UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Building Adaptability & Deconstruction: Using Less Materials to Reduce Environmental Impact

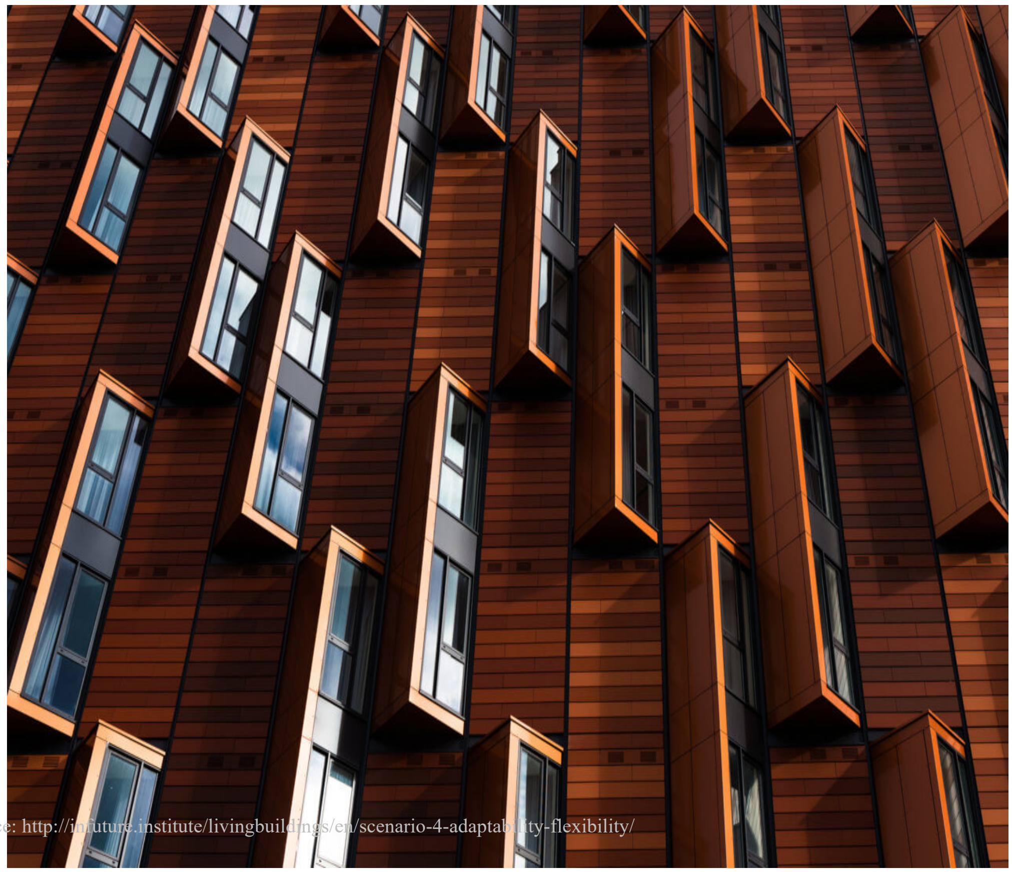
Hamid Abdolkarimi, Shima Banaei, Mansoureh Bastamipour, Marianne De Costella, Daniel Eden

University of British Columbia

HPB 501

Themes: Buildings, Health, Materials

April 30, 2019



Source: http://infuture.institute/livingbuildings/en/scenario-4-adaptability-flexibility/

Building Adaptability & Deconstruction

Using Less Materials to Reduce Environmental Impact

Hamid Abdolkarimi
Shima Banaei
Mansoureh Bastamipour
Marianne De Costella
Daniel Eden

HPB 501 – Green Building Contemporary Practice Assignment 2

Executive Summary

The research presented in this report explores how to increase building adaptability and how to design for deconstruction, with the ultimate goal of reducing materials used at UBC. This exploration is directly in-line with the “Materials” component of UBC’s Green Building Action Plan. Reducing materials used in construction or choosing materials that are less harmful to the environment is critical to reduce UBC’s environmental impact.

The team that conducted this research used two frameworks to guide its investigation: the 7S Model and the ReSOLVE framework. The 7S model breaks buildings down into 7 layers – these are presented as sections in this report. The ReSOLVE framework considers 6 components of the circular economy: Regenerate, Share, Optimize, Loop, Virtualize and Exchange. Theses lenses were applied to each building layer to generate research ideas.

For each idea presented, supporting examples and recommendations are provided. A summary of these recommendations is presented below (and a full table with prioritizations is found in section 12 of this report):

7S Component	**ReSOLVE**	**Action**
System and Site	Regenerate	➢ Evaluate the feasibility of onsite sewage treatment plants for new institutional facilities.
	Optimize	➢ Use solar power to cover the emergency needs of each building.
	Loop	➢ Incorporate Design for Deconstruction guidelines into the UBC Design Process Policies.
Structure	Exchange	➢ Initiate a concrete reduction challenge, encouraging designers/builders to use alternative lower impact concrete (such as CarbonCure).
Skin	Regenerate	➢ Provide maintenance considerations for green façade concepts in new construction (such as enough soil depth, irrigation infrastructure).
	Loop	➢ Apply modular façade design for all new construction.
Service	Share	➢ Complete a pilot project for BAMB/materials passport.
	Exchange	➢ Consider a leasing model or a “lumen-as-a-service” model for lighting retrofit projects or in new construction.
Space & Stuff	Optimize	➢ Source furniture (and stuff) from companies who provide material that is either renewable, recycled, recyclable, non-toxic and low-energy content.
	Optimize	➢ Complete a pilot project for a space designed with biocomposite movable partition walls.
	Loop	➢ Use Cradle-to-Cradle carpeting.

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1 Introduction

This report was completed as part of the UBC SEEDS Sustainability Program for the project titled “UBC’s Green Building Action Plan: Materials & Resources in buildings at UBC”, option A. The research project description form is included in Appendix 1.

Furthermore, this report was completed as the final assignment for the class HPB 501: Green Building Contemporary Practice.

2 Project Context

2.1 Goals and Objectives

The main goal of this report is to identify recommendations to reduce the use of materials in the construction of new institutional buildings at the University of British Columbia, in line with UBC’s Green Building Action Plan - Materials and Resources component. The recommendations proposed are focused on achieving material reduction by applying two lenses: 1) building adaptability and 2) building deconstruction guidelines/policies. This project is the first step at exploring these lenses.

The second goal was to compare the research findings to the existing practices at UBC, both the UBC Technical Guidelines and the UBC LEED Implementation Guide, and to identify and prioritize any gaps in the current practice at the university.

For building adaptability, the objective was to consider use change, space requirement changes, building additions, adaptation to climate change, and adaptation to visual appearance. For building deconstruction, the objective was to consider financial and life cycle considerations.

2.2 Relevance to Sustainability

The materials used in construction have important environmental impacts, such as the carbon emissions released into the atmosphere associated with their life cycle and extraction of limited natural resources. Reducing the quantity of material used, improving the adaptability of buildings to increase their lifespan, and planning for building deconstruction and material re-use are critical steps in minimizing the environmental impacts of UBC’s buildings.

3 Literature Review/Background

The research conducted for this project was inspired by ARUP’s 2016 report “The Circular Economy in the Built Environment” [1] which describes two key frameworks: 1) Ellen McArthur Foundation’s “ReSOLVE” framework and 2) Frank Duffy’s and Stuart Brand’s “7S Model”.

The ReSOLVE framework proposes evaluating projects through six perspectives, summarized below [1]. The icons will be used throughout this report to create a visual link.

Regenerate: restoring natural capital, e.g., increasing the resilience of the ecosystem and returning nutrients to the biosphere.

Share: maximizing the use of an asset by re-using it.

Optimize: improve the asset performance, e.g., by increasing its useful life or reducing its material use.

Loop: maintaining products/materials within inner cycles, e.g., by recycling or re-manufacturing.

Virtualise: displacing a product/asset by using a virtual source, e.g., a virtual service or location.

Exchange: using alternative material inputs, using renewable resources, replacing products with services.

The 7S Model breaks a building down in the following seven main layers, as per the list and Figure 1 below:

1. **System**: the services that enable the overall functionality of the building, e.g. the local infrastructure that the building connects to.
2. **Site**: the fixed location of the building.
3. **Skin**: the building envelope/exterior.
4. **Structure**: the building's structural components and frame.
5. **Services**: the mechanical, electrical and plumbing of the building.
6. **Space**: the fixed internal fit-out of the building, e.g., the partition walls and doors.
7. **Stuff**: the movable elements of a fit-out, e.g., furniture.

Figure 1 - 7S Model illustrative example [1]

4 Research Approach/Methodology

The research for this project was completed according to the following steps:

1. The 7S model was used to divide the research, and each team member reviewed one or two components of the model.
2. For each component, the ReSOLVE framework was then applied. Each team member conducted a literature review, first by using examples proposed in ARUP's report, then by completing a web search, and finally by completing a literature review based on documentation available through UBC's online library.
3. The results from the research were then compared to UBC's existing construction guidelines, both the Technical Guidelines and the LEED Implementation guideline. Any gaps that were identified are listed in the "recommendations" portion of each section.
4. The highest priority actions are summarized under the "Key Findings" section of this report, and all recommended actions are summarized in a table under the "Summary Table of Recommendations" section.

4.1 Project team

Team Member	Experience	Role/Section
Daniel Eden	Civil Engineering/ Green Building Consulting	Project Manager & Building Structure
Hamid Abdolkarimi	Mechanical Engineering	Building Site and System
Shima Banaei	Architecture	Building Envelope (Skin)
Mansoureh Bastamipour	Civil Engineering/Project Management	Building Services
Marianne De Costella	Architecture	Building Space and Stuff

4.2 Action Prioritization

We have categorized each recommendation in this report based on three priority levels which consider the ease of implementation at UBC based on current policies, the risk level, urgency, and environmental impact:

- **Phase 1**: these recommendations could be implemented in the short term, with little or no changes to UBC policies. They are generally low-risk (e.g., existing technology) and have a higher environmental impact.
- **Phase 2**: these recommendations likely require modifying UBC policies; however, the environmental benefits are significant;
- **Phase 3**: these recommendations are achievable by creating new policies at UBC, but perhaps carry more risk or have little precedent. They are therefore more likely to be long-term goals.

5 System and Site

On a site and system level we are looking into the actual location of the building along with all the utilities, amenities and systems which provide services to the building. A holistic investigation into the ReSOLVE approach shows multiple opportunities to reduce the material use and improve the resilience and adaptability of our buildings.

Adaptability on the site and system level focuses on increasing the resiliency of the building and community against the climate change and natural disasters. BC in particular has been warned against possible earthquake and experienced increasing number of storms, floods and heat waves on the recent years.

A self-sustained building can survive longer in case of a disaster by providing its own water, power and treat its own waste water. This not only improve the resiliency of the building, will also decrease the material consumption by reducing the level of operation from a large and city-wide network to a site or community-based network.

The followings are the areas with opportunity to reduce material consumption and improve adaptability for new institutional buildings on the site and system level.

5.1 Wastewater and Sewage Recycling (Regenerate)

With the advancement of wastewater treatment technologies, local treatment has become much smaller, more energy efficient and practically more feasible. Designing a system to collect, treat and recycle wastewater on a building level is possible through the combination of anaerobic digestion and sequential batch reactor (SBR) treatment. This approach can also be taken on a wider scale and at a community level. Local wastewater treatment is a good example of "Regenerate", i.e., returning biological nutrients to the biosphere.

Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process offers several benefits over aerobic treatment, including lower energy requirements, less chemicals, and less sludge production. Although the sludge is stable and safe to use as a soil enhancer, it is advised to proceed with further SBR treatment to reduce the volume and improve the quality of the final effluent.

A by-product of this process is a methane-rich biogas which can be treated and used as a renewable energy source, helping save money and the environment. Although the use of this application is more feasible on a community level rather than a building level which will depend on the size and the volume of each individual system [2] [3].

SBR or sequential batch reactors are a type of activated sludge process for the treatment of wastewater. SBR reactors treat wastewater such as sewage or output from anaerobic digesters in batches. Oxygen is bubbled through the mixture of wastewater and activated sludge to reduce the organic matters, measured as biochemical oxygen demand (BOD) and chemical oxygen demand

(COD). The treated effluent can be suitable for discharge to surface waters or possibly for use on land [4].

5.1.1 Discussion

Adaptability: Although having a community or on-site sewage treatment plant will holistically reduce the amount of material use on a larger scale by avoiding a much bigger transfer system, but probably the main advantage of this approach will be improving resiliency and adaptation to the climate change.

UBC Context: UBC is currently relying on the city of Vancouver sewage network to transfer and treat their wastewater. Although this approach has its own benefit (economies of scale, for example), it also comes with its own risk and impact in the event of a natural disasters such as flood and earthquake. Small-scale waste water treatment also has challenges, such as cost and the ability to maintain the system (e.g., this approach was tested at the CIRS building and is not yet fully functional). Although such designs have been implemented in some countries such as Germany, small scale waste water treatment is not very common in Canada.

5.1.2 Recommendations

5.1.2.1 Actions

We recommend that UBC evaluates the feasibility of designing and building onsite sewage treatment plan for any new institutional building.

Priority: UBC can bring this approach into their design policy and first experiment it for a single building to get feedback and create knowhow and experience. Due to the cost, risk of failure, lower direct impact on building materials, and since this would need to be introduced as a new policy, we have categorized this recommendation as a phase 3 priority.

5.1.2.2 Future Research

As these systems can be also beneficial on generating heat and power using a biogas plant, we recommend UBC to do further research on feasibility of adding a central biogas plant as annex to the existing Bioenergy Research Demonstration Facility (BRDF).

5.2 Solar Energy Production, Storage and Microgrids (Optimize)

Blackouts are almost the first problem in case of any natural disaster whether it’s an earthquake, storm or flood and with the level of power dependency in our buildings, communities and lifestyle, there are many benefits on preventing a power loss in any of these cases.

5.2.1 Discussion

With the dramatic reduction in solar power production cost in recent years, having a solar power production seems feasible for buildings or communities. This approach will have multiple advantages such as:

- Improving the building resiliency in case of a blackout
- Improving the energy consumption of the building by reducing power intake from BC Hydro
- Improving the building energy efficiency design by incorporating the solar panels as part of the shading system as per Figure 2 and Figure 3 below.
- Improving the energy lost in transfer by promoting micro grid networks.
- Creating the possibility of sharing the energy within the community

Similar to the local sewage treatment plant, having a community or on-site solar power generation system will also reduce the amount of material use on a larger scale and holistically by avoiding a much bigger power transmission system as a high percentage of the power is usually lost through the transmission to the end user.

Figure 2 - Rooftop solar system on the multipurpose Bullit Centre in Seattle, WA [5]

Figure 3 - "Levolux" PV film covered solar shading system [6]

Adaptability: The main advantage of this approach will be in improving resiliency and adaptation to the climate change. This becomes even more important when we bring the high prediction of earthquake in BC as well as the higher possibility of storms happening in lower mainland within the past few years. As we know a blackout is almost the immediate effect of both disasters and having solar power on the building site is a great advantage.

UBC Context: We think having solar system in UBC is long overdue as it is in BC in general. As UBC has always been an example and a pioneer in sustainability, this can be the opportunity for UBC to become the leader in solar system design and application both on a building and the community level.

5.2.2 Recommendations

5.2.2.1 Actions

Although it is obvious that a production to fulfill the complete requirement of a building is not feasible due to the space limitation in UBC, generating and storing enough power to cover the emergency need of each building seems quite possible and is strongly recommended.

Priority: The price of solar power is slowly dropping, however, the payback for such projects would still need to be thoroughly analyzed. As this is not currently within UBC policies, we believe this is a level 2 priority.

Synergy: This approach has a synergy with another recommendation mentioned under "Services", where we suggest replacing ownership with a service. In this case for example, leasing the solar power equipment from a manufacturer can be considered instead of purchase. Obviously, this will be UBC's discretion based on the financial plan and the will to commit to the capital investment and owning the system from the beginning.

5.2.2.2 Future Research

Additional research in developing microgrids and power storage is also recommended in order to increase the resiliency of the power network on a wider scale in UBC. Pursuing the opportunity to become a leader in "Community solar power production" will also align with UBC's sustainability policy in general.

5.3 Digital Platforms to Share Building Design (Share)

In the light of virtualization and sharing economy, there are organizations that promote and facilitate the possibility of sharing design and information for to improve construction, reduce material and improve performance.

WikiHouse is an open source project to reinvent the way we make homes. It is being developed by architects, designers, engineers, inventors, manufacturers and builders, collaborating to develop the best, simplest, most sustainable, high-performance building technologies, which anyone can use and improve [7].

The sharing economy is gaining a lot of traction these days and it is not only for the personal and commercial properties, but it is also expanding into the intellectual property realm as well. Tesla, for example, converted a lot of their technologies into an open source for public in order to promote the industry and create further opportunities.

The same idea has also been applied in building industry where organizations share building design, technologies and material resources to public for the benefit of promoting high performing building and material use.

5.3.1 Discussion

UBC Context: We believe UBC can pursue the opportunity to develop a digital platform for not only sharing the best building design aspects and practices, but also expanding it to include a database of best suggested construction materials with highest level of durability, least amount of embodied carbon and best performance.

5.3.2 Recommendations

5.3.2.1 Future Research

We highly recommend that UBC investigates creating a database for all the material used in its building and trace their path through their life cycle and after the deconstruction to reduce waste and promote the opportunity to reuse, recycle and further reduce material consumption.

Synergy: This suggestion is in synergy with other two suggestions made in “Services”. We believe both BAMB (Building as Material Bank) and Material Passport can be an extension to this digital platform by not only sharing the design and technology, but also material stock for further life cycles.

5.4 Design for Deconstruction (Loop)

Construction waste management has become extremely important due to the importance of reducing environmental impact, stricter disposal and landfill regulations and a lesser number of available landfills. There are extensive works done on waste management within the construction industry.

Deconstruction is the process of dismantling a building in order to salvage its materials for recycle or reuse which will eventually contribute to lower the amount of material used in general. Design for Deconstruction (DfD) is the practice to ease the deconstruction processes and procedures through planning and design [8], and is a great example of “Loop” from the ReSOLVE framework.

Design for Deconstruction plays a facilitating role to ensure there is a systematic plan to take and direct any material used in the building towards their next life cycle at the time of deconstruction. The Design for Deconstruction process essentially changes the traditional waste management process. It is an important strategy to conserve raw materials in a Reduce, Reuse and Recycle (3R) process and could eliminate the need for composting, burning and disposing of waste. Figure 4 below is a graphical representation of DfD.

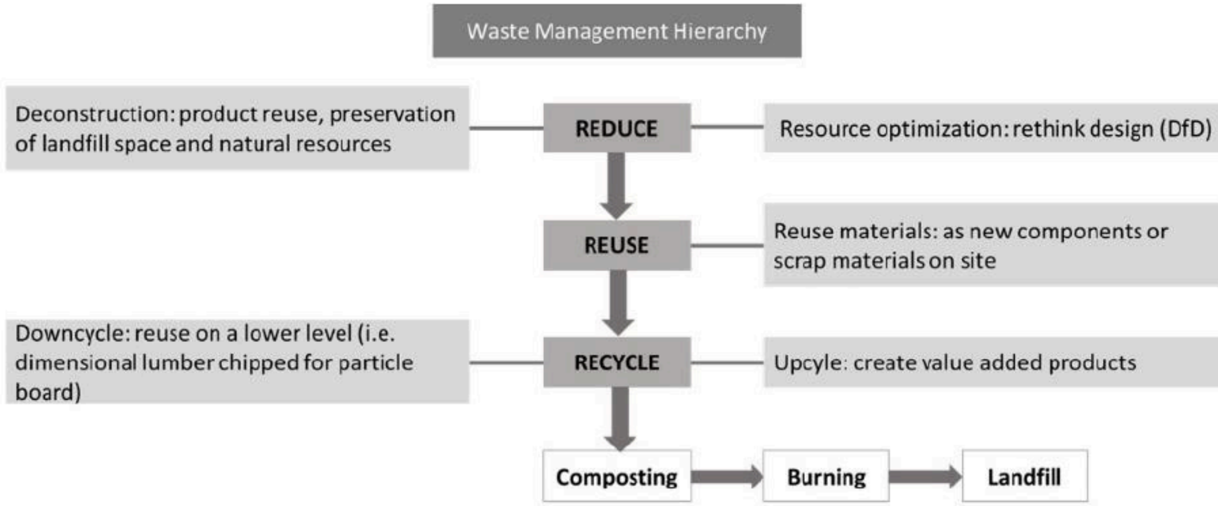

Figure 4 - The Hierarchy of waste management [8].

2012 London Olympic Stadium The 2012 London Olympic stadium is a good example of design for deconstruction. Although the main stadium was initially designed to home over 80,000 visitors during the game, the structure was designed to be shrunk down to a 25,000 seat local stadium through a process of deconstruction after the games, as shown inFigure 5 below.

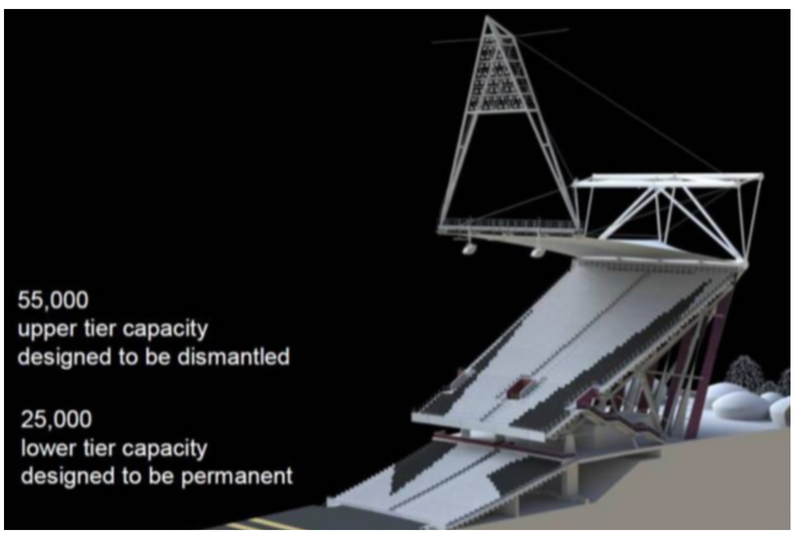

Figure 5 - Two level stadium, partially designed for deconstruction [9]

This was due to the fact that the initial plan for putting the stadium in eastern London was to give a boost to the area, however there was no intention to leave the community with the burden of maintaining such a massive structure and rather to use it better and towards the community benefits.

The designers of this project also provided the stadium with a PVC based roof with a combination of tubular steel awning structure. The roof covered almost 75% of the seats and the steel pipes were recycled from an old gas pipeline.

The PVC roof design made the stadium among the lightest ever built bringing down the use of structural steel down to 11,000 tons in comparison to 42,000 tons used in a similar structure like the Bird Nest in China.

Although the downsized stadium might not look strikingly great as the similarly built structures, deconstructing the structure provided the opportunity to build a small size stadium at the spot and provide the opportunity to use the extra 55,000 seat of the second tier in a separate structure elsewhere [10].

5.4.1 Discussion

Adaptability: The building use, space layout, additions/deletions to the building and changing the visual exterior or interior of the building is much more achievable when designing a building with deconstruction in mind. Using prefabricated, unit assembly and moving systems will systematically improve the possibility for buildings to be dismantled and reshaped on a different level whenever its necessary. Furthermore, a major adaptability consideration with DfD is the systematic facilitation of reuse or recycling the materials used in the building for their next cycle of life at the time of deconstruction

When designing buildings for deconstruction, care should be taken in the selection of building materials. While the quality of each building component and the performance of the structure as a whole should not be compromised, designing for flexibility, balancing durability and adaptability and using building layers a s a base for design is strongly advised [11].

UBC Context: DfD may require some compromises on the building interior and exterior aesthetics, e.g., a simpler design, but this could lead to reducing the material use and extending the lifecycle of the structure with giving it a second purpose. At UBC, some design for deconstruction principles has been applied to the timber structure at the CIRS building.

5.4.2 Recommendations

5.4.2.1 Actions

We recommend UBC to consider incorporating “Design for Deconstruction” into their “Design Process Policies” to ensure that at the end-of-life the building can be disassembled relatively easily, the waste generated is minimized and the salvaged materials are maximized. They also need to require designers to use materials and construction methods that will yield a high percentage of salvaged materials that are fit for reuse and recycling so that buildings can be the resource pool of the future.

Priority: Implementing this concept is quite viable for UBC as this has already been implemented in a few buildings such as CIRS. With some effort, we believe UBC can immediately integrate this concept into their guidelines and policies and bring it into action as a level 2 priority.

Synergy: Design for deconstruction is absolutely in synergy with a few of other suggestions made in “Skin”, “Services” & “Space and Stuff” by facilitating a base to make those suggestion happen easier and on a systematic design. Here are the other suggestion in synergy with “Design for Deconstruction”:

- Modular façade design;
- Prefabricated and off-site manufacturing;
- Internal movable partitioning;
- Material passport;
- Building as material bank.

6 Structure

The structure consists of the structural elements of the building, the bones which give it rigidity. Choosing a sustainable structure has long lasting implications as it is the building component which will likely not be renewed for the entire life cycle of the building. As such, we recommend considering the following ideas.

6.1 Lower Impact Concrete (Exchange)

Concrete is the most widely used, yet environmental impactful building material in the world. It carries a high quantity of embodied carbon mainly from its cement content (1lb of cement is equivalent to 1lb of CO_2 emissions,), it comes from a non-renewable source, and it does not naturally degrade back to nature. Concrete production is the 2nd highest source of industrial CO_2 on the planet [12]. There are several emerging and innovative technologies which promote either reducing the amount of cement in concrete or replacing traditional concrete, ultimately reducing the quantity being used in building construction. This is a great example of "Exchange", using alternative material inputs to improve a product and reduce its environmental impact.

Carbon Dioxide Injected Concrete - Carboncure. Carboncure is a US-based company, with its research and development based in Canada. Its technology directly injects CO_2 into the concrete mixture using a proprietary process, reducing the quantity of cement required. Their research has shown that CO_2 injected into concrete becomes a mineral which improves its compressive strength [13]. Carboncure currently has partnerships with 90 plants across US and Canada, including in Victoria and Surrey, British Columbia (Butler and Basalite, respectively). The technology has been used for large scale projects, including a 360,000ft^2 office building in Atlanta, Georgia, as per Figure 6 below displacing 680 tonnes of CO_2.

Figure 6 - 725 Ponce de Leon Ave in Atlanta. 365,000ft2 – the structure built entirely with CarbonCure concrete [14]

Ferrock – Carbicrete. A second low-carbon to traditional concrete is ferrock, a concrete mixture that uses a waste product from steel manufacturing to strengthen concrete, reduces or eliminates the cement content, and which absorbs carbon dioxide during the curing process. One supplier is "Carbicrete", based out of Montreal, Quebec, which notes that their product is "carbon negative" compared to regular concrete: they report that the product does not use cement, sequesters CO_2 via injection, and further absorbs CO_2 during curing [15].

Other Alternative Concrete Examples. There are several other examples of alternative concretes which are listed below [16]:

- Autoclaved aerated concrete (AAC) and timbercrete are two lightweight alternatives. AAC is a foam concrete which is best used to create concrete blocks or architectural elements such as lintels or cladding elements. Timbercrete is a concrete mixture with sawdust, most suitable for concrete blocks or smaller site elements such as pavers.
- Ashcrete, hempcrete, and recycled plastic concrete are three types of concrete which use an added material to improve the concrete properties. They each use a "sustainable" additive, waste fly ash, fast-growing hemp, and recycled plastic, respectively.

6.1.1 Discussion

Adaptability: Carbon dioxide injected concrete is a relatively new technology and appears to have many variations in process. Based on our research, there are few commercially available products, with Carboncure leading the way. Due to the limited supply, the costs of using Carboncure concrete are likely higher than traditional concrete at the present time; however, this may change as supply increases. The carbon reduction potential of the technology is noteworthy (Carboncure reports that if all concrete used their process, it would reduce yearly global CO_2 emissions by 700 mega tonnes [12]. For this process, a source of CO_2 needs to be secured; emissions produced directly from the concrete production process could be captured and re-used, or other sources of CO_2 could be located.

The other concrete alternatives listed above (e.g., timbercrete, ashcrete, etc.) do not appear to be specifically designed for structural purposes, but rather for architectural uses such as demising walls, exterior cladding, or site elements such as pavers.

UBC Context: The UBC Technical Guidelines (section 03 00 00) specify that structural concrete should contribute to a 100-year building structure design life and should follow LEED requirements, but do not specify that traditional concrete has to be used.

Based on the UBC LEED Implementation Guide, 3 points should be targeted under the mandatory MR credit: Building Life Cycle Impact Reduction. Using a low-carbon concrete solution, such as Carboncure, would contribute towards achieving this credit.

Relative to traditional concrete, carbon dioxide injected concrete, such as Carboncure's product, provides a low-CO_2 option, however, more research on price, supply availability, and examples of application would provide a clearer picture on financial viability. Carboncure is available locally.

6.1.2 Recommendations

6.1.2.1 Actions

We believe there is an opportunity for UBC to initiate a "Concrete reduction challenge" bringing the idea out to the designers, contractors and the material suppliers to reduce the amount of "traditional" concrete being used in UBC's project either through design or alternative material.

Priority: As using CarbonCure does agree with UBC policies and since the environmental impact is high, we recommend assigning a phase 1 priority level to this recommendation.

6.1.2.2 Future research

We recommend completing further research on CO_2-injected concrete, including a detailed cost and supply analysis and a better understanding of the sources of CO_2 used.

7 Skin

7.1 Green Façade (Regenerate)

A green façade is an example of “regenerate” that restores the ecosystem and increases resilience [1]. By considering that nowadays, cities have a lack of space at ground level for green infrastructure, vertical green façades are a good replacement [17].

Bosco Verticale / Boeri Studio *“The Vertical Forest is an architectural concept which replaces traditional materials on urban surfaces using the changing polychromy of leaves for its walls”* [18] The project contains a screen of vegetation, which creates a suitable microclimate, increases biodiversity, filters sunlight, produces humidity, absorbs CO_2 and particles, produces oxygen, and protects the building against strong wind, radiation, noise, pollution and other annoying external factors [18].

In terms of sunlight control, as seen in Figure 8, the vertical forest acts similar to smart living shadings that controls sun entry based on the sun angle in different seasons. Leafy trees and vegetation lose their leaves on winter which provides more opportunities for sunlight entrance; however, on summer their dense leaves decrease heat and light entry to reduce overheating inside the building.

Figure 7 - the Bosco Verticale [18]

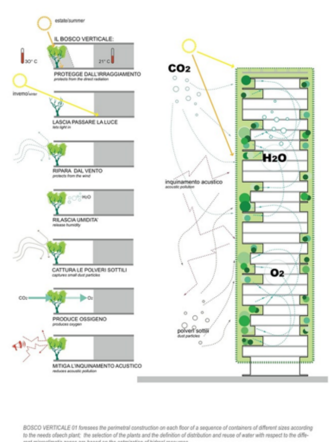

Figure 8 - A green facade has many benefits [18]

Vegitecture Supersized Green Wall. Vegitecture is a new concept of green wall designed in Barcelona. It is a 21m wall covered by vertical infrastructure which is separated from the original building, as seen in Figure 9 and Figure 10. The green wall has its own irrigation and fertilizer system. It also runs independently from existing building structures and it is installed on an exposed unused wall. Like other forms of green walls, Vegitecture walls offer multiple benefits such as enhancing the cityscape, reducing greenhouse gases and improving air quality [17].

Figure 9 - A finished installation of Vegitecture [17]

Figure 10 - Step-by-step Installation of Vegitecture [17]

7.1.1 Discussion

Adaptability: By considering the above concepts and multiple benefits of green façade, specifically its function as a smart living shading device, installing green façades could reduce the need for external shading materials. Also, implementation of green wall concept (Vegitecture) on unused walls can reduce finishing material usage for exposed façades.

However, maintenance costs for green walls can be considerable and careful selection of plant species is a key to managing expense [17]. Low-cost solutions also include using existing structures for climbing plants [17]. In terms of cost efficiency, implementation of green façade concept needs careful design considerations to reduce its maintenance costs. Also, proper considering to soil depth and a suitable irrigation system is essential to the systems survival.

Green façades are an example of “regenerate”, and it can be also considered as part of “exchange”, due to its ability to change the type of material for shading devices from conventional construction materials to liveable natural ones.

UBC Context: At present, some UBC buildings, such as CIRS, benefit from green façades as smart living shading devices. This technique can be applied in a wider scale through UBC buildings by targeting its advantages in terms of reducing material usage. Fortunately, there is a good opportunity to apply green façade concept based on the UBC context by considering high level of annual rain in Vancouver. Rain water capturing system can be a good option for irrigation of the green façade which reduces maintenance cost very effectively.

7.1.2 Recommendations

7.1.2.1 Actions

We recommend UBC to provide maintenance considerations for green façade concept in new constructions, such as providing enough soil depth on building setbacks or balconies, irrigation infrastructures, etc.

Priority: The green façade concept can be completed as a phase 1 priority at UBC, as a few examples already exist on campus, the reduction in "hard" materials is significant, and the added cost is not expected to be substantial.

7.1.2.2 Future Research

In terms of lowering maintenance costs of green façade, UBC would benefit from doing an in-depth research on the most resilient plant species based on climate and context of UBC to select as the best choices on new constructions.

7.2 Modular Design and Off-Site Prefabrication (Loop)

Alternative methods of construction such as prefabrication, modularization, and off-site construction are effective techniques to design out waste or in other words, reducing the overall construction waste during construction rather than managing and diverting it after the fact [19].

Sky Believe in Better Building, UK. The Believe in Better building is the tallest commercial timber structure in the UK and was designed and constructed in less than one year [20]. Its facade is an example of prefabricated modular design [1], as shown in Figure 11below.

Based on 2007 report published by WRAP, off-site manufacturing processes can help the construction industry reduce waste [21]. It also shows up to a 90% reduction can be achieved by reducing wastes such as wood pallets, shrink wrap, cardboard, plasterboard, timber, concrete, bricks and cement by increasing the use of off-site manufacture and modular construction [21]. Other benefits of off-site construction are reduced construction related transport movements, improved health and safety on site through avoidance of accidents, and reduced construction timescales and improved programs [19].

Figure 11 - Photo of Sky's Believe prefabricated building [20]

7.2.1 Discussion

Modular design and off-site prefabrication generally can reduce material usage for façade design in two stages. First, reducing material waste for new constructions and secondly, waste reduction in deconstruction.

Benefits of Modular design and off-site prefabrication for new constructions:

- With off-site construction, the materials can be managed prior to leaving the factory, which offers a much more efficient process to reduce the amount of waste sent to landfills [19].
- Since modular builders work in a factory-controlled environment, they can have many construction projects underway simultaneously in one location, so they are better able to re-inventory materials that may have been allocated to one project, for use in another [19].
- Modular construction helps the industry reduce waste by improving the workmanship quality and reducing on site errors and re-work, which themselves cause considerable on-site waste, delay and disruption [19].

Benefits of Modular design and off-site prefabrication for deconstructions:

- Whole facade can be reused by reversing the process in which it was installed. The facade can come apart in pieces in the same way they were created [19]
- Modular design and off-site prefabrication can reduce material waste in façade design. Moreover, it provides better opportunities for deconstruction and all modular used pieces of façade can be reused for new construction or rearranged very flexibly.

Adaptability: Modular façade can be changed flexibly by rearranging the prefabricated prices in different patterns based on interior changes or other requirements during the building life-time.

UBC Context: There is an opportunity for UBC in doing prefabricated modular design off-site at the factory environment. Due to UBC simultaneously have several projects under construction, waste of one project can be used for the others, which in overall reduces the amount of raw material usage for UBC. Brock Commons is a great example of modular design at UBC.

7.2.2 Recommendations:

7.2.2.1 Action

At the present, UBC applied off-site prefabrication for some of its recent constructions, such as Brock Commons. We recommend to at least apply modular façade design for all new constructions.

Priority: We recommend using a phase 1 priority as offsite pre-fabrication can be done as a short-medium term for new constructions at UBC after providing factory space and considerations at the UBC site.

7.2.2.2 Further Research

Modular design and off-site prefabrication can be applied for the whole building components rather than just the façade. UBC would benefit from doing research on finding suitable materials for modular design and prefabrication to be used for different building components.

8 Services

Building services are the systems installed to make buildings comfortable, functional, efficient and safe. Building services might include, building control systems, energy distribution such as water, lighting, heating, air conditioning, lifts, and telecommunication systems.

8.1 Reuse of Building Components (Share)

The new buildings and infrastructure are a huge store of potential resources. The best way to save the natural resources and making any building most effective is to reduce and reuse the building components, it will protect the environment and also economically will save money at the end of the road.

Buildings, which are static, are built to serve human needs, which are dynamic. The idea of re-using building components is an attempt to make buildings more dynamic.

The following projects exemplify the “Share” component from the ReSOLVE framework.

Buildings as Material Banks (BAMB). BAMB is a project created by EU Horizon 2020 where the main purpose is to enable the re-use of building components at the highest level and quality possible: firstly, within other buildings, then at the product level, and finally at the material level. BAMB builds on several concepts, notably “Material Passports” and Reversible Design. It includes 15 partners in 7 European countries [22].

Material Passports are electronic sets of information that describe specific building components and materials, making them easier to recover for a second life. The data is captured in a database, a detailed inventory of the building components. They provide information on the value of materials and products, their reusability, their toxicity, and their ease of disassembly. Information is collected in a database to facilitate the recovery, recycling and/or re-use of materials [1]. Figure 12 below conceptually shows how a building can be broken down into its components.

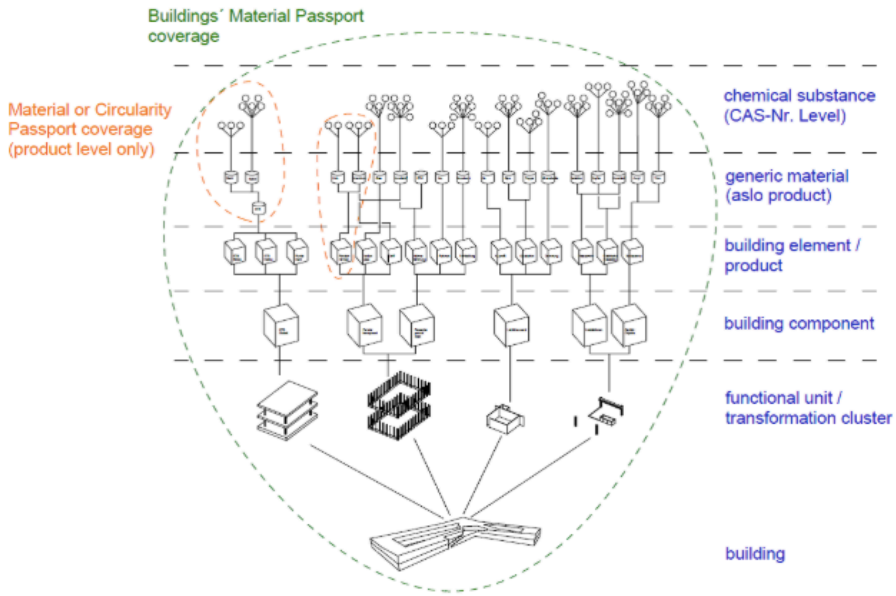

Figure 12 - BAMB breaks a building down at several levels into its components [23]

8.1.1 Discussion

The BAMB pilot projects and prototyping have demonstrated that these tools and methodologies can prevent upward of 75% of all waste generated and raw materials used over the course of several building transformations.

Although BAMB and the Materials Passport are both forward thinking ideas, they will not directly increase the adaptability of the buildings at UBC.

UBC Context: These concepts are closely related to life cycle assessments, which are already a requirement for new construction at UBC (through the LEED Implementation Guide).

8.1.2 Recommendations

8.1.2.1 Actions

UBC can follow the concept of the “material passports” which is currently being developed by multiple parties, mainly in European countries. The second-hand material market or material-bank could become a reality in the future. Another alternative would be for UBC to establish an organization like BAMB to share the database of building supplies that can be reused from demolished or renovated buildings into the new construction projects.

Priority: Since BAMB/passport are unfamiliar concepts to the Canadian construction industry, and since the effort to categorize building materials are serious barriers to implementation, we have categorized it as a level 3 priority.

Synergy: Potential synergies with modular construction (as it would be easier to categorize items built in a controlled production line, and definite synergies with design for deconstruction (as knowing which components can be used after deconstruction is one of the main goals of BAMB).

8.2 Leasing of Lighting and Light Sensors (Exchange)

One movement in the construction industry is to prioritize leasing equipment versus ownership.

Leasing can take many different shapes; for example, the end of the lease could result in purchase, return, or a renewed lease of the equipment. Also, several different parties may be involved in the leasing, typically a combination of manufacturers, vendors, and sometimes third-party lessors. Four main lease types exist: capital leases, operating leases, tax-exempt leases and solar leases.

Philips' 'product-as-a-service' business model is an example of leasing: the client pays Philips on a regular basis to handle their lighting "service", i.e., everything from design to equipment to installation to maintenance and upgrades. They provide the most cost effective and efficient lighting on the market, encouraging the energy saving market. When the contract ends, the products are returned to Philips where they re-use the raw materials, recycling and reducing waste [24].

As slight variation is **lumens-as-service**, where the provider also controls the lighting remotely. In this model, the providers earn the calculated lighting savings, incentivizing them to provide an energy efficient design that will provide them dividends. The clients, on the other hand, charge "rent" on their ceiling space, giving the provider the rights to install their system [25].

In general, these are purely performance contracts – the client specifies what output they want from their ceiling, i.e., the desired lumen levels, and then the provider is responsible for choosing and installing the lighting system that will meet the client's requirements. It moves the responsibility from the client to the provider.

8.2.1 Discussion

With this approach UBC will fully aligns the benefits and will receive the share of the savings in the form of a fixed rent for the term of the agreement, along with the indirect benefits of a higher-quality lighting system. Service providers are paid the calculated lighting energy savings realized over the term of the agreement.

8.2.2 Recommendations

8.2.2.1 Actions

LED leasing warrants the application of high-tech lighting to achieve minimum long-term costs and CO2 emissions for UBC. With no investing in LED lamps of uncertain durability, UBC will be assured the quality lighting without failure or maintenance and the cost reductions are immediate.

Priority: As the relative risk of leasing lighting/lumens is low, we recommend completing this action as a phase 1 priority.

9 Space and Stuff

Spaces and furniture can be designed and built to be more durable, repaired, refurbished, reused and disassembled. Maintaining components and their materials at the highest useful purpose minimizes resource waste. Also, holding them in repetitive loops keeps them at their highest possible intrinsic value. Today's generation is more inclined to rent, lease or share items than previous generations what means that fewer resources are going to be needed, assets are used more fully and their lifecycles can be extended and diversified [1].

9.1 Biodegradable and Compostable Materials (Regenerate)

Use biodegradable and compostable materials, such as MycoComposite (a self-assembling, biological binder for agricultural hemp waste), that are a biomaterials platform that utilizes utilizing mycelium as a self-assembling.

Gunlocke's Savor Chair and Gryphon Doors. Gunlocke's Savor chair uses heat pressed MycoComposite™ technology for the structure in their chair back. Gryphon Doors uses MycoComposite™ 584 for the interior core of their hand-crafted doors [26].

Figure 13 - Gunlocke's Savor Chair [27]

Figure 14 - Gunlocke's Gryphon Doors [27]

9.1.1 Discussion

UBC Context: The UBC Technical Guidelines (section 09 00 10 Finishes – General Requirements) mention to consider the use of finishes that are recyclable, recycled, non-toxic, low maintenance and durable but does not specify in which extent they should be applied. Under section 12 00 00 Furnishings is mentioned "Where feasible, re-use or re-furbish existing furniture. Alternately, specify new furniture that is durable and provides an extended service cycle that will also provide future opportunities to be repurposed or recycled.", it also could become mandatory to some extent.

Evoking synergies between interrelated sources at UBC, such as materials science, design and new business models, could allow UBC to develop its furniture made of biodegradable materials in campus in a long term. Selecting new materials, such as biodegradable and compostable, would allow UBC to increment its standards while increasing efficiency gains and minimize waste and other negative externalities. There would be great opportunities to find new materials sources and develop new products within the campus through student's competition and other initiatives, which would enhance UBC's student's awareness for the circular economy, from a material point of view.

9.1.2 Recommendations

In a first phase, we recommend UBC to buy "stuff" from companies who provide material that is made of renewable, recycled, recyclable, non-toxic components and lower energy content. In the future, furniture guidelines more specific in materials could be an asset, where materials should achieve "minimum standard" or being made from bio products. This could be achieved in phases.

Priority: Durability could be a risk, but prototypes could be developed and tested in small scales, and as they improve their performance scale could be increased. We have categorized this as a phase 1 priority.

9.2 Biocomposite Internal Partition and Ceiling Kits (Optimize)

Optimizing is about designing with better materials for better solutions. When optimizing, the designer should be thinking about flexible use and easy installation, maximizing the use of daylighting and natural ventilation in spring and summer, prolonging products' use period (e.g. through repair/maintenance, design for durability and upgradability), and material efficiency (renewable, recycled, recyclable, non-toxic components and lower energy content).

The BioBuild project – through the collaborative effort of architects, engineers, materials scientists and manufacturers – proved the viability for the effective use of natural composite materials in construction. Biocomposites demonstrate mechanical and physical performance comparable to traditional materials while reducing resource depletion (an "exchange" characteristic). This is possible through a circular model where fibres and resins from fast-growing plants are used to make architectural products and feedback into the biological cycle at the end of their life cycle [28]

The Biobuild Internal Partition Kit (IPK) is a movable partition wall system, used to subdivide spaces. It includes its own support structure and insulation [29]. An example is shown in Figure 15 below.

The BioBuild IPK uses skins of jute-PFA, which has been chosen for its low embodied energy and low cost. The PFA resin is used because of its characteristic intrinsically flame retardant.

The panel is painted with a silicate-based paint, for aesthetic reasons which can provide a better decorative finish and an additional layer of fire protection, and the interior of the panel can be filled with a variety of insulating materials [29].

Figure 15 - Biobuild Internal Partition Kits [29]

Design drivers and technical requirements of the product:

- the acoustic separation of adjacent spaces
- a simple, lightweight substructure, for ease and speed of installation
- a self-supporting panel
- minimal use of floor space (minimum thickness)
- impact resistance Class E4: 343 J

The Suspended Ceiling Kit (SCK) is a suspended ceiling system, as shown in Figure 16 below. It is intended for internal use only and will consist of lamella suspended from the structural ceiling which will be made using biocomposites. This product has the general function of providing a cohesive architectural surface and acoustic damping, and at the same time allowing for technical installations to be routed in the space above it. Also, it will include any fixings needed for the installed system to comply with the functions described in this document [30].

Design drivers and technical requirements of the product:

- an open, lamellar structure
- an aesthetic design
- a high-speed installation with simple connections
- be lightweight
- not load-bearing

- possible inclusion of air-control components
- addition of lighting fixtures
- integration with the internal partition wall
- simple connection with the substructure

Figure 16 - Biobuild's Suspended Ceiling Kits [30]

9.2.1 Discussion

The advantages of bio-composite materials can be utilized to ensure ease and speed of installation, integration of functionality and low embodied energy.

The use of biocomposites has the potential to support this change and the BioBuild project demonstrated that it is possible to develop solutions that comply with the stringent building construction standards. However, the use of biocomposites is still subject to a special approval process, since the material is not included in building codes. It is therefore essential to gather consensus from the vast scientific and engineering community to create new opportunities for using such materials in future projects at UBC.

Adaptability: The vast use of movable partitions could allow for functional changes in the future: allowing the building to be used for longer, adapting to new uses and demands more efficiently, and decreasing the necessity of building new buildings in order to attend new working or students space demands. The suspended ceiling kit could contribute with these changes, like new lighting and technical installations are needed as spaces change, so the ceiling needs to be adapted as well in order to attend the users' necessities.

UBC Context: UBC LEED Implementation Guide mentions “Materials with recycled and recyclable content; Materials that are appropriately and responsibly sourced; and Biobased materials”, which could be more specified.

The UBC Technical Guidelines (section 09 00 10 Finishes – General Requirements) mention to consider the use of finishes that are recyclable, recycled, non-toxic, low maintenance and durable but does not specify in which extent they should be applied. Under section 12 00 00 Furnishings is mentioned “Where feasible, re-use or re-furbish existing furniture. Alternately, specify new furniture that is durable and provides an extended service cycle that will also provide future opportunities to be repurposed or recycled.”, it also could become mandatory to some extent.

9.2.2 Recommendations

9.2.2.1 Actions

UBC could test a few pilot projects where spaces are designed for movable partitions therefore a high degree of functional adaptability.

Priority: Since the environmental benefit of more flexible space-use are not as tangible as some of the other recommendations in this report, we have categorized this as a phase 3 priority.

9.3 Cradle-to-Cradle Carpeting (Loop)

Desso, a Tarkett company, has adopted its Cradle to Cradle® (see Figure 17), where goods are designed to be returned at the end of their first life cycle. The materials are considered nutrients for the next life cycle either through production (technical) or the earth (biosphere). C2C also means ensuring the materials used are positive for the environment and human health, relevant for all product cycles. Therefore, products were assessed and designed against C2C environmental and human health criteria, in this case, the customer, an adult education centre, wanted to procure its flooring in a positive, sustainable way and act as a role model to its students [31].

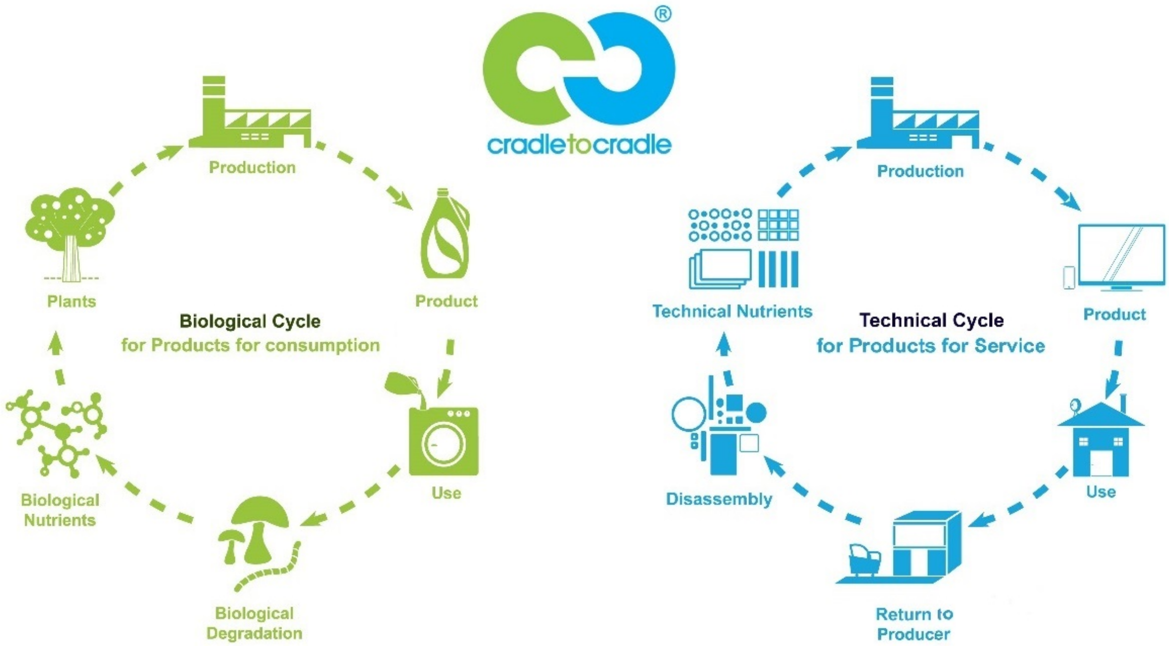

Figure 17 - Desso AirMaster carpet follows the Cradle-to-Cradle certification [32]

Desso AirMaster is four times more effective than regular carpets at retaining the fine dust. In addition, the carpet tile is delivered with a C2C Gold Certified EcoBase™ backing, consisting of C2C-assessed material ingredients. Designing with healthy materials in this way helps to ensure the product is positive to people and planet both during its use and when it's taken back for recycling or reuse. In the latter case, the backing is 100% recyclable in Desso's production process, with the purity of the materials acceptable for C2C upcycling, ensuring the maximum amount of material is transformed for a new life cycle [33].

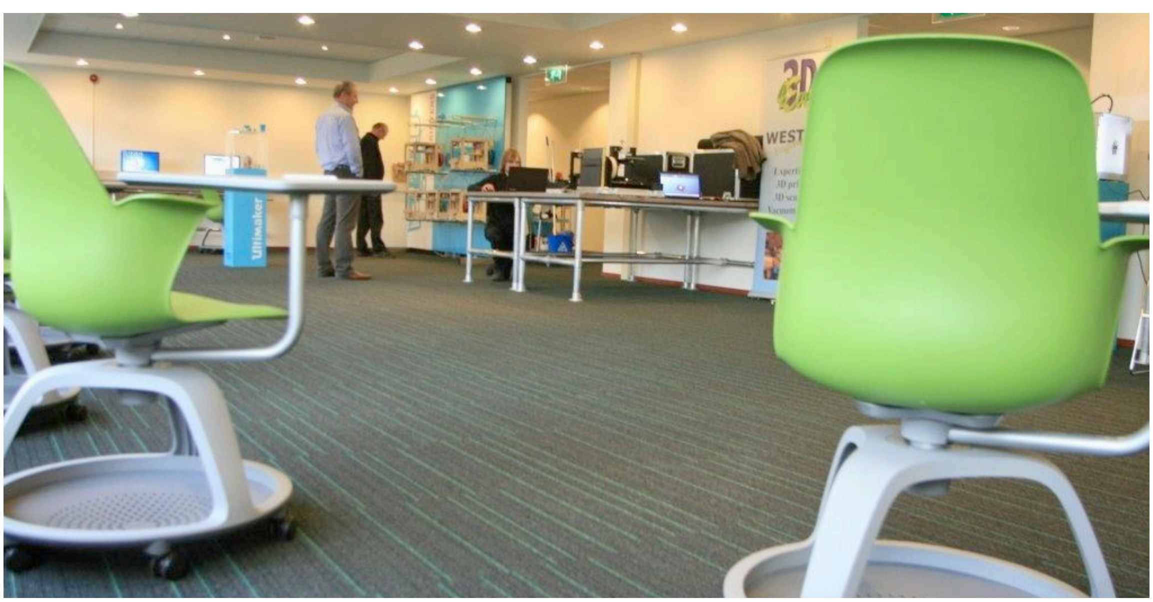
Figure 18 - Desso Airmaster Carpet [33]

9.3.1 Discussion

Carpets have an important impact on work and student spaces as they help to absorb sound and improve air quality. Also, there is often less fine dust in carpeted rooms, and this carpet example prevents dust from becoming airborne again once captured. It helps to improve indoor air quality as it absorbs more particulates from the air than a smooth surface, so the concentration of fine dust (PM10) is significantly reduced through this finishing. Particulate matter is probably the most significant pollutant in terms of the impact on human health, so adopting these new materials could result in improvements in people overall studying and working environments.

In addition, the materials, such as this example, which contains 100% regenerated nylon yarn, made from recovered waste materials such as end-of-life carpet yarn and discarded fishing nets, prove that it is possible to have great materials made of waste, which could be pursued at UBC when specifying materials that are in direct contact with the occupant such as the floor.

Making use of materials that innovate to contribute to people's health and wellbeing could have a significant good impact on UBC's community.

9.3.2 Recommendations

The use of finishes that can do more than attend their primary function, such as C2C carpets that improve air quality, should be pursued

Priority: As this is a lower risk item and has already been widely adopted in the industry, we recommend this as a phase 1 priority.

9.4 Virtual Meeting Rooms (Virtualize)

Video conferencing and virtual meeting rooms enable users to achieve the physical experience of a face-to-face meeting via a virtual platform. Participants can share information, documents and presentations via platforms like Facetime and Skype, using PCs, laptops, smartphones or tablets. They can collaborate on projects in real-time and connect directly with colleagues around the world using real-time language translation. Services such as Mezzanine by Oblong provide a collaborative multi-wall platform for professional sharing and presenting [1].

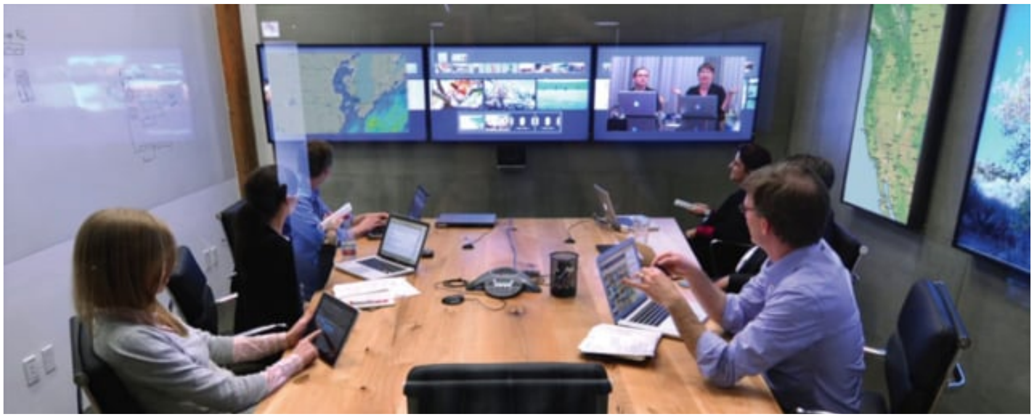

Figure 19 - Mezzanine's virtual meeting room [34]

Advances in virtual reality technology mean people will soon be able to interact in a computer-simulated office environment using an avatar. These technologies will allow virtual testing and optimization of designs, provide better quality communications and enhance relationships between stakeholders and facilitate flexible working [1].

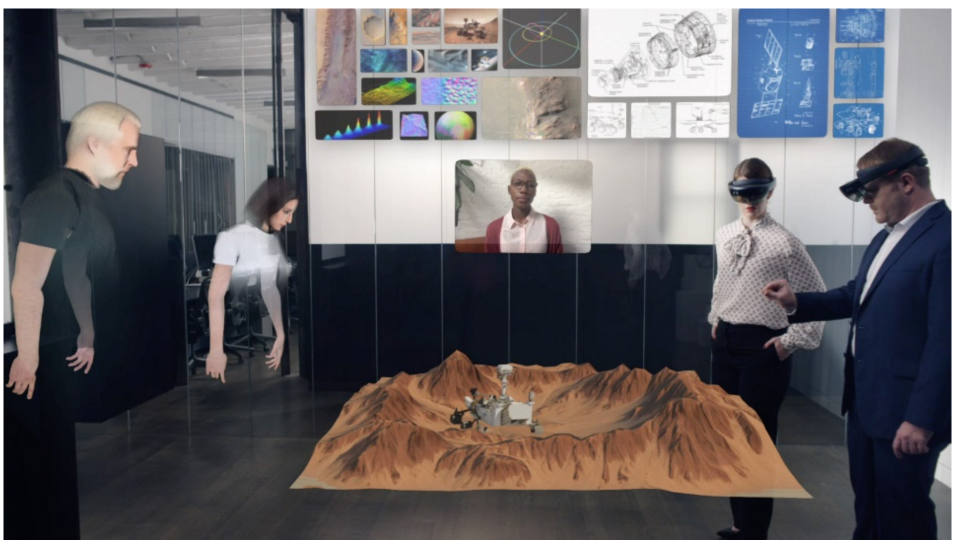

Figure 20 - Virtual reality technology [35]

9.4.1 Discussion

Designing spaces for longevity ensure the long-term durability, reduces waste and helps ensure assets are used optimally throughout their lifecycles. Advanced technologies that enable optimized, flexible, and user-focused design are slowly replacing static products and top-down design approaches.

UBC Context: The UBC Learning Space Design Guidelines (LSDG) mention "Multiple walls with marker boards" to be used [36] but as students need to share information, screens can be gradually added in the rooms replacing boards, transforming them in virtual meeting rooms.

9.4.2 Recommendations

9.4.2.1 Future Research

Widescale adoption of virtual reality meeting spaces still requires research to confirm the costs and benefits. We recommend researching other case studies and companies that are producing these materials and verifying whether it has an impact on reducing space requirements.

Research could also be completed to verify the impacts of virtual reality meetings psychological health (i.e., creativity and feeling “connected” to other humans), and whether including other social area with plants and water (nature contact) in the building would be required.

10 Other Considerations

UBC is a leader in sustainability and has already adopted several concepts that reduce the impact of the materials used for construction. For example, UBC prioritizes using local timber, and this idea was therefore not included in this report.

11 Applying ReSOLVE at UBC

For the purpose and scope of this project, we strictly applied the ReSOLVE framework on the Materials section of the UBC Green Building Action Plan. We believe that UBC would benefit from applying this framework and its six lenses – Renegerate, Share, Optimize, Loop, Virtualize and Exchange – to all components within the GBAP, promoting a circular economy in many realms. For example, the solar system and the sewage treatment plant suggested in this report can both contribute to improving “Energy” and “Water” consumption, which are both individually mentioned in UBC Green Building Action Plan.

Applying ReSOLVE to every project, on the other hand, would be onerous. We recommend applying the framework at a “component” level, on a cyclical basis, e.g., every 2-3 years, to uncover new circular economy precedents that come to light in the industry.

12 Summary Table of Recommendations/Actions

The following table summarizes the actions recommended in this report, by section, and also identifies how it relates to the ReSOLVE framework.

Priority phases are described in section 4.2 “Action Prioritization”.

7S Model Component	ReSOLVE	Action	Priority Phase
System and Site	Regenerate	➢ Evaluate the feasibility of onsite sewage treatment plants for new institutional facilities.	➢ Phase 3
	Optimize	➢ Use solar power to cover the emergency needs of each building.	➢ Phase 2
	Loop	➢ Incorporate Design for Deconstruction guidelines into the UBC Design Process Policies.	➢ Phase 2
Structure	Exchange	➢ Initiate a concrete reduction challenge, encouraging designers/builders to use alternative lower impact concrete (such as CarbonCure).	➢ Phase 1
Skin	Regenerate	➢ Provide maintenance considerations for green façade concepts in new construction (such as enough soil depth, irrigation infrastructure).	➢ Phase 1
	Loop	➢ Apply modular façade design for all new construction.	➢ Phase 1

Services	Share	➢ Complete a pilot project for BAMB/materials passport.	➢ Phase 3
	Exchange	➢ Consider a leasing model or a "lumen-as-a-service" model for lighting retrofit projects or in new construction.	➢ Phase 1
Space & Stuff	Optimize	➢ Source furniture (and stuff) from companies who provide material that is either renewable, recycled, recyclable, non-toxic and low-energy content.	➢ Phase 1
	Optimize	➢ Complete a pilot project for a space designed with biocomposite movable partition walls.	➢ Phase 3
	Loop	➢ Use Cradle-to-Cradle carpeting.	➢ Phase 1

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