University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Enhanced Environmental Resilience for REAP 4.0

Connecting Biodiversity, Stormwater and Climate Change Adaptation

Prepared by: Grace Schaan, Vanessa Amorocho, Annika Ord, Celeste Pomerantz, Shuoqi Ren

Prepared for: [clients/community partners – organization name (NOT people)]

Course Code: RES 510

University of British Columbia

Date: 14 December 2021

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Prepared for: Campus & Community Planning: Sustainability & Engineering (Penny Martyn & Jake Li)

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Date: 12/14/21

EXECUTIVE SUMMARY

UBC has designed the Residential Environmental Assessment Program (REAP) to align with the University's objectives for sustainable development and climate action. REAP is like the energy efficient building code known internationally as LEED though the defining difference is that REAP is only for residential buildings on the UBC campus. The REAP program functions by setting preconditions that must be met for proposed development of new residential buildings. There are additional credits that can also be gained by meeting different criteria of sustainability. The current version, REAP 3.2, was published in 2020 and the next edition, REAP 4.0, is set to be released in the next few years. With future climate scenarios in mind, the creation of REAP 4.0 poses an opportunity to increase the resilience of the UBC campus by evaluating the existing document and making recommendations for improvement. For the purposes of this project, resilience will be defined as "the capacity to develop and sustain human well-being in diverse contexts in the face of…change…through adapting or transforming in response to change" (Folke, 2016, 13). This project considers methods that combine biodiversity, stormwater mitigation, and climate adaptation and that work in unison to increase climate adaptation and resilience on the UBC Vancouver Campus. In order to do so, we worked from the existing REAP 3.2 Reference Manual (UBC, 2020) and looked for gaps in the credit system to develop recommendations. We accomplished this through the following methods: analyzing the REAP 3.2 credits, conducting a literature review, interviewing UBC faculty members, incorporating social-ecological systems (SES) concepts. This allowed us to create REAP 4.0 recommendations that tied together stormwater management, biodiversity, and climate adaptation.

An analysis of the stormwater preconditions and credits in the existing REAP 3.2 policy exposed several gaps that could be addressed in REAP 4.0. First, the current policy does not mention greywater use or harvesting stormwater. The current policy highlights a desire to "reduce potable water use associated with irrigation" in W P2 and reduce the total amount of potable water used in W Credit 1.1 (UBC, 2020, 37). Adding separate preconditions for stormwater harvesting and greywater use would contribute to reducing the total amount of potable water used and the amount associated with irrigation. These recommendations are put forth to increase the sustainability of the REAP buildings particularly to adapt to climate change. Meadows (2009) suggests intervening in a system by making changes at leverage points such as buffers which stabilize stocks relative to their flows. Greywater use and stormwater harvesting can be considered buffers as they buffer the effects of both heavy rainfall and drought in a social-ecological system. Moreover, despite requirements to detain stormwater using LID and green infrastructure on-site in REAP 3.2, recommendations connecting biodiversity and LID can be further addressed in REAP 4.0. First, we found that current policies do not address on-site stormwater pollution reduction. Adding a credit on the use of sequential LID devices can improve the quality and quantity of runoff from rainfall events. Second, stormwater management policies could benefit from involving the biodiversity section by integrating ecological plantings of native plants and adding structural heterogeneity to LID techniques. We recommend the use of enhanced bio-LID, or Bio-SUDS (Sustainable Urban Drainage Systems). These could include bioretention basins coupled with tree boxes, rocks, poles, and logs, to increase habitat conditions heterogeneity for small insects and invertebrates. Trees will also help with the retention of stormwater.

Building biodiversity in residential areas is a bridge between humans and nature. It is a way to enhance the human living environment, conserve and restore natural health, and support community sustainability and resilience. We identified some potential aspects missing in the biodiversity section of REAP 3.2, including mitigation of negative impacts of building construction, emphasis on structural planting of native and edible species with comprehensive

consideration for climate change, and adding cultural ecosystem services for the residents. These recommendations also support stormwater management and climate adaptation. Firstly, various mitigation practices should be implemented before, during, and after construction. The "Protocol for Wildlife Protection during Construction" (2015) from the City of Ottawa can be referenced for this purpose. The main goal is to mitigate the impacts and compensate biodiversity loss generated from construction. Secondly, building community gardens in the residential buildings' areas is a way to add cultural ecosystem services for the residents with various benefits. While designing community gardens, equitable access and plant selections should be considered at the same time. Thirdly, realizing structural diversity and planting species with more comprehensive considerations like climate adaptation, food security, and supporting wildlife and ecosystem functions are good directions for species selections. Within the biodiversity section of this paper a reference list we created can be found recommending species based on the plant information.

