the Conference of the Parties on its Third Session, Held at Kyoto from 1 to 11

December 1997" (United Nations 1997). This report contained 37 countries who initially signed onto the Kyoto Protocol.

2. The emission calculations are detailed in Article 3, item (3) of the Kyoto Protocol which states "The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I" (United Nations 1998).

3. The emissions for 1990, 2008, 2009, 2010, and 2011 were obtained from the GHG total including Land Use, Land Use Change, and Forestry on the United Nations website. These figures are included in the following Table 6.1.

4. Each country's percentage difference in emissions between 2011 and 1990 is provided in Table 6.1 under the column "2011 Actual Change".

5. The total weighted average of the 38 countries' agreed upon emission reduction was calculated from the totals for "2011 Emissions Target (tonnes of GHG equivalent) (G)" and the "1990 (A) Actual Emissions (tonnes GHG equivalent)" in Table 6.1. These respective values are below:

   2011 Emissions Target (tonnes of GHG equivalent) = 16,723,066

   1990 Actual Emissions (tonnes GHG equivalent) = 17,593,829

   Let Z = total weighted average of the 38 countries' agreed upon emission reduction

$$Z = \frac{16{,}723{,}066 - 17{,}595{,}829}{17{,}593{,}829} * 100 = 4.949$$

Table 19: First 38 signatories for Kyoto Protocol actual emissions for 1990, 2008, 2009, 2010, and 2011, as well as percentage of change between 2011 and 1990 (United Nations 2011b)

First 38 signatories for Kyoto Protocol actual emissions for 1990, 2008, 2009, 2010, and 2011, as well as percentage of change between 2011 and 1990

		Actual Emissions (tonnes GHG equivalent)**							
Country	Reduction Commitment	1990 (A)	2008 (C)	2009 (D)	2010 (E)	2011 (F)	2011 Emissions Target (tonnes of GHG equivalent) (G) = (A * B)	2011 Actual Change (H) = (G – B) / (B)	Met Target
Australia	108.00%	524,049	520,593	589,413	587,811	511,951	565,973	97.69%	Yes
Austria	92.00%	68,232	87,446	76,418	81,497	79,353	62,773	114.01%	No
Belgium	92.00%	142,307	135,561	123,286	130,563	119,040	130,922	83.65%	Yes
Bulgaria*	92.00%	107,596	58,662	49,417	52,243	58,154	98,989	54.05%	Yes
Canada	94.00%	529,451	719,854	679,188	804,044	789,058	497,684	132.90%	No
Croatia*	95.00%	25,282	23,550	21,277	20,909	21,390	24,018	84.60%	Yes
Czech Republic*	92.00%	192,571	137,503	127,136	132,257	126,387	177,166	65.63%	Yes
Denmark	92.00%	75,561	63,939	65,185	62,306	55,084	69,516	72.90%	Yes
Estonia*	92.00%	31,693	11,492	8,919	14,047	16,693	29,158	52.67%	Yes
Finland	92.00%	55,290	40,590	26,791	49,928	42,456	50,867	76.79%	Yes
France	92.00%	537,671	490,094	475,743	486,828	448,517	494,657	83.42%	Yes
Germany	92.00%	1,214,506	982,752	919,818	952,239	925,830	1,117,345	76.23%	Yes
Greece	92.00%	102,090	127,465	121,020	114,678	112,505	93,923	109.26%	No
Hungary*	94.00%	113,774	68,776	63,432	63,921	62,492	106,947	54.93%	Yes
Iceland	110.00%	4,727	5,900	5,633	5,461	5,206	5,200	109.21%	Yes

First 38 signatories for Kyoto Protocol actual emissions for 1990, 2008, 2009, 2010, and 2011, as well as percentage of change between 2011 and 1990

Country	Reduction Commitment	Actual Emissions (tonnes GHG equivalent)** 1990 (A)	2008 (C)	2009 (D)	2010 (E)	2011 (F)	2011 Emissions Target (tonnes of GHG equivalent) (G) = (A * B)	2011 Actual Change (H) = (G – B) / (B)	Met Target
Ireland	92.00%	52,585	64,902	58,823	57,382	53,813	48,378	102.28%	No
Italy	92.00%	506,830	504,507	450,860	456,973	458,202	466,284	90.41%	Yes
Japan	94.00%	1,197,614	1,204,280	1,133,169	1,181,974	1,232,650	1,125,757	102.84%	No
Latvia*	92.00%	4,006	-8,030	-8,924	-4,314	-5,634	3,686	-140.62%	Yes
Liechtenstein	92.00%	221	257	241	227	215	203	97.35%	No
Lithuania*	92.00%	44,467	16,484	9,793	10,725	11,131	40,910	25.03%	Yes
Luxembourg	92.00%	13,249	11,915	11,394	11,957	11,804	12,189	89.09%	Yes
Monaco	92.00%	108	100	95	92	90	100	82.61%	Yes
Netherlands	92.00%	214,849	206,339	200,708	212,169	197,645	197,661	91.99%	Yes
New Zealand	100.00%	31,634	50,570	49,690	54,126	59,383	31,634	146.73%	No
Norway	101.00%	35,105	29,940	29,642	30,756	25,873	35,456	73.70%	Yes
Poland*	94.00%	558,075	382,897	362,589	383,862	384,948	524,591	68.98%	Yes
Portugal	92.00%	69,449	72,221	68,989	67,897	64,667	63,893	93.11%	No
Romania*	92.00%	251,813	116,165	92,056	90,809	98,054	231,668	38.94%	Yes
Russian Federation*	100.00%	3,436,472	1,658,976	1,474,868	1,566,674	1,692,416	3,436,472	49.25%	Yes
Slovakia*	92.00%	61,763	41,895	36,519	38,981	37,830	56,822	61.25%	Yes
Slovenia*	92.00%	11,011	11,703	9,754	9,830	9,891	10,130	89.83%	Yes

First 38 signatories for Kyoto Protocol actual emissions for 1990, 2008, 2009, 2010, and 2011, as well as percentage of change between 2011 and 1990

Country	Reduction Commitment	Actual Emissions (tonnes GHG equivalent)**					2011 Emissions Target (tonnes of GHG equivalent) (G)	2011 Actual Change (H)	
		1990 (A)	2008 (C)	2009 (D)	2010 (E)	2011 (F)	= (A * B)	= (G – B) / (B)	Met Target
Spain	92.00%	263,683	369,789	334,205	319,746	321,412	242,588	117.96%	No
Sweden	92.00%	35,566	30,580	26,584	34,851	26,216	32,721	73.71%	Yes
Switzerland	92.00%	49,894	52,225	50,412	51,850	46,752	45,902	93.70%	No
Ukraine*	100.00%	860,156	410,844	347,039	345,256	394,287	860,156	45.84%	Yes
United Kingdom of Great Britain and Northern Ireland	92.00%	781,732	644,182	589,602	605,234	564,081	719,194	72.16%	Yes
United States of America	93.00%	5,388,746	6,146,159	5,704,017	5,921,548	5,797,284	5,011,533	107.05%	No
	TOTALS	**17,593,829**	**15,493,077**	**14,384,802**	**15,007,339**	**14,857,124**	**16,723,066**		

Note: *Undergoing a transition to a market economy in 1998, **GHG total including Land Use, Land Use Change, and Forestry

Appendix B Average Greenhouse Gas Emission for Canadian Municipalities with Populations over 10,000 people

The goal was to calculate how much municipalities with over 10,000 people are expelling in greenhouse gases in Canada on average by province. To help refine the GHG estimates for all the 400 municipalities that have 10,000 or more people both a top-down and a bottom-up calculation were used. For the top-down approach, the provincial GHG emission data, provincial population data, and municipal population data was used to determine estimates for GHG emissions per municipality. The bottom-up approach used the actual municipality GHG emission data. These numbers were then brought together to provide GHG emission data for all 400 municipalities. This was meant to be more of a back of the envelop calculation.

Methodology

1. Obtain national and provincial population data
2. Obtain population data for municipalities.
3. Obtain national and provincial GHG emission data (Tonnes CO_2 equivalent)
4. Obtain GHG emission data from at least 10% of the municipalities in each province. (Ensure that the number sampled is greater than 2 if possible.)
5. Determine average GHG emissions per capita for municipalities in each province. Averages for each province are important as each one has different energy inputs that can affect the emissions.

Steps

1. Obtain national and provincial population data
    a. Obtained national and provincial population data for 2009, 2010, 2011, 2012, and 2013 from Statistics Canada (Canada 2013).
2. Obtained national and provincial GHG emission data (Tonnes CO_2 equivalent)

a. Data was obtained from the United Nations website for National Inventory Submissions 2013. The National Inventory Report for Canada was used to obtain Provincial CO_2 equivalent GHG data for 1990, 2000, and 2011 (United Nations 2013).

3. Obtain population data for municipalities.

   a. Obtained national and provincial population data for 1996, 2001, 2006, and 2011 was obtained from Statistics Canada. (Canada 2002) (Canada 2012) This data was also cleaned as some municipalities had amalgamated during these years.

4. Obtain GHG emission data from at least 10% of the municipalities in each province. (Ensure that the number sampled is greater than 2 if possible)

   a. Much of this data was obtained directly from municipal websites and from the Federation of Canadian Municipalities website. Using search techniques like “"site:.fcm.ca/documents/reports/pcp/ "burlington"” proved useful. All together 33 reports were obtained that contained at the very least, municipal emissions data. Sources for these are listed in Table 6.2.

5. Determine average GHG emissions per capita for municipalities in each province. Averages for the municipalities in each province are important as each one has different energy inputs that can affect the emissions.

   a. Given that CO_2 equivalent data was obtained from various years, this data first needed to be all placed in a 2011 equivalent. The following calculations were used to bring data from 1996 to 2010 into a 2011 equivalent.

Let A = 2011 Census Data for the Municipality
Let B = 2006 Census Data for the Municipality
Let C = 2001 Census Data for the Municipality
Let D = 1996 Census Data for the Municipality
Let GHG_Data_2009 = Respective municipal GHG data from 2009
Let GHG_Data_2008 = Respective municipal GHG data from 2008
Let GHG_Data_2007 = Respective municipal GHG data from 2007
Let GHG_Data_2006 = Respective municipal GHG data from 2006

Let GHG_Data_2005 = Respective municipal GHG data from 2005
Let GHG_Data_2004 = Respective municipal GHG data from 2004
Let GHG_Data_2003 = Respective municipal GHG data from 2003
Let GHG_Data_2002 = Respective municipal GHG data from 2002
Let GHG_Data_2001 = Respective municipal GHG data from 2001
Let GHG_Data_2000 = Respective municipal GHG data from 2000
Let GHG_Data_1999 = Respective municipal GHG data from 1999
Let GHG_Data_1998 = Respective municipal GHG data from 1998
Let GHG_Data_1997 = Respective municipal GHG data from 1997
Let GHG_Data_1996 = Respective municipal GHG data from 1996

Bringing 2010 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2010 * \frac{A}{B + \left(\frac{A-B}{5}\right) * 4}$$

Bringing 2009 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2009 * \frac{A}{B + \left(\frac{A-B}{5}\right) * 3}$$

Bringing 2008 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2008 * \frac{A}{B + \left(\frac{A-B}{5}\right) * 2}$$

Bringing 2007 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2007 * \frac{A}{B + \left(\frac{A-B}{5}\right) * 1}$$

Bringing 2006 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2006 * \frac{A}{B + \left(\frac{A-B}{5}\right) * 0}$$

Bringing 2005 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2005 * \frac{A}{C + \left(\frac{B-C}{5}\right) * 4}$$

Bringing 2004 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2004 * \frac{A}{C + \left(\frac{B-C}{5}\right) * 3}$$

Bringing 2003 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2003 * \frac{A}{C + \left(\frac{B-C}{5}\right) * 2}$$

Bringing 2002 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2002 * \frac{A}{C + \left(\frac{B-C}{5}\right) * 1}$$

Bringing 2001 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2001 * \frac{A}{C + \left(\frac{B - C}{5}\right) * 0}$$

Bringing 2000 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_2000 * \frac{A}{D + \left(\frac{C - D}{5}\right) * 4}$$

Bringing 1999 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_1999 * \frac{A}{D + \left(\frac{C - D}{5}\right) * 3}$$

Bringing 1998 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_1998 * \frac{A}{D + \left(\frac{C - D}{5}\right) * 2}$$

Bringing 1997 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_1997 * \frac{A}{D + \left(\frac{C - D}{5}\right) * 1}$$

Bringing 1996 GHG data to 2011:

$$2011\ equivalent = GHG\_Data\_1996 * \frac{A}{D + \left(\frac{C - D}{5}\right) * 0}$$

The base data is provided in Table 6.2 and Table 6.3, and the results of these calculations are listed in Table 6.4.

Table 20: Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent)

Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent)

National population rank, 2011	Geographic code	City	Province	Year of GHG data obtained	GHG Data from Year Obtained	Data converted to 2011	Source
1	3520005	Toronto (Ont.)	Ontario	2011	23,200,000	23,200,000	(Fund 2013)
2	2466023	Montréal (Que.)	Quebec	2009	13,090,000	13,182,145	(Montreal 2013)
3	4806016	Calgary (Alta.)	Alberta	2010	17,000,000	17,341,575	(Calgary 2006)
4	3506008	Ottawa (Ont.)	Ontario	1998	9,113,757	10,845,882	(Ottawa 2004)
5	4811061	Edmonton (Alta.)	Alberta	2009	13,681,000	14,255,495	(Pembina 2012)
7	4611040	Winnipeg (Man.)	Manitoba	2007	2,383,000	2,472,929	(Transportation & Winnipeg 2007)
8	5915022	Vancouver (B.C.)	British Columbia	2008	2,740,000	2,811,160	(Pembina 2009)
10	3525005	Hamilton (Ont.)	Ontario	2006	12,758,652	13,147,815	(Stantec 2009)
12	5915004	Surrey (B.C.)	British Columbia	2007	2,276,185	2,601,917	(Surrey 2013)
14	1209034	Halifax (N.S.)	Nova Scotia	2002	6,775,289	7,040,664	(Consulting 2006)
15	3539036	London (Ont.)	Ontario	2012	2,900,000	2,900,000	(London 2013)
16	3519036	Markham (Ont.)	Ontario	2006	2,451,268	2,827,393	(Canada 2009)

Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent)

National population rank, 2011	Geographic code	City	Province	Year of GHG data obtained	GHG Data from Year Obtained	Data converted to 2011	Source
17	3519028	Vaughan (Ont.)	Ontario	2006	1,695,612	2,046,531	(Vaughan 2013)
21	4711066	Saskatoon (Sask.)	Saskatchewan	2004	3,674,637	4,101,807	(Group 2009)
27	3524001	Oakville (Ont.)	Ontario	2004	990,183	1,180,551	(Oakville 2004)
28	3524002	Burlington (Ont.)	Ontario	2003	1,909,577	2,111,312	(Parkin 2004)
34	3543042	Barrie (Ont.)	Ontario	2008	856,000	884,472	(CH2MHILL 2006)
44	5917021	Saanich (B.C.)	British Columbia	2007	521,000	526,709	(District of Saanich 2010)
85	4811062	St. Albert (Alta.)	Alberta	2008	742,019	769,839	(Stantec 2010a)
87	3521024	Caledon (Ont.)	Ontario	2011	312,300	769,839	(Gerard 2011)
103	4607062	Brandon (Man.)	Manitoba	2003	1,327,619	1,568,067	(Bates 2008)
133	5907041	Penticton (B.C.)	British Columbia	2007	231,789	237,380	(Stantec 2011)
140	3531011	Stratford (Ont.)	Ontario	2005	323,070	334,350	(CH2MHILL 2008)
155	4811049	Spruce Grove (Alta.)	Alberta	2003	329,840	592,882	(City of Spruce Grove 2004)
167	1001485	Conception Bay South (N.L.)	Newfoundland	2008	143,753	154,505	(South 2012)

Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent)

National population rank, 2011	Geographic code	City	Province	Year of GHG data obtained	GHG Data from Year Obtained	Data converted to 2011	Source
215	1306020	Riverview (N.B.)	New Brunswick	2008	198,711	207,131	(Stantec 2010b)
234	5915070	Pitt Meadows (B.C.)	British Columbia	2007	88,567	97,898	(HYLA Environmental Services Ltd. 2011)
268	4811048	Stony Plain (Alta.)	Alberta	2006	129,087	157,153	(Schmidt 2007)
297	5927008	Powell River (B.C.)	British Columbia	2010	69,610	69,831	(River 2014)
327	1315011	Bathurst (N.B.)	New Brunswick	2000	201,394	188,679	(Torrie 2007)
345	5949011	Terrace (B.C.)	British Columbia	2010	80,303	80,536	(Terrace 2014)

Table 21: Population data for selection of Canadian municipalities whose GHG emissions data was obtained

Population data for selection of Canadian municipalities whose GHG emissions data was obtained

National population rank, 2011	Geographic code	City	Province	1996	2001	2006	2011
1	3520005	Toronto (Ont.)	Ontario	2,385,421	2,481,494	2,503,281	2,615,060
2	2466023	Montréal (Que.)	Quebec	1,016,376	1,039,534	1,620,693	1,649,519
3	4806016	Calgary (Alta.)	Alberta	768,082	878,866	988,812	1,096,833
4	3506008	Ottawa (Ont.)	Ontario	721,136	774,072	812,129	883,391
5	4811061	Edmonton (Alta.)	Alberta	616,306	666,104	730,372	812,201
7	4611040	Winnipeg (Man.)	Manitoba	618,477	619,544	633,451	663,617
8	5915022	Vancouver (B.C.)	British Columbia	514,008	545,671	578,051	603,502
10	3525005	Hamilton (Ont.)	Ontario	467,799	490,268	504,559	519,949
12	5915004	Surrey (B.C.)	British Columbia	330,393	343,005	394,976	468,251
14	1209034	Halifax (N.S.)	Nova Scotia	342,851	359,111	372,679	390,096
15	3539036	London (Ont.)	Ontario	325,669	336,539	352,395	366,151
16	3519036	Markham (Ont.)	Ontario	173,383	208,615	261,573	301,709
17	3519028	Vaughan (Ont.)	Ontario	132,549	182,022	238,866	288,301
21	4711066	Saskatoon (Sask.)	Saskatchewan	193,653	196,811	202,408	222,189
27	3524001	Oakville (Ont.)	Ontario	128,405	144,738	165,613	182,520
28	3524002	Burlington (Ont.)	Ontario	136,976	150,836	164,415	175,779

Population data for selection of Canadian municipalities whose GHG emissions data was obtained

National population rank, 2011	Geographic code	City	Province	1996	2001	2006	2011
34	3543042	Barrie (Ont.)	Ontario	79,191	103,710	128,430	135,711
44	5917021	Saanich (B.C.)	British Columbia	101,388	103,654	108,265	109,752
85	4811062	St. Albert (Alta.)	Alberta	46,888	53,081	57,764	61,466
87	3521024	Caledon (Ont.)	Ontario	39,893	50,595	57,050	59,460
103	4607062	Brandon (Man.)	Manitoba	39,175	39,716	41,511	46,061
133	5907041	Penticton (B.C.)	British Columbia	30,987	30,985	31,909	32,877
140	3531011	Stratford (Ont.)	Ontario	29,676	29,007	30,516	30,886
155	4811049	Spruce Grove (Alta.)	Alberta	14,271	15,983	19,541	26,171
167	1001485	Conception Bay South (N.L.)	Newfoundland	19,265	19,772	21,966	24,848
215	1306020	Riverview (N.B.)	New Brunswick	16,684	17,010	17,832	19,128
234	5915070	Pitt Meadows (B.C.)	British Columbia	13,436	14,670	15,623	17,736
268	4811048	Stony Plain (Alta.)	Alberta	8,274	9,589	12,363	15,051
297	5927008	Powell River (B.C.)	British Columbia	13,131	12,983	12,957	13,165
327	1315011	Bathurst (N.B.)	New Brunswick	13,815	12,924	12,714	12,275
345	5949011	Terrace (B.C.)	British Columbia	12,783	12,109	11,320	11,486

Table 22: Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent) provided in 2011 estimates and per person

Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent) provided in 2011 estimates and per person

National population rank, 2011	Geographic code	City	Province	2011 Population	2011 Municipal GHGs	Tonnes CO2 per person from municipal data source*	Tonnes CO2 equivalent per person in municipality from Provincial data source**
1	3520005	Toronto (Ont.)	Ontario	2,615,060	23,200,000	8.87	13.45
2	2466023	Montréal (Que.)	Quebec	1,649,519	13,182,145	7.99	10.62
3	4806016	Calgary (Alta.)	Alberta	1,096,833	17,341,575	15.81	44.50
4	3506008	Ottawa (Ont.)	Ontario	883,391	10,845,882	12.28	13.45
5	4811061	Edmonton (Alta.)	Alberta	812,201	14,255,495	17.55	44.50
7	4611040	Winnipeg (Man.)	Manitoba	663,617	2,472,929	3.73	14.99
8	5915022	Vancouver (B.C.)	British Columbia	603,502	2,811,160	4.66	11.06
10	3525005	Hamilton (Ont.)	Ontario	519,949	13,147,815	25.29	13.45
12	5915004	Surrey (B.C.)	British Columbia	468,251	2,626,854	5.56	11.06
14	1209034	Halifax (N.S.)	Nova Scotia	390,096	7,040,664	18.05	20.27
15	3539036	London (Ont.)	Ontario	366,151	2,900,000	7.92	13.45
16	3519036	Markham (Ont.)	Ontario	301,709	2,827,393	9.37	13.45

Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent) provided in 2011 estimates and per person

National population rank, 2011	Geographic code	City	Province	2011 Population	2011 Municipal GHGs	Tonnes CO2 per person from municipal data source*	Tonnes CO2 equivalent per person in municipality from Provincial data source**
17	3519028	Vaughan (Ont.)	Ontario	288,301	2,046,531	7.10	13.45
21	4711066	Saskatoon (Sask.)	Saskatchewan	222,189	4,101,807	18.46	41.37
27	3524001	Oakville (Ont.)	Ontario	182,520	1,180,551	6.47	13.45
28	3524002	Burlington (Ont.)	Ontario	175,779	2,111,312	12.01	13.45
34	3543042	Barrie (Ont.)	Ontario	135,711	884,472	6.52	13.45
44	5917021	Saanich (B.C.)	British Columbia	109,752	526,709	4.80	11.06
85	4811062	St. Albert (Alta.)	Alberta	61,466	769,839	12.52	44.50
87	3521024	Caledon (Ont.)	Ontario	59,460	325,493	5.47	13.45
103	4607062	Brandon (Man.)	Manitoba	46,061	1,568,067	34.04	14.99
133	5907041	Penticton (B.C.)	British Columbia	32,877	237,380	7.22	11.06
140	3531011	Stratford (Ont.)	Ontario	30,886	334,350	10.83	13.45
155	4811049	Spruce Grove (Alta.)	Alberta	26,171	592,882	22.65	44.50
167	1001485	Conception Bay South (N.L.)	Newfoundland	24,848	154,505	6.22	17.62

Selection of Canadian municipal GHG emissions data (tonnes CO_2 equivalent) provided in 2011 estimates and per person

National population rank, 2011	Geographic code	City	Province	2011 Population	2011 Municipal GHGs	Tonnes CO2 per person from municipal data source*	Tonnes CO2 equivalent per person in municipality from Provincial data source**
215	1306020	Riverview (N.B.)	New Brunswick	19,128	207,131	10.83	21.25
234	5915070	Pitt Meadows (B.C.)	British Columbia	17,736	97,898	5.52	11.06
268	4811048	Stony Plain (Alta.)	Alberta	15,051	157,153	10.44	44.50
297	5927008	Powell River (B.C.)	British Columbia	13,165	69,831	5.30	11.06
327	1315011	Bathurst (N.B.)	New Brunswick	12,275	188,679	15.37	21.25
345	5949011	Terrace (B.C.)	British Columbia	11,486	80,536	7.01	11.06

*This data was determined by dividing the municipal GHG emission data by Statistics Canada municipal population data.

** This data was determined by using multiplying the municipal population as a percentage of provincial population by the total GHGs for the province. An example of this is provided in item 5c following Table 6.5.

b. After this was completed, municipal averages were taken from each province from the data set of 33 municipalities. This data is provided in Table 6.5.

Table 23: Summary of data obtained and per capita comparisons for data sources

Summary of data obtained and per capita comparisons for data sources				
			Tonnes CO_2 equivalent	
Province	**# Cities Per Capita GHG data Obtained**	**% of Cities over 10,000 where Per Capita GHG data Obtained**	**Average per capita GHG emission estimates based on StatCan municipal population data and actual municipal GHG data for cities with over 10,000 people**	**Average per capita GHG emission estimates based on StatCan municipal population data and UN GHG data for cities over 10,000 people**
Newfoundland and Labrador	1	14.29%	6.22	16.36
Prince Edward Island	0	0.00%	N/A	14.11
Nova Scotia*	3	23.08%	19.01	20.27
New Brunswick	2	20.00%	13.10	21.25
Quebec	1	1.00%	7.99	10.62
Ontario	11	7.69%	10.19	13.45
Manitoba	2	18.18%	18.88	14.99
Saskatchewan	1	11.11%	18.46	46.04
Alberta	5	11.36%	15.80	44.50
British Columbia	7	11.86%	5.73	11.06
Yukon	0	0.00%	N/A	14.45
Northwest Territories	0	N/A	N/A	N/A
Nunavut	0	N/A	N/A	N/A

c. The above averages were then compared against provincial CO_2 equivalent GHG emission data for each province. An example is below.

- Ontario had a population of 13,263,500 in 2011.

- Toronto had a population of 2,615,060 in 2011.
- Toronto had 19.91% of the population of Ontario in 2011.
- Ontario had 170,600,000 tonnes of CO_2 equivalent in GHG emissions in 2011.
- Multiplying the percentage of Ontario's population that Toronto had in 2011 by the amount of emissions for Ontario, one would obtain 33,966,460.
- This would provide Toronto per capita emissions of 13.45 tonnes of CO_2 equivalent in 2011.

d. When the previous calculation was completed for (c) above, for all 400 of the municipalities with populations of over 10,000 it became apparent that there could be potentially a large gap between what municipalities were reporting and what was recorded for the province. This gap could be accounted for by not having all municipal GHG data available, which could in turn skew the results if some of these municipalities were extremely large emitters of GHGs. Given that the primary goal of this research was not to necessarily uncover this, it was thought best to simply use the provincial GHG data to estimate municipal emissions. The averages of every municipality were obtained in the same fashion as the example above for Toronto. Once these averages were obtained, a ratio of GHG emissions was also created using Quebec as a baseline of "1" since it had the lowest emissions per capita. This table was used for other calculations for Universities and is provided below.

Table 24: Multiplier table for how much more each municipality with populations over 10,000 expel in tonnes CO_2 equivalent in other provinces

Multiplier table for how much more each municipality with populations over 10,000 expel in tonnes CO_2 equivalent in other provinces	
Province	**Ratio Table (Quebec = 1)**
Newfoundland and Labrador	1.54
Prince Edward Island	1.33
Nova Scotia*	1.91
New Brunswick	2.00
Quebec	1.00
Ontario	1.27
Manitoba	1.41
Saskatchewan	4.34
Alberta	4.19
British Columbia	1.04
Yukon	1.36
Northwest Territories	N/A
Nunavut	N/A

Appendix C Average Greenhouse Gas Emission for Canadian Colleges and Universities with Populations over 10,000 people

The estimation of the GHG emissions for the 33 universities and colleges for 2010/2011 was determined by the following process: [15]

Methodology

1. Obtain the number of full time equivalent (FTE) students and faculty to determine which universities have a combined total of over 10,000.
2. Estimate the GHG data for the Canadian universities and colleges whose combined full time equivalent students and faculty are over 10,000.

Steps

1. Obtain the number of full time equivalent (FTE) students and faculty to determine which universities have a combined total of over 10,000.
   a. Data for the number of full time equivalent (FTE) students and faculty was obtained from Almanacs from the Canadian Association of University Teachers. All of the actual data is listed in the following Table 6.8 to Table 6.12.
   b. The almanac data from 2006/2007 to 2010/2011 was utilized to estimate the FTE students and faculty in each university and college for 2011/2012. The calculations for this follow.

Let A = the total number of full time equivalent students and faculty for the university in 2006/2007

[15] Note: There could be problems with the below calculation for the following reasons: 1) universities may consume more GHG than municipalities due to the research intensity, but this could level out due to industrial GHG emissions in municipalities, 2) not all the Universities listed may have the same research intensity. Kwantlen may not have any energy intensive research projects occurring.

Some solutions to the problems listed above include the following: 1) investigate the actual GHG emissions to see how much is actually being emitted from the colleges and universities 2) eliminate universities without graduate programs as their energy intensity is less.

Let B = the total number of full time equivalent students and faculty for the university in 2007/2008

Let C = the total number of full time equivalent students and faculty for the university in 2008/2009

Let D = the total number of full time equivalent students and faculty for the university in 2009/2010

Let E = the total number of full time equivalent students and faculty for the university in 2010/2011

Let F = the total number of full time equivalent students and faculty for the university in 2011/2012

$$F = E * \left(1 + \left(\frac{\left(\left(\frac{B-A}{A}\right) + \left(\frac{C-B}{B}\right) + \left(\frac{D-C}{C}\right) + \left(\frac{E-D}{D}\right) \right)}{4} \right) \right)$$

2. Estimate the GHG data for the Canadian universities and colleges whose combined full time equivalent students and faculty are over 10,000

   a. The data for 10 of the universities is provided in Table 6.13. For universities where the GHG data was not in 2011 figures, the following calculations were used: [16]

Let A = University population data for same year as GHG data

Let B = University population data for 2011

Let C = GHG data obtained for the university for year other than 2011

Let D = GHG estimate for 2011

$$D = C * \left(\frac{B}{A}\right)$$

[16] This calculation assumes that GHG emissions increase proportionately to an increase in university population.

b. GHG data for the remaining 23 universities and colleges where GHG data was not obtained was determined by obtaining average per capita emissions for the provinces where university GHG data was obtained. These averages are provided in Table 6.7.

Table 25: Estimated GHG emissions for Canadian universities

Estimated GHG emissions for Canadian universities in 2011					
Number of Samples	**Province**	**Total Estimated GHG in 2011**	**Total Estimated Population in 2011**	**Estimated Per Capita GHG Emissions in 2011**	**Universities in Sample**
4	Ontario	331,259	162,971	2.03	Universities listed in Table 6.13.
1	Quebec	67,840	32,933	2.06	
2	British Columbia	87,336	60,486	1.44	
1	Alberta	374,195	30,331	12.34	
1	Saskatchewan	172,601	19,713	8.76	
1	Nova Scotia	111,141	12,037	9.23	

c. As the per capita GHG emissions for universities varied significantly to per capita municipal emissions in Table 6.5, estimates for provinces not listed in Table 6.7 were not calculated. However, for other universities in the same provinces as listed in Table 6.7, the estimated per capita GHG emissions in 2011 figures were used in calculating estimated GHG emissions. The calculation is below and the results are in Table 6.14.

Let A = estimated population of the university in 2011

Let B = estimated per capita GHG emissions in 2011

Let C = estimated total GHG emissions for the university in 2011

$$C = A * B$$

Table 26: 2006/2007 Full time equivalent student and full time faculty data (CAUT 2010)

	2006/2007 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data			
	Institution	**FTE Students**	**FT Faculty**	**Total**
1	University of Toronto	64,814	2,520	67,334
2	Université de Montréal	32,065	1,503	33,568
3	York University	45,026	1,323	46,349
4	University of British Columbia	31,305	2,127	33,432
5	University of Alberta	33,444	1,446	34,890
6	Université d'Ottawa / University of Ottawa	29,607	1,029	30,636
7	University of Western Ontario	31,361	1,359	32,720
8	Université Laval	29,025	1,290	30,315
9	McGill University	N/A	N/A	N/A
10	University of Waterloo	25,209	954	26,163
11	University of Calgary	24,579	1,527	26,106
12	Université du Québec à Montréal	26,898	951	27,849
13	University of Guelph	20,486	744	21,230
14	Concordia University	23,833	870	24,703
15	McMaster University	21,964	1,161	23,125
16	Ryerson University	22,040	681	22,721
17	University of Manitoba	22,500	1,098	23,598
18	Carleton University	20,577	660	21,237
19	Simon Fraser University	17,479	756	18,235
20	Queen's University at Kingston	18,097	777	18,874
21	University of Saskatchewan	15,114	936	16,050
22	University of Victoria	14,528	654	15,182
23	Université de Sherbrooke	15,648	900	16,548
24	Brock University	15,009	540	15,549
25	Memorial University of Newfoundland	15,480	828	16,308
26	Wilfrid Laurier University	13,244	474	13,718
27	Dalhousie University	13,282	960	14,242
28	University of Windsor	13,937	495	14,432
29	Grant McEwan University	N/A	N/A	N/A
30	Mount Royal University	N/A	N/A	N/A
31	University of New Brunswick	10,593	522	11,115

2006/2007 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data

	Institution	FTE Students	FT Faculty	Total
32	Kwantlen Polytechnic University	N/A	N/A	N/A
33	University of Regina	N/A	N/A	N/A

Table 27: 2007/2008 Full time equivalent student and full time faculty data (CAUT 2011)

	2007/2008 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data			
	Institution	**FTE Students**	**FT Faculty**	**Total**
1	University of Toronto	67,689	2,019	69,708
2	Université de Montréal	44,892	1,698	46,590
3	York University	45,005	1,368	46,373
4	University of British Columbia	38,964	1,641	40,605
5	University of Alberta	34,047	1,290	35,337
6	Université d'Ottawa / University of Ottawa	31,316	1,044	32,360
7	University of Western Ontario	31,110	1,146	32,256
8	Université Laval	28,727	1,233	29,960
9	McGill University	27,738	1,407	29,145
10	University of Waterloo	26,179	960	27,139
11	University of Calgary	24,389	1,068	25,457
12	Université du Québec à Montréal	26,622	930	27,552
13	University of Guelph	20,714	744	21,458
14	Concordia University	24,313	891	25,204
15	McMaster University	23,558	732	24,290
16	Ryerson University	22,692	702	23,394
17	University of Manitoba	24,500	852	25,352
18	Carleton University	20,649	681	21,330
19	Simon Fraser University	17,965	789	18,754
20	Queen's University at Kingston	18,216	696	18,912
21	University of Saskatchewan	17,126	666	17,792
22	University of Victoria	14,528	648	15,176
23	Université de Sherbrooke	15,748	618	16,366
24	Brock University	14,587	531	15,118
25	Memorial University of Newfoundland	15,022	684	15,706
26	Wilfrid Laurier University	13,379	465	13,844
27	Dalhousie University	13,115	735	13,850
28	University of Windsor	13,170	504	13,674
29	Grant McEwan University	N/A	N/A	N/A
30	Mount Royal University	N/A	N/A	N/A
31	University of New Brunswick	10,413	528	10,941

2007/2008 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data

	Institution	FTE Students	FT Faculty	Total
32	Kwantlen Polytechnic University	N/A	N/A	N/A
33	University of Regina	11,010	342	11,352

Table 28: 2008/2009 Full time equivalent student and full time faculty data (CAUT 2012)

	2008/2009 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data			
	Institution	**FTE Students**	**FT Faculty**	**Total**
1	University of Toronto	67,689	2,019	69,708
2	Université de Montréal	44,892	1,698	46,590
3	York University	45,005	1,368	46,373
4	University of British Columbia	38,964	1,641	40,605
5	University of Alberta	34,047	1,290	35,337
6	Université d'Ottawa / University of Ottawa	31,316	1,044	32,360
7	University of Western Ontario	31,110	1,146	32,256
8	Université Laval	28,727	1,233	29,960
9	McGill University	27,738	1,407	29,145
10	University of Waterloo	26,179	960	27,139
11	University of Calgary	24,389	1,068	25,457
12	Université du Québec à Montréal	26,622	930	27,552
13	University of Guelph	20,714	744	21,458
14	Concordia University	24,313	891	25,204
15	McMaster University	23,558	732	24,290
16	Ryerson University	22,692	702	23,394
17	University of Manitoba	24,500	852	25,352
18	Carleton University	20,649	681	21,330
19	Simon Fraser University	17,965	789	18,754
20	Queen's University at Kingston	18,216	696	18,912
21	University of Saskatchewan	17,126	666	17,792
22	University of Victoria	14,528	648	15,176
23	Université de Sherbrooke	15,748	618	16,366
24	Brock University	14,587	531	15,118
25	Memorial University of Newfoundland	15,022	684	15,706
26	Wilfrid Laurier University	13,379	465	13,844
27	Dalhousie University	13,115	735	13,850
28	University of Windsor	13,170	504	13,674
29	Grant McEwan University	N/A	N/A	N/A
30	Mount Royal University	N/A	N/A	N/A
31	University of New Brunswick	10,413	528	10,941

2008/2009 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data

	Institution	FTE Students	FT Faculty	Total
32	Kwantlen Polytechnic University	N/A	N/A	N/A
33	University of Regina	11,010	342	11,352

Table 29: 2009/2010 Full time equivalent student and full time faculty data (CAUT 2013)

2009/2010 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data				
	Institution	**FTE Students**	**FT Faculty**	**Total**
1	University of Toronto	71,085	2,646	73,731
2	Université de Montréal	47,669	1,707	49,376
3	York University	46,768	1,362	48,130
4	University of British Columbia	35,966	2,511	38,477
5	University of Alberta	34,903	1,581	36,484
6	Université d'Ottawa / University of Ottawa	33,411	1,263	34,674
7	University of Western Ontario	32,322	1,443	33,765
8	Université Laval	29,912	1,209	31,121
9	McGill University	29,473	1,434	30,907
10	University of Waterloo	29,080	1,017	30,097
11	University of Calgary	26,898	1,650	28,548
12	Université du Québec à Montréal	26,406	921	27,327
13	University of Guelph	23,212	765	23,977
14	Concordia University	25,949	927	26,876
15	McMaster University	25,463	1,254	26,717
16	Ryerson University	24,713	897	25,610
17	University of Manitoba	23,331	1,140	24,471
18	Carleton University	21,672	792	22,464
19	Simon Fraser University	19,957	912	20,869
20	Queen's University at Kingston	20,043	783	20,826
21	University of Saskatchewan	17,886	993	18,879
22	University of Victoria	16,731	699	17,430
23	Université de Sherbrooke	16,382	654	17,036
24	Brock University	15,335	549	15,884
25	Memorial University of Newfoundland	15,311	888	16,199
26	Wilfrid Laurier University	14,944	486	15,430
27	Dalhousie University	13,930	972	14,902
28	University of Windsor	13,683	498	14,181
29	Grant McEwan University	11,794	315	12,109
30	Mount Royal University	10,991	321	11,312
31	University of New Brunswick	9,989	516	10,505

2009/2010 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data

	Institution	FTE Students	FT Faculty	Total
32	Kwantlen Polytechnic University	9,359	345	9,704
33	University of Regina	9,951	429	10,380

Table 30: 2010/2011 Full time equivalent student and full time faculty data (CAUT 2014)

2010-2011 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data				
	Institution	**FTE Students**	**FT Faculty**	**Total**
1	University of Toronto	72,331	2,649	74,980
2	Université de Montréal	49,325	1,248	50,573
3	York University	47,835	1,362	49,197
4	University of British Columbia	37,199	2,574	39,773
5	University of Alberta	35,610	1,524	37,134
6	Université d'Ottawa / University of Ottawa	34,995	1,269	36,264
7	University of Western Ontario	33,396	1,449	34,845
8	Université Laval	31,265	1,206	32,471
9	McGill University	30,535	1,419	31,954
10	University of Waterloo	30,671	1,056	31,727
11	University of Calgary	27,878	1,599	29,477
12	Université du Québec à Montréal	27,405	1,389	28,794
13	University of Guelph	27,878	756	28,634
14	Concordia University	26,873	966	27,839
15	McMaster University	25,866	1,275	27,141
16	Ryerson University	25,468	915	26,383
17	University of Manitoba	23,622	1,152	24,774
18	Carleton University	22,354	795	23,149
19	Simon Fraser University	21,343	915	22,258
20	Queen's University at Kingston	20,831	771	21,602
21	University of Saskatchewan	17,829	1,047	18,876
22	University of Victoria	17,213	714	17,927
23	Université de Sherbrooke	16,922	669	17,591
24	Brock University	15,893	543	16,436
25	Memorial University of Newfoundland	15,449	900	16,349
26	Wilfrid Laurier University	15,741	501	16,242
27	Dalhousie University	14,701	963	15,664
28	University of Windsor	14,031	501	14,532
29	Grant McEwan University	12,673	333	13,006
30	Mount Royal University	11,336	333	11,669
31	University of New Brunswick	10,015	534	10,549

2010-2011 Full Time Equivalent (FTE) Student and Full Time (FT) Faculty Data

	Institution	FTE Students	FT Faculty	Total
32	Kwantlen Polytechnic University	9,954	363	10,317
33	University of Regina	9,653	453	10,106

Table 31: Selection of Canadian university GHG emissions data (tonnes CO_2 equivalent)

Selection of Canadian university GHG emissions data (tonnes CO_2 equivalent)						
University	**City**	**Province**	**Year of GHG data obtained**	**GHG Data from Year Obtained**	**Data converted to 2011**	**Source**
University of Toronto	Toronto	Ontario	2008	164,491	177,828	(Toronto & Honeywell 2009)
University of British Columbia	Vancouver	British Columbia	2011	63,803	63,803	(UBC 2011e)
University of Western Ontario	London	Ontario	2011	50,180	50,180	(Western 2014)
McGill University	Montréal	Quebec	2004	60,038	67,840	(Gell 2006)
University of Calgary	Calgary	Alberta	2008	328,573	374,195	(Calgary 2009)
McMaster University	Hamilton	Ontario	2007	47,360	55,076	(Zerofootprint 2009)
Queen's University at Kingston	Kingston	Ontario	2010	46,586	48,125	(Queen's 2012)
University of Saskatchewan	Saskatoon	Saskatchewan	2009	165,300	172,601	(Saskatchewan 2011)
University of Victoria	Victoria	British Columbia	2009	21,940	23,533	(Victoria 2010)
Dalhousie University	Halifax	Nova Scotia	2010	108,537	111,141	(Sustainability 2011)

Table 32: Estimated GHG emissions of Canadian universities

Estimated GHG emissions of Canadian universities			
University	**Province**	**Total Estimated Population in 2011**	**Estimated GHG in 2011**
University of Toronto	Ontario	77,000	177,828
Université de Montréal	Quebec	56,690	116,777*
York University	Ontario	49,930	101,488*
University of British Columbia	British Columbia	41,791	63,803
University of Alberta	Alberta	37,644	464,419*
Université d’Ottawa / University of Ottawa	Ontario	37,768	76,768*
University of Western Ontario	Ontario	35,384	50,180
Université Laval	Quebec	33,063	68,108*
McGill University	Quebec	32,933	67,840
University of Waterloo	Ontario	33,312	67,710*
University of Calgary	Alberta	30,331	374,195
Université du Québec à Montréal	Quebec	29,634	61,044*
University of Guelph	Ontario	30,927	62,863*
Concordia University	Ontario	28,703	58,343*
McMaster University	Ontario	28,248	55,076
Ryerson University	Ontario	27,341	55,573*
University of Manitoba	Manitoba	25,130	N/A
Carleton University	Ontario	23,623	48,016*
Simon Fraser University	British Columbia	23,361	33,731*
Queen’s University at Kingston	Ontario	22,339	48,175
University of Saskatchewan	Saskatchewan	19,713	172,601
University of Victoria	British Columbia	18,696	23,533
Université de Sherbrooke	Quebec	17,941	36,958*
Brock University	Ontario	16,669	33,881*
Memorial University of Newfoundland	Newfoundland	16,357	N/A

Estimated GHG emissions of Canadian universities			
University	**Province**	**Total Estimated Population in 2011**	**Estimated GHG in 2011**
Wilfrid Laurier University	Ontario	16,956	34,466*
Dalhousie University	Nova Scotia	16,040	111,141
University of Windsor	Ontario	14,574	29,624*
Grant McEwan University	Alberta	13,970	172,342*
Mount Royal University	Alberta	12,037	148,504*
University of New Brunswick	New Brunswick	10,429	N/A
Kwantlen Polytechnic University	British Columbia	10,969	15,838*
University of Regina	Manitoba	9,765	N/A

*Note: Estimate was obtained by multiplying the estimated population by the estimated per capita GHG emissions from data in Table 6.7.

Appendix D US Patent and World Population Statistics

In order to provide a better assessment of the increase in patent applications and grants the data was normalized with the following:

- the increase population of the age group of the population that would likely file applications,
- the increase of the population that is functionally literate within the above age group.

As some of the best data available for ages in the USA and the world provided a span of ages of 15-64 years, this age range was used for the age group likely to file USA patent applications. It is understood that there may not be very many people filing patents at the age of 15, but with the increase of accelerator programs like Silicon Valley's Y-Combinator, and Vancouver's GrowLab and "The Next Big Thing" the average age of people being listed on patents could decrease over time.

The tables below show the population growth as well as the aggregated data for US utility patent applications and patents granted for USS and the rest of the world.

This appendix is broken into the following sub-sections:

- Population Data
- USA Patent Applications and Grant Data
- Normalized Data for USA Patent Applications and Grants

Population Data

Table 33: Population statistics for the USA and the rest of the world (WorldBank 2012)

Population Statistics for the USA and the Rest of the World						
	5-Year Averages			% Growth		
5-Year Intervals	(World minus USA)	USA	World	(World minus USA)	USA	World
63' - 67'	3,135,556,902	194,141,200	3,329,698,102	--	--	--
68' - 72'	3,482,873,644	205,198,400	3,688,072,044	11.1%	5.7%	10.8%
73' - 77'	3,849,169,628	216,002,000	4,065,171,628	10.5%	5.3%	10.2%
78' - 82'	4,212,945,277	227,199,000	4,440,144,277	9.5%	5.2%	9.2%
83' - 87'	4,604,861,364	237,992,600	4,842,853,964	9.3%	4.8%	9.1%
88' - 92'	5,026,658,359	250,087,200	5,276,745,559	9.2%	5.1%	9.0%
93' - 97'	5,430,828,047	266,274,800	5,697,102,847	8.0%	6.5%	8.0%
98' - 02'	5,818,975,439	281,930,112	6,100,905,551	7.1%	5.9%	7.1%
03' - 07'	6,195,271,589	295,608,190	6,490,879,779	6.5%	4.9%	6.4%
08' - 12'	6,576,628,505	309,138,715	6,885,767,220	6.2%	4.6%	6.1%

After obtaining the data above, the goal was to determine the number of people between the ages of 15-64 years old in the same categories. All of this data was available on the WorldBank.org website with the exception of an aggregate percentage figure for the population of all countries outside of the US that is between the ages of 15-64 years old. To determine this, the below calculation was used.

Let A = % of world population between the ages of 15-65 years old

Let B = % of world population between the ages of 15-65 years old (excluding only the US statistics)

Let C = % of the USA population between the ages of 15-65 years old

Let D = World population

Let E = USA population

Solving for B:

$$A = \left(\frac{(D-E)}{D}\right) * B + \left(\frac{E}{D}\right) * C$$

$$A - \left(\frac{E}{D}\right) * C = \left(\frac{(D-E)}{D}\right) * B$$

$$B = \left(A - \left(\frac{E}{D}\right) * C\right) * \left(\frac{D}{(D-E)}\right)$$

After solving for B above the "World minus US" sections of the table below were able to be completed for Table 6.16, Table 6.19, and Table 6.20.

Table 34: Population statistics for the USA and the rest of the world (ages 15-64 years) (WorldBank 2012)

Population Statistics for the USA and the Rest of the World (Ages 15-64 years)						
	5-Year Averages			% Growth		
5-Year Intervals	(World minus USA)	USA	World	(World minus USA)	USA	World
63' - 67'	1,780,229,701	117,189,868	1,897,412,639	--	--	--
68' - 72'	1,977,275,418	127,235,052	2,104,499,341	11.1%	8.6%	10.9%
73' - 77'	2,200,261,922	139,024,307	2,339,280,214	11.3%	9.3%	11.2%
78' - 82'	2,459,454,878	150,066,895	2,609,529,718	11.8%	7.9%	11.6%
83' - 87'	2,753,945,532	158,023,110	2,911,984,276	12.0%	5.3%	11.6%
88' - 92'	3,045,291,199	164,711,209	3,210,009,630	10.6%	4.2%	10.2%
93' - 97'	3,330,481,438	174,714,945	3,505,199,472	9.4%	6.1%	9.2%
98' - 02'	3,653,076,002	186,894,584	3,839,973,501	9.7%	7.0%	9.6%
03' - 07'	3,996,452,875	198,351,665	4,194,808,070	9.4%	6.1%	9.2%
08' - 12'	4,309,793,036	207,264,838	4,517,063,765	7.8%	4.5%	7.7%

USA Patent Applications and Grant Data

All of the USA patent data was readily available from the "US Patent and Trademark Office" website. The below stables show the steady increase in USA patent applications and sporadic increase in USA patents granted.

Table 35: USA utility patent applications (USA 2013)

USA Utility Patent Applications						
5-Year Intervals	Foreign Origin (5-Year Average)	USA Origin (5-Year Average)	Total (5-Year Average)	% Growth Foreign	% Growth USA	% Total Growth
63' - 67'	21,552	66,910	88,462	--	--	--
68' - 72'	30,925	68,960	99,885	43.5%	3.1%	12.9%
73' - 77'	37,504	64,677	102,181	21.3%	-6.2%	2.3%
78' - 82'	42,397	61,959	104,355	13.0%	-4.2%	2.1%
83' - 87'	52,687	63,781	116,469	24.3%	2.9%	11.6%
88' - 92'	73,186	85,717	158,903	38.9%	34.4%	36.4%
93' - 97'	85,788	111,697	197,484	17.2%	30.3%	24.3%
98' - 02'	131,654	162,372	294,026	53.5%	45.4%	48.9%
03' - 07'	184,553	209,895	394,448	40.2%	29.3%	34.2%
08' - 12'	246,808	243,002	489,810	33.7%	15.8%	24.2%

Table 36: USA utility patents granted (USA 2013)

USA Utility Patents Granted						
5-Year Intervals	Foreign Origin (5-Year Average)	USA Origin (5-Year Average)	Total (5-Year Average)	% Growth Foreign	% Growth USA	% Total Growth
63' - 67'	11,629	46,364	57,994	--	--	--
68' - 72'	18,696	50,148	68,844	60.8%	8.2%	18.7%
73' - 77'	24,658	46,925	71,583	31.9%	-6.4%	4.0%
78' - 82'	23,725	36,361	60,087	-3.8%	-22.5%	-16.1%
83' - 87'	31,419	38,488	69,907	32.4%	5.8%	16.3%
88' - 92'	43,256	48,301	91,556	37.7%	25.5%	31.0%
93' - 97'	47,044	57,570	104,613	8.8%	19.2%	14.3%
98' - 02'	73,606	84,767	158,372	56.5%	47.2%	51.4%
03' - 07'	78,405	83,230	161,635	6.5%	-1.8%	2.1%
08' - 12'	105,014	99,465	204,479	33.9%	19.5%	26.5%

Normalized Data for USA Patent Applications and Grants

This above base data also needs to take into account the age of the population as well as the literacy rate. For ease of calculations with the data sources available the following assumptions were made:

- That people filing patents would be between the ages of 15-64 years old.
- That the rate of functional literacy remained constant
- That people foreign applicants for US patents is equally proportional to each foreign countries respective population

Taking an example of how the calculation for 60’ – 72’ in “World minus USA” column was in the below table was simply calculated by the following method:

Take the “% Foreign Growth” from the “USA Utility Patent Applications” table for 60’ – 72’ and subtract the “World minus USA” from the “Population Statistics for the USA and the Rest of the World” table. For example, the numerical calculation for 60’ – 72’ in “World minus USA” below is [43.5% - 11.1% = 32.4%]. Similar calculations are used for the remainder of the table.

Table 37: USA utility patent applications (normalized with population growth for people ages 15-64 years)

USA Utility Patent Applications (Normalized with Population growth for people ages 15-64 years)			
5-Year Intervals	World minus USA (% Growth)	USA (% Growth)	World (% Growth)
63' - 67'	--	--	--
68' - 72'	32.4%	-5.5%	2.0%
73' - 77'	10.0%	-15.5%	-8.9%
78' - 82'	1.3%	-12.1%	-9.4%
83' - 87'	12.3%	-2.4%	0.0%
88' - 92'	28.3%	30.2%	26.2%
93' - 97'	7.9%	24.2%	15.1%
98' - 02'	43.8%	38.4%	39.3%
03' - 07'	30.8%	23.1%	24.9%
08' - 12'	25.9%	11.3%	16.5%

Taking an example of how the calculation for 60’ – 72’ in “World minus USA” column was in the below table was simply calculated by the following method:

Take the “% Foreign Growth” from the “USA Utility Patents Granted” table for 60’ – 72’ and subtract the “World minus USA” from the “Population Statistics for the USA and the Rest of the World” table. For example, the numerical calculation for 60’ – 72’ in “World minus USA” below is [60.8% - 11.1% = 49.7%]. Similar calculations are used for the remainder of the table.

Table 38: USA utility patents granted (normalized with population growth for people ages 15-64 years)

USA Utility Patents Granted (Normalized with Population growth for people ages 15-64 years)			
5-Year Intervals	World minus USA (% Growth)	USA (% Growth)	World (% Growth)
63' - 67'	--	--	--
68' - 72'	49.7%	-0.4%	7.8%
73' - 77'	20.6%	-15.7%	-7.2%
78' - 82'	-15.6%	-30.5%	-27.6%
83' - 87'	20.5%	0.5%	4.8%
88' - 92'	27.1%	21.3%	20.7%
93' - 97'	-0.6%	13.1%	5.1%
98' - 02'	46.8%	40.3%	41.8%
03' - 07'	-2.9%	-7.9%	-7.2%
08' - 12'	26.1%	15.0%	18.8%

Appendix E CLL Meetings Attended

The following table outlines a list of all the CLL meetings that were attended, and the number of data points that were obtained. (The data points are discrete approximate 5-minute intervals where notes were taken during the meetings.)

Table 39: Campus as a Living Lab Working Group meetings attended and data points (notes) written

Campus as a Living Lab Working Group Meetings Attended			
Meeting #	**Date**	**Running Count**	**Data Points**
113	2012-12-06	1	10
114	2012-12-13	2	9
115	2013-01-10	3	6
118	2013-02-07	4	5
119	2013-02-14	5	7
120	2013-02-28	6	7
121	2013-03-07	7	14
122	2013-03-14	8	16
123	2013-03-21	9	40
124	2013-03-28	10	30
125	2013-04-04	11	16
126	2013-04-11	12	15
130	2013-05-09	13	16
131	2013-05-23	14	6
133	2013-06-06	15	16
134	2013-06-20	16	11
135	2013-06-27	17	15
137	2013-07-25	18	13
139	2013-08-22	19	14
140	2013-09-05	20	12
144	2013-10-10	21	11
145	2013-10-17	22	14
146	2013-10-24	23	13
147	2013-10-31	24	14
148	2013-11-07	25	14
149	2013-11-21	26	18
151	2013-12-05	27	12
152	2013-12-12	28	20
153	2014-01-09	29	10
154	2014-01-16	30	17
155	2014-01-23	31	12

Campus as a Living Lab Working Group Meetings Attended			
Meeting #	**Date**	**Running Count**	**Data Points**
156	2014-01-30	32	16
157	2014-02-13	33	20
159	2014-02-27	34	17
160	2013-03-06	35	15
162	2014-03-27	36	16
		Total Data Points Collected	**517**

Appendix F Past and Current UBC Partnerships

The following table provides a list of current UBC partnerships as well as current projects they are engaged with UBC.

Table 40: Past and current UBC partnerships (UBC 2013d)

Past and Current UBC Partnerships	
Who	**Current Project(s)**
Alpha Technologies Inc.	Energy Storage
BC Hydro	Continuous Optimization
Builtspace Technologies	Centre for Interactive Research on Sustainability
	(Building Information Modeling)
CISCO Canada	Integration of All Building Systems
	Testing and Certification Facility For “Converged Network” Devices
City of Vancouver	Greenest City Scholars
Cooledge Lighting Inc.	LED Lighting, Department of Psychology
Corvus Energy Limited	Energy Storage
FPInnovations	Bioenergy Research and Demonstration Facility
Fraunhofer-Gesellschaft	Clean Energy Research Centre, Faculty of Applied Science
GE Energy	Bioenergy Research and Demonstration Facility
Haworth, Inc.	Centre for Interactive Research on Sustainability
Honeywell	Centre for Interactive Research on Sustainability
Modern Green Development Co., Ltd.	Centre for Interactive Research on Sustainability
National Research Council of Canada	
Natural Resources Canada	Centre for Interactive Research on Sustainability
	Bioenergy Research and Demonstration Facility
	Energy Storage
Nexterra Systems Corp.	Bioenergy Research and Demonstration Facility
Powertech Labs Inc. (BC Hydro subsidiary)	Energy Storage
	EV Charging Stations
Pulse Energy	Continuous Optimization
SunCentral Inc.	UBC Biological Sciences Complex
Sustainable Development Technology Canada	Centre for Interactive Research on Sustainability
	Bioenergy Research and Demonstration Facility

Appendix G Additional Organizational Charts

Links to two additional organizational charts are provided below to provide context to how the governance of the UBC CLL fits into the larger picture at UBC.

- The latest version available of a high level organizational chart for UBC is available here: http://president.ubc.ca/files/2013/02/UBC-Org-Chart-2014Feb-High-Level3.pdf [17]
- The latest version available of the UBC Infrastructure development organizational chart is available here: http://www.projectservices.lbs.ubc.ca/about/organization-chart/ID%20Organization%20Chart.pdf

[17] The position of John Robinson as "Executive Director" has now been changed to "Associate Provost, Sustainability".

Appendix H Slide Deck for Unsolicited Proposals to Present Value Proposition to the Campus as a Living Lab

The following 12 slides in Figure 6.1 to Figure 6.12 are from the UBC "slide deck" that is provided to companies inquiring to participate in a UBC CLL project (Evans 2012). The company then fills in the slides to "pitch" the concept.

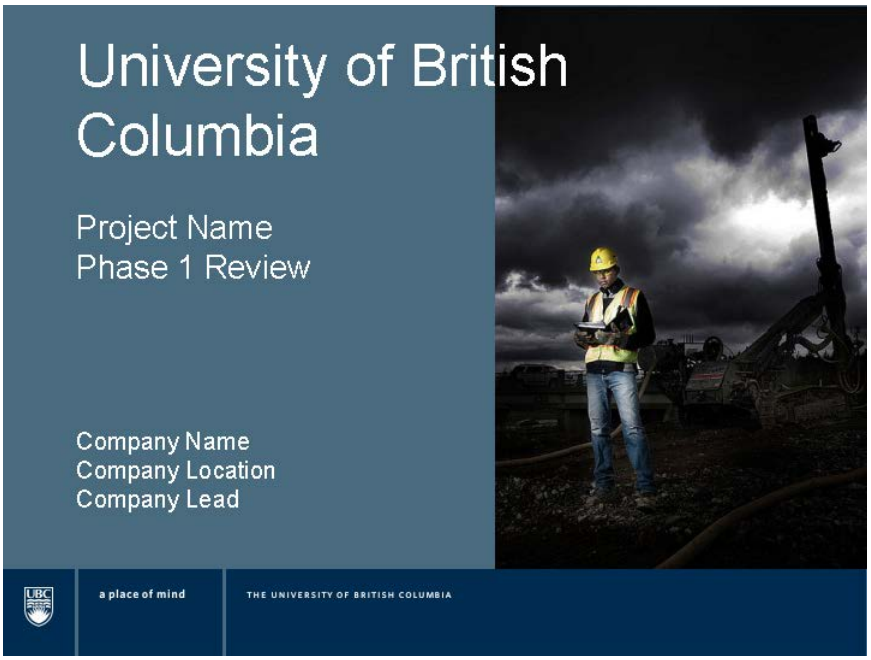

Figure 58: Slide deck introduction slide

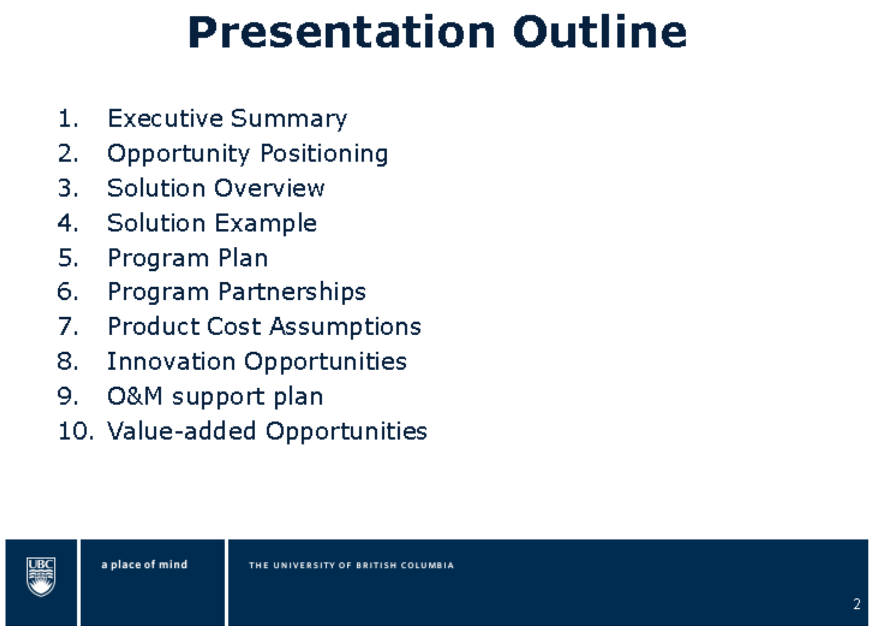

Figure 59: Slide deck presentation outline

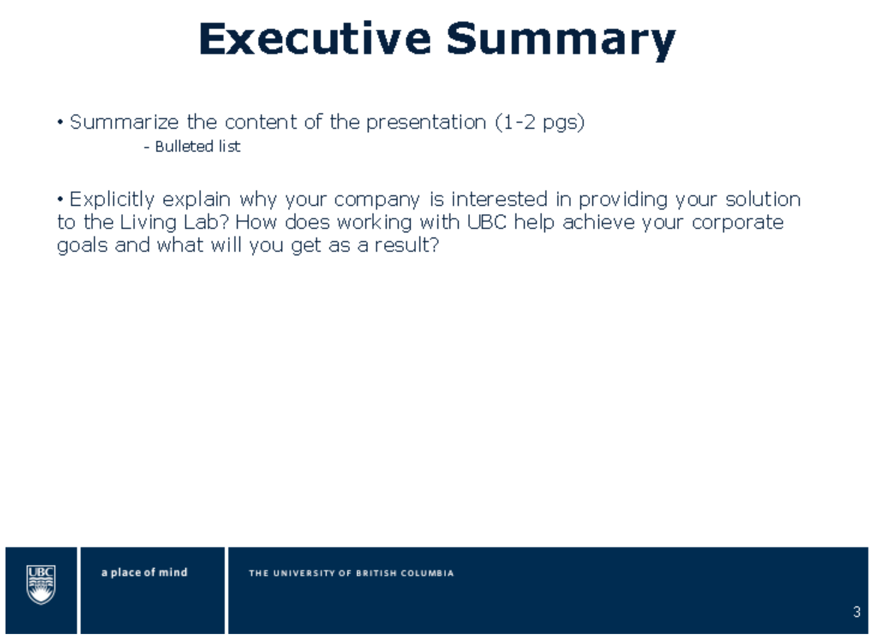

Figure 60: Slide deck executive summary

Figure 61: Slide deck opportunity positioning

Figure 62: Slide deck solution overview

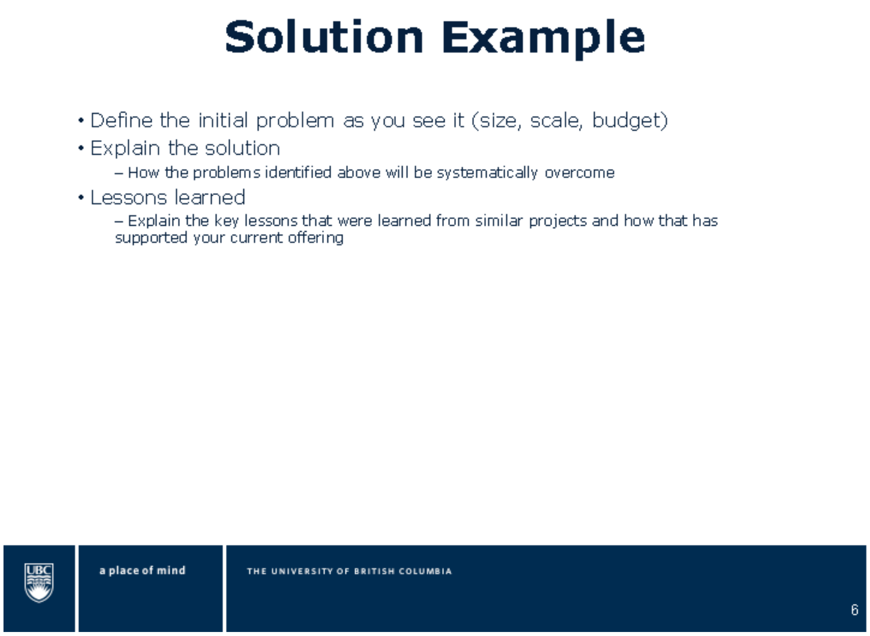

Figure 63: Slide deck solution example

Figure 64: Slide deck program plan

Figure 65: Slide deck program partnerships

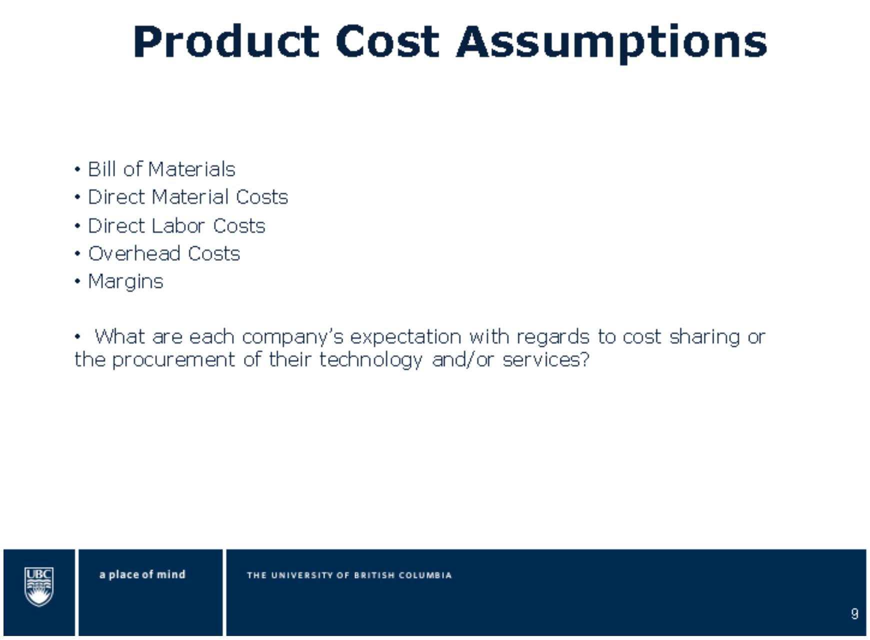

Figure 66: Slide deck product cost assumptions

Figure 67: Slide deck innovation opportunities

Figure 68: Slide deck operations and maintenance support plan

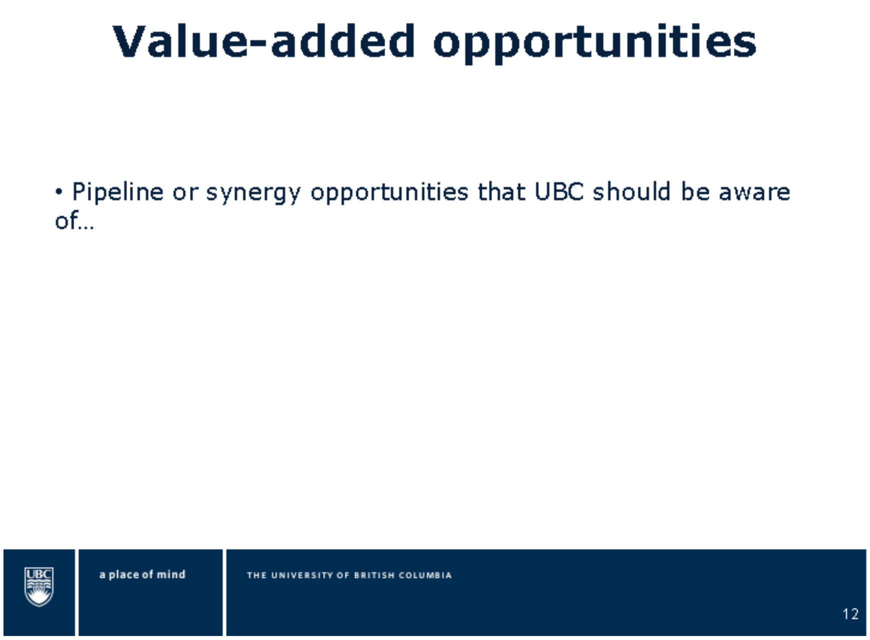

Figure 69: Slide deck value-added opportunities

Appendix I Spider Chart Criteria

As noted in Section 3.4.2.2 the criteria in the following pages are used to evaluate the potential for a new project to be part of the CLL (Evans 2013). This criteria first goes through the deal requirements to see if it meets three basic components of the CLL: Operational need, academic interest and if there is an interested third party. Once this initial pass is completed the project is then rated on Operational Efficiency, Research Excellence, Student Learning, Community Engagement, and Sustainability.

Project Name: Sample Project

Spider Chart Analysis Detail

Deal Requirements

Minimum Req (Operations)	Y/N	Comments
Operational need		

Minimum Req (Research)	Y/N	Comments
Academic Area of Interest		

Minimum Req (Partnerships)	Y/N	Comments
Third Party		

Figure 70: Spider chart deal requirements

Project Name: Sample Project

Spider Chart Analysis Detail

	Living Lab Characteristics	Possible Score	Score	
Operational Efficiency	CapEx (UBC cash)			Comments
	<$50K	-1		
	>$2.5M	0		
	>$50K but <$2.5M	1		
	OpEx (NPV based on building operations budget)			Comments
	Negative 10yr NPV	-1		
	Neutral 10 yr NPV	0		
	Positive 10 yr NPV	1		
	Risks			Comments
	Unidentified and unquanitied risks	-1		
	Identified but unquantified risks	0		
	Identiifed and quantified risks	1		
	Identifiable Environmental Benefit (Proxy for environmental sustainability)			Comments
	Unidentified and unquanitied benefit	-1		
	Identified but unquantified benefit	0		
	Identiifed and quantified benefit	1		
	Guidleines (Proxy for making innovations stick at UBC)			Comments
	Non negotiable guidelines	-1		
	Alteration of existing guidelines	0		
	New Guidelines to be developed	1		
	Leverage Dynamics - cash on cash potential (favorable leverage multiples on UBC invested capital)			Comments
	<1x potential	-1		
	2-4x potential	0		
	>4x potential	1		
		Scoring:	0	

Figure 71: Spider chart operational efficiency criteria

Project Name: Sample Project

Spider Chart Analysis Detail

Research Excellence				
Publications				Comments
	Long-term opportunities to publish (>5years)	-1		
	Opportunities to publish (2-5 years)	0		
	Immediate opportunities to publish (<2 years)	1		
Research funding				Comments
	No research funding opportunities	-1		
	Tri-council funding opportunities	0		
	Industry sponsored reseearch opportunities	1		
Leverageable Expertise (identify opportunities with low cost of research and operational diligence)				Comments
	No Prof experience in sector	-1		
	At least one Prof with experience in sector	0		
	Multiple Profs with experience in sector	1		
Enhanced infrastructure to support leading edge research				Comments
	No infrastructure proposed for research purposes	-1		
	Limited enhancements to infrastructure for research	0		
	Dedicated new research infrastructure	1		
Engagement by CRC, CERC, CIRC holder (Proxy for enhancing resources in areas of				Comments
	No engagement	-1		
	Affiliated research	0		
	Principal Investigator	1		
Number of departments engaged (Proxy for collaborative, interdisciplinary and multi disciplinary research)				Comments
	One department	-1		
	Two departments	0		
	> Two departments	1		
Knowledge Transfer Dynamics - activity (probability of uptake)				Comments
	Unknown acquirers with unknown acitvity	-1		
	Active acquirers in space with activity within past 3 years	0		
	Active acquirers of direct competitors with activity within past 3 years	1		
		Scoring:	0	

Figure 72: Spider chart research excellence criteria

Project Name: Sample Project

Spider Chart Analysis Detail

Student Learning				
	Undergraduate project work			Comments
	No interest at this stage	-1		
	Interest to supply topics	0		
	Interest to supply topics with match-funding	1		
	Graduate project work (e.g. MBA, M.Eng)			Comments
	No interest at this stage	-1		
	Interest to supply topics	0		
	Interest to supply topics with match-funding	1		
	Recruit and retain top ranked graduate students and postdoctoral fellows			Comments
	No recruitment	-1		
	Retention of top grads	0		
	Recruitment of top grads and post-docs	1		
	e@UBC opportunities			Comments
	No interest at this stage	-1		
	…	0		
	Company present within accelerator	1		
		Scoring:	0	

Figure 73: Spider chart student learning criteria

Project Name: Sample Project

Spider Chart Analysis Detail

Community Engagement	Cross-campus collaboration			Comments
	No interest at this stage	-1		
	Interest to either UBCV or UBCO	0		
	Strategic interest to UBCV & UBCO	1		
	Engagement with UNA			Comments
	No interest at this stage	-1		
	Interest to either UBC or UNA	0		
	Strategic interest to both UBC & UNA	1		
	Engagement with policy bodies			Comments
	Has no impact on current standards and policies	-1		
	Is disruptive to existing policies	0		
	Enables the development of new polciies	1		
	Engagement with local industry			Comments
	No local industry engagement	-1		
	Local industry present in consortium	0		
	Local industry leading project	1		
	Engagement with other federal/provincial/municipal/nfp organisation			Comments
	No interest at this stage	-1		
	Interest to one party	0		
	Strategic interest to both parties	1		
		Scoring:	**0**	

Sustainability	tbd		0	Comments
		-1		
		0		
		1		
	tbd		0	Comments
		-1		
		0		
		1		
	tbd		0	Comments
		-1		
		0		
		1		
		Scoring:	**0**	

Figure 74: Spider chart community engagement and sustainability criteria

Appendix J Chronological Order of Implementation for the Centre for Interactive Research on Sustainability

The ten year timeline of events that led to the construction and eventual occupancy of CIRS is listed in the following Table 6.23: CIRS twelve year timeline.

Table 41: CIRS twelve year timeline (Fedoruk & Save 2012)

CIRS Twelve Year Timeline	
Date	**Item**
1999	"Martha Piper asks all research units on campus to develop a strategic plan for future development." (UBC 2012b)
1999	"Dr. Robinson proposes an idea to create a BC showcase building." (UBC 2012b)
2001	"Dr. John Robinson met with Peter Busby, the architect, to discuss the creation of the "greenest building in North America". Multiple key concepts including the "living laboratory" and "accelerating sustainability" were developed during this meeting." (UBC 2012b)
2001	Busby & Associates created the first feasibility study for CIRS on UBC Vancouver campus. (UBC 2012b)
2001	"The leadership team applied for the first Canada Foundation for Innovation (CFI) grant to fund the project. It was denied." (UBC 2012b)
2001	"Busby & Associates Architects prepared a feasibility study for the first iteration of Centre for Interactive Research on Sustainability, located on UBC's Vancouver Campus." (UBC 2012b)
2003	"A decision was made to move CIRS to a site on the Great Northern Way Campus." (UBC 2012b)
2003-05-23	Second CFI grant submitted (UBC 2005a)
2003	A steering committee created to provide expert advice and guidance. The committee consisted of local academic institutions, government agencies and industries. (Fedoruk & Save 2012)
2003	"Other academic institutions became partners in the project: Emily Carr University of Art and Design, British Columbia Institute of Technology, Simon Fraser University." (UBC 2012b)
2004	"The CFI and BCKDF grants were approved." (UBC 2012b)
2004	CIRS feasibility report was completed which contained 22 design goals that guided the project. (Busby Perkins + Will 2008a)
2004-06-10	First application to Sustainable Development Technology Canada for funding. (UBC 2004a)
2004-09-30	$175K was released for the project by the UBC Board of Governors. (UBC 2004b)
2005	A Sustainable Development Technology Canada grant was secured for the photovoltaic cells. (UBC 2012b)
2005-04	A Memorandum of Understanding was signed between BC Hydro and UBC. (UBC 2005b)
2005-06-03	$110K was released for the project by the UBC Board of Governors. (UBC 2005d)
2005	$400K released

CIRS Twelve Year Timeline	
Date	**Item**
2005	Schematic design set issued
2005	$300K issued
2005-12-08	Board 2 conditional approval (UBC 2005c)
2006-05-23	Board 2 approval finalized (UBC 2006a)
2006	Space plan issued
2006	Project put on hold
2006	Board release of $125K, bringing total release to $1,535,000
2007	Haworth becomes industry partner
2007	LOI with Honeywell and UBC
2007-12-07	Funding contract signed with Sustainable Development Technology Canada (UBC 2007)
2008	CIRS is relocated to UBC and a 500 seat auditorium is included. (Busby Perkins + Will 2008b) UBC also becomes the sole owner of the project. (UBC 2012b)
2008	Design Principals charette
2008	Board 1 approval release of $600K
2008	Board 2 approval release of $900K
2008	Water, daylighting and shading charette
2008	Energy charette
2008	Request for funding from Western Economic Diversification
2008	Conditional Board 3 approval – release of $2,200K
2008	CIRS awarded NRCan funding to describe the Integrated Design Process
2009	Signed contract with Ministry of Economic Development
2009	Tenders received within budget
2009	BOG approval to release remaining $31,323K
2009	Floor plan IFC, IFC electrical, IFC mechanical drawings submitted. (Busby Perkins + Will 2009)
2010	LOI with Modern Green (UBC 2012b)
2011	Occupancy granted

Appendix K Listing of Number of Data Points by Category and Process in the Campus as a Living Lab Specific Framework

The following Table 6.24 provides a listing of the number of data points that were recorded by category and by process.

Table 42: Listed number of data points by category and process in the Campus as a Living Lab Framework

Number of Data Points by Category and Process in the Campus as a Living Lab Specific Framework	
Category	**Listed Number of Data Points**
(1.0) Develop Vision, Strategy and Assessment Tools	148
(1.1) Develop, evaluate, establish, and re-evaluate vision and mission	5
(1.2) Develop, evaluate, establish, and re-evaluate high level goals	13
(1.3) Develop, evaluate, establish, and re-evaluate objectives	14
(1.4) Develop, evaluate, establish and re-evaluate organizational structure, reporting, and governance	21
(1.5) Develop, evaluate, establish and re-evaluate tools for assessing projects	41
(1.6) Learn from others and develop ideas for improvement	54
(2.0) Develop and Manage Business Capabilities	61
(2.1) Develop, evaluate, establish, and re-evaluate human resource management, planning, policies, and strategies	7
(2.2) Manage financial resources	1
(2.3) Develop, evaluate, establish, publish, and re-evaluate process management	10
(2.4) Develop, evaluate, establish, and re-evaluate knowledge management practices	8
(2.5) Develop, evaluate, establish and re-evaluate metrics for post-implementation of projects	4
(2.6) Plan meetings	31
(3.0) Develop Opportunities	261
(3.1) Develop, and evaluate opportunities	64
(3.2) Evaluate risk, determine and implement risk mitigation strategies	32
(3.3) Evaluate opportunity alignment with vision, mission, goals, and objectives	28
(3.4) Identify requirements, objectives and resources for opportunities	56
(3.5) Develop, and evaluate, and present business case(s)	19
(3.6) Develop requests for information/proposals; negotiate, establish, and manage contracts	26
(3.7) Develop, evaluate, and obtain funding	36
(4.0) Assess the Environment	161
(4.1) Assess internal needs, capabilities, and opportunities	89
(4.2) Evaluate the internal economic, environmental, and social landscape	26
(4.3) Assess external needs, capabilities, and opportunities	29

Number of Data Points by Category and Process in the Campus as a Living Lab Specific Framework

Category	Listed Number of Data Points
(4.4) Evaluate the external economic, environmental, and social landscape	17
(5.0) Manage Researcher Opportunities	52
(5.1) Identify projects for researchers / students looking for collaboration opportunities	18
(5.2) Identify research champion	2
(5.3) Identify potential candidates for research opportunity available	15
(5.4) Engage researchers already working on projects external to Living Lab for information / updates	6
(5.5) Engage researchers already working on projects internal to Living Lab for information / updates	11
(6.0) Relationship Management	56
(6.1) Develop, evaluate, and manage external Campus relationships	28
(6.2) Develop, evaluate, and manage internal Campus relationships	14
(6.3) Develop, evaluate, establish, and re-evaluate internal and external relationship service	14
(7.0) Marketing and Communications	48
(7.1) Develop, evaluate, establish, and re-evaluate marketing and communications strategy	17
(7.2) Implement marketing and communications strategy	10
(7.3) Share information about upcoming and past events/meetings within committee	21
(8.0) Project Management	60
(8.1) Receive updates and provide feedback on project scope	15
(8.2) Receive updates and provide feedback on project schedule	17
(8.3) Receive updates and provide feedback on project cost	10
(8.4) Receive updates and provide feedback on project human resources	1
(8.5) Receive updates and provide feedback on project risk	11
(8.6) Receive updates and provide feedback on project procurement	6