Climate adaptation is a key piece in the REAP 3.2 manual and a major category in which credits can be accumulated. All REAP buildings must be built to meet the requirements for weather data for both present weather conditions and to accommodate for future weather conditions (UBC, 2020; PCIC, 2021). Of the four preconditions under climate adaptation, the Enhanced Resiliency precondition is the area in which the most connection to both the stormwater and biodiversity areas. However, under the Enhanced Resiliency credit, REAP states that there are no current resilience strategies being adopted while stressing the importance of having these strategies be cost-effective (UBC, 2020). According to the BC Housing Energy Step Code and the Mobilizing Building Adaptation and Resilience (MBAR) papers, planting external vegetation not only reduces local temperatures outside buildings but is also one of the most cost-friendly options for infrastructure (Strebly, 2019; BC Housing, c). Other design features that should be considered for improved climate adaptation include integrating deciduous trees as a means of passively cooling residential spaces, increasing biodiversity, and aiding with the absorption of rainwater are green roofs and living walls. Neither green nor living roofs are mentioned in any of the climate adaptation literature for REAP 3.2 but are mentioned in the On-Site Rainwater Management (W 2.1) credit as a recommended strategy as well as in the biodiversity section under Site Green Space credit (BIO 2.1). Studies have shown that green roofs have major cooling effects for both interior and exterior environments (Dong, 2020; La Roche, 2020).

Through our research, we have identified a number of guiding principles to consider when designing REAP 4.0. Firstly, it is important to identify the target outcomes and work backwards to design strategies. Secondly, while the REAP policy is a useful credit and guide, it does not provide the guidance and contextual information that may be needed to effectively identify or implement appropriate design strategies on a case-by-case basis that could be provided by consulting with experts (Forestry interviewee, 2021). Furthermore, for strategies to be long lasting and effective, we need to provide adequate training, resources, and personnel to support and care for these projects. Lastly, we want to encourage UBC and developers to be creative in implementing the REAP policy. In urban landscapes, we often see repeating landscape forms due to lengthy permitting processes and institutionalized design standards (Forestry interviewee, 2021); however, these configurations may not be the most effective at managing stormwater, biodiversity, or climate adaptation. Future research should take into account: the possible eco-gentrification that may arise out of REAP, the need for institutional support backing the implemented strategies, how to ensure inclusivity and equity, how to establish biodiversity offsets to compensate for loss through land development, and the importance of reducing human-wildlife conflicts. Through employing strategies that link biodiversity, stormwater mitigation, and climate adaptation, REAP 4.0 will be better suited to deal with the present and future challenges of climate change and support climate resiliency on campus.

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LIST OF ABBREVIATIONS

CIRS: Centre for Interactive Research on Sustainability

GBAP: Green Building Adaptation Plan

IRES: Institute for Resources, Environment and Sustainability

ISMP: Integrated Stormwater Management Plan

LID: Low Impact Development

REAP: Residential Environmental Assessment Program

SALA: School of Architecture and Landscape Architecture

SEEDS: Social Ecological Economic Development Studies

SES: Social-Ecological System

SUDS: Sustainable Urban Drainage Systems

1. INTRODUCTION

UBC has designed the Residential Environmental Assessment Program (REAP) to align with the University's objectives for sustainable development and climate action. REAP is like the energy efficient building code known internationally as LEED though the defining difference is that REAP is only for residential buildings on the UBC campus. The REAP program functions by setting preconditions that must be met for proposed development of new residential buildings. There are additional credits that can also be gained by meeting different criteria of sustainability. The current version, REAP 3.2, was published in 2020 and the next edition, REAP 4.0, is set to be released in the next few years. With future climate scenarios in mind, the creation of REAP 4.0 poses an opportunity to increase the resilience of the UBC campus by evaluating the existing document and making recommendations for improvement. For the purposes of this project, resilience will be defined as "the capacity to develop and sustain human well-being in diverse contexts in the face of…change…through adapting or transforming in response to change" (Folke, 2016, 13). This project considers methods that combine biodiversity, stormwater mitigation, and climate adaptation and that work in unison to increase climate adaptation and resilience on the UBC Vancouver Campus.

2. METHODOLOGY AND METHODS

2.1 RESEARCH METHODS

We focused our research on sustainable systems and strategies that work in concert to improve stormwater management, biodiversity, and climate adaptation on the UBC campus. Working from the existing REAP 3.2 Reference Manual (UBC, 2020), we looked for gaps in the credit system and developed recommendations. We accomplished this through the following methods:

(I) Analyze REAP 3.2 Credits: Using the REAP 3.2 Manual (UBC, 2020), we analyzed the current credit system and looked for areas that can be further developed, this informed our literature review and interviews.

(II) Literature Review: We conducted a literature review examining stormwater management, biodiversity, and climate change adaptation, with particular attention to how these concepts can work in unison to increase climate change resiliency on campus. Topics of particular focus included: stormwater and greywater harvesting, urban rewilding and habitat corridors, indigenous plants and their role in drought and stormwater resiliency, green passive cooling, comparison with other sustainable building codes (such as LEED), and the role of biodiversity in cultural services.

(III) Following guidelines from the Behavioral Research Ethics Board, we interviewed three UBC faculty members to explore the feasibility of different sustainability credits, identify possible gaps, and explore ongoing sustainability and climate adaptation efforts at UBC and in the broader region. We reached out to select UBC faculty working in relevant fields to our three areas of interest: biodiversity, stormwater mitigation, and climate adaptation. Interviewees were faculty in the Forestry Department; Institute for Resources, Environment, and Sustainability (IRES); and School of Architecture and Landscape Architecture (SALA). Interviews were semi-structured and followed a series of guiding questions that were relevant to our research areas research and the interviewee's field of expertise. For the remainder of the report, interviewees will be referred to as: forestry interviewee, IRES interviewee, and SALA interviewee.

(III) Incorporate social-ecological systems (SES) concepts: Through our research we incorporated social-ecological concepts from the course material in RES 510: Social-Ecological Systems to help consider contextual vulnerabilities, complexity and adaptive capacity, and issues of access and equity within the REAP policy.

(IV) REAP 4.0 Recommendations: Lastly, we developed a series of REAP 4.0 recommendations based on our literature review, interviews, and concepts from SES literature.

2.1 ETHICS AND INTERVIEWS

Interviewees were first contacted by a SEED's partner and if interested in being interviewed, were contacted by students to set up the interviews. All interviewees gave consent to be interviewed and recorded and could choose to remain anonymous or be named. The students participating in the interviews completed the TCPS 2 Tutorial, Course on Research Ethics (CORE). Interviews were conducted over zoom between November 25th and December 2, 2021, lasted 45 minutes to an hour, and with consent were recorded for maximum retention. Interviewees were asked general questions to evaluate their familiarity and expertise with REAP policy and the research areas of interest and were asked to follow up questions relevant to their responses. Interviews were kept on a personal laptop in an encrypted file that was password protected. We would have liked to interview more people but were limited by time and by the number of people who responded to our interview request; out of 10 people asked, we did not hear back from five (50%), two declined (20%), and three agreed to be interviewed (30%).

3. RESULTS & RECOMMENDATIONS

3.1 STORMWATER

In UBC's Green Building Adaptation Plan (GBAP), the goal is to maintain the natural hydrology on campus as development advances. Land cover changes from development pertain to increases in impervious surfaces, soil compaction and vegetation loss that result in the increase of the volume and peak flow of runoff, the increase of pollutant loadings and the increase of runoff temperature (EPA, 2009). Furthermore, the UBC Integrated Stormwater Management Plan (ISMP) seeks to transition from a traditional practice of collection and conveyance of stormwater to one that utilizes nature-based systems for stormwater management like low impact development (LID). Current policies address detention of stormwater on-site to release it at a rate like the pre-development condition. This strategy decreases the impacts from runoff flows off campus, more importantly, it directly addresses the root cause of impairment and not just the symptoms (EPA, 2009; UBC,2017). Some of the major consequences of uncontrolled runoff within the campus are cliff erosion, flooding, and dispersion of water pollutants to neighboring stakeholders, among others. The UBC campus has identified four flood-prone areas with possible additional ones. There is also a concern regarding the increase of the flow of water through the shallow soil strata underneath the campus that could erode cliff walls, therefore infiltration should be avoided within 300 meters of the top of the cliffs (UBC, 2017).

The REAP 3.2 preconditions and credits within this project's scope are: W P2: Outdoor Water Use Reduction, W P4: Rainwater Management, W Credit 1.1: Total Water Use Reduction, and W Credit 2.1: On-Site Rainwater Management. The outdoor water use reduction precondition requires that outdoor watering is reduced by 30% from its baseline during the peak watering month using efficient irrigation systems or through plant selection. REAP 3.2 aligns with the UBC plans and sets the W P4 precondition for all new buildings to detain stormwater and release it at rates that are, or intend to be, like the predevelopment condition using low impact development practices. The total water use reduction credit is given when indoor and outdoor water use is reduced using efficient landscaping or rainwater collection for toilet flushing and irrigation. Two optimization credits are given in

W Credit 2.1 part 2, for enhanced stormwater detention and release at a smaller rate than that in the precondition and up to two credits are given in W Credit 2.1 part 1 for stormwater retention through infiltration by adding permeable soil on site or low impact development structures. Larger permeable areas as related to the total parcel size are encouraged by giving additional credits (UBC, 2020).

An initial analysis of the stormwater preconditions and credits in the existing REAP 3.2 policy exposed several gaps that could be addressed in REAP 4.0. First, the current policy does not mention greywater use or harvesting stormwater. The current policy highlights a desire to "reduce potable water use associated with irrigation" in W P2 and reduce the total amount of potable water used in W Credit 1.1 (UBC, 2020, 37). Adding separate preconditions for stormwater harvesting and greywater use would contribute to reducing the total amount of potable water used and the amount associated with irrigation. These recommendations are put forth to increase the sustainability of the REAP buildings particularly to adapt to climate change. Meadows (2009) suggests intervening in a system by making changes at leverage points such as buffers which stabilize stocks relative to their flows. Greywater use and stormwater harvesting can be considered buffers as they buffer the effects of both heavy rainfall and drought in a social-ecological system. Moreover, despite requirements to detain stormwater using LID and green infrastructure on-site in REAP 3.2; recommendations connecting biodiversity and LID, as well as a more holistic and integrative use of LID can be further addressed in REAP 4.0. First, we found that current policies do not address on-site stormwater pollution reduction. Adding a credit on the use of sequential LID devices, also named LID treatment trains, can improve the quality and quantity of runoff from rainfall events. Second, we consider that stormwater management policies could benefit from using bounded credits with the biodiversity section by integrating ecological plantings of native plants and adding structural heterogeneity to LID techniques. We recommend the use of enhanced bio-LID, or Bio-SUDS (as in sustainable urban drainage systems) which was the term used in most of the references consulted. These could include bioretention basins coupled with tree boxes, rocks, poles, and logs, to increase habitat conditions heterogeneity for small insects and invertebrates. Trees will provide refuge for birds as well as will help with the retention of stormwater. Our recommendations are flexible to account for current limitations within the UBC campus, such as unsuitable areas for infiltration within the 300 meters range from the coast walls.

3.1.1 GREYWATER USE

Greywater use, a practice that has been around since the 90s, involves the re-use of all household wastewater apart from toilet water (Christova-Boal, 1996). As can be seen in figure 1, water is collected from within the home and is then either pumped to the sewer or sent to a tank. This water can then be distributed for irrigation or toilet flushing when needed. For garden irrigation, shallow subsurface irrigation of greywater must be used to avoid health risks or risks of human contact (Christova-Boal, 1996). Above-ground irrigation is possible with treated greywater systems which collect, store, then treat the water prior to use (Government of B.C., 2017).

Greywater can be used as a source of water for irrigation and would lead to added benefits for biodiversity and the recommended credits highlighted in the biodiversity and climate adaptation sections of this paper. For example, living walls and green roofs generally require watering to support the vegetation. To increase the resilience of the Vancouver campus residential buildings to the effects of climate change, including a potential increase of drought in the summer months, greywater reuse should be considered. Not only does greywater reuse help support vegetation in periods of drought, but it also reduces the total water consumed, such as to flush toilets, which also leads to increased water security. According to Troy Vassos, a UBC professor of engineering, greywater used for flushing toilets can lead to a 30% decrease of water consumption within the home (Corpuz-Bosshart, 2015).

Furthermore, by using greywater as opposed to potable water, plants are provided with some nutrients from the water while also contributing to the treatment of the greywater (Pradhan et al., 2018).

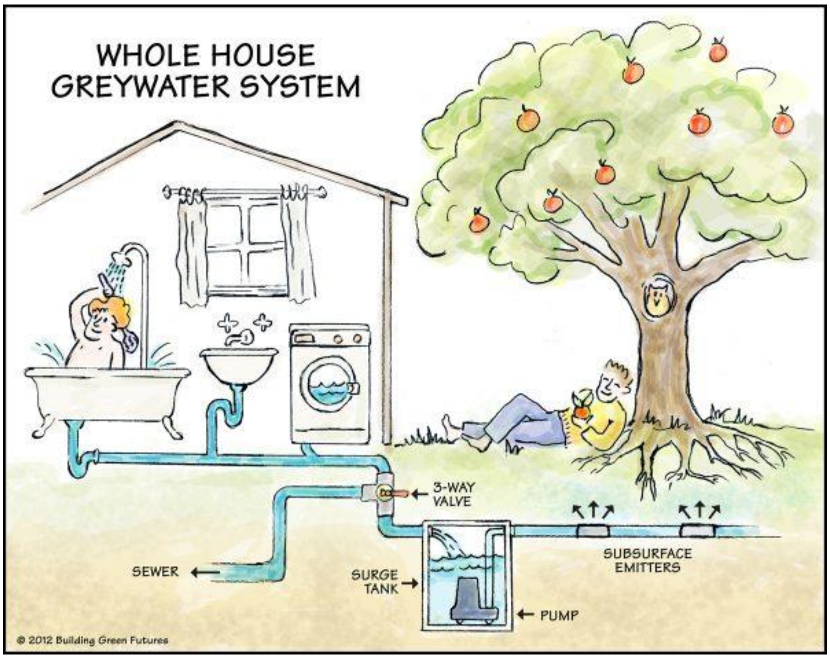

Fig 1. Greywater uses for subsurface irrigation (Friedman's Home, n.d.).

Moreover, greywater use is already established in some UBC campus buildings. UBC's LEED certified Centre for Interactive Research on Sustainability (CIRS) building on campus collects greywater, treats it, and then uses it for toilet flushing and irrigation. With this precedent, it is likely possible to collect and use greywater in residential buildings on campus and should therefore be included in REAP 4.0. In fact, as of 2015, B.C. had the most progressive water reclamation legislation in Canada and greywater use has already been implemented to a large extent (Corpuz-Bosshart, 2015). For greywater reuse to be ecologically friendly, it likely would need to be treated first prior to use in irrigation (IRES Interviewee, Forestry Interviewee). Building-specific water treatment is not uncommon and many major cities such as Tokyo and Beijing have already decentralized wastewater treatment to buildings (Corpuz-Bosshart, 2015).

3.1.2 STORMWATER HARVESTING

Currently, stormwater is given credits for detention and retention, but there is not a clear connection between detention or retention with harvesting it for practical uses. In W Credit 1.1: Total Water Use Reduction, there is a brief mention of rainwater usage for toilet flushing and irrigation (UBC, 2020). Stormwater harvesting is different from rainwater in that rainwater collection mainly stems from rooftops while stormwater also includes collection from catchment areas, creeks, and other runoff from impervious surfaces (McArdle et al., 2011). Furthermore, stormwater harvesting alleviates water runoff issues by reducing runoff volume, reducing the peak streamflow during storm events, reducing flooding, and increasing groundwater recharge (Minnesota Pollution Control Agency, 2021). These benefits are particularly advantageous as climate change is anticipated to cause more frequent, and intense, flooding events (IPCC, 2021). For this reason, it may have greater benefits for managing stormwater than merely rooftop harvesting. Stormwater can be captured and reused on site for irrigation and toilet flushing. This would have similar benefits to greywater use, in that stormwater harvesting reduces water usage and maintains vegetation, including the biodiversity and climate adaptation recommendations mentioned in this paper. Typically, stormwater harvesting systems are composed of four parts: collection, storage, treatment, and distribution (Minnesota Pollution Control Agency, 2021). This process can be seen in figure 2.

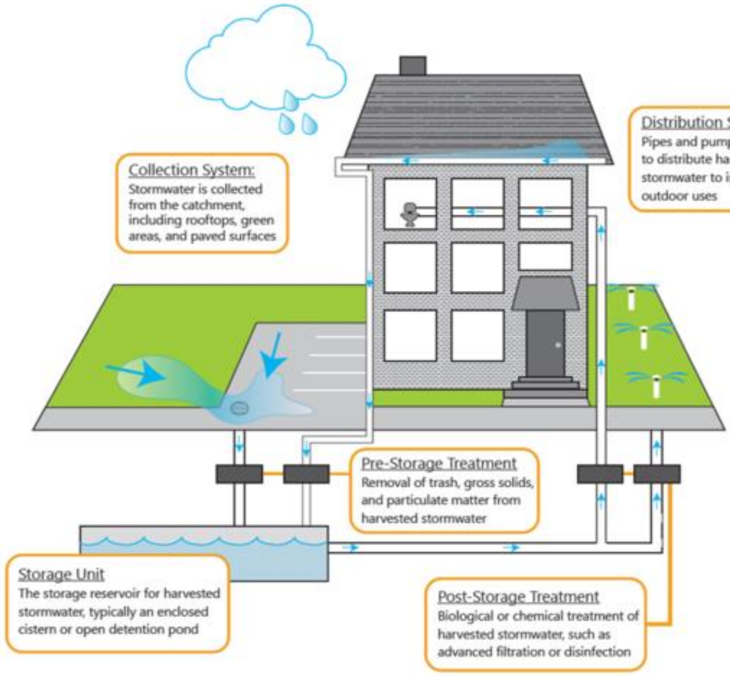

Fig 2. Stormwater harvesting system (Minnesota Pollution Control Agency, 2021).

3.1.3 LOW IMPACT DEVELOPMENT

LID is an approach to land development or redevelopment that works with nature-based systems for the management of stormwater. Stemming from the philosophy to replicate natural hydrological processes before development, the main objective of LID is to minimize the impacts from the addition of new impervious surfaces in the urban contexts. Its principle is to preserve and recreate natural landscapes features to create functional and appealing on-site drainage systems that treat stormwater as a resource rather than as a waste (EPA, 2021); this way it works to support green space amenities while providing flood protection. The term LID is mainly used in Canada and the United States, but in the United Kingdom and some countries of South America, the same concept is referred to as Sustainable Urban Drainage Systems (SUDS). The EPA now refers to these systems as Green Infrastructure (GI) or LID/GI. LID works in the intersections of three principles: reduce the quantity of runoff, increase the quality of runoff, and maximize amenity and biodiversity opportunities (Figure 3.; Woods-Ballard et al., 2007). In this way, LID/GI is a multi-disciplinary research field working in the intersection of different disciplines (Zhou, 2014).

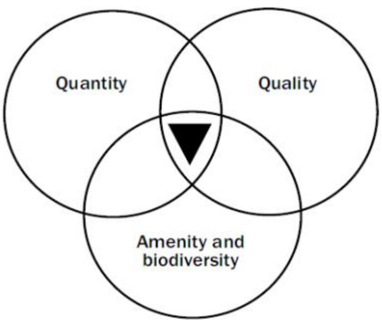

Fig 3. The SUDS triangle (Zhou, 2014)

Current credits focus only on the detention of stormwater but do not directly address issues of stormwater quality. REAP 4.0 can benefit from the use of LID treatment trains, in which individual LID structures arranged in sequence in the 3D space, work together to manage stormwater. Treatment trains have been proven to enhance water quality and water retention to increase flood resilience (Maqbool & Wood, 2022). Lashford et al (2020) demonstrated that a sequence of green roofs, porous pavement and detention basins can effectively reduce runoff and flooding. Jimenez et al (2019) found that the most suitable LIDs for high density residential areas include rain barrels, tree boxes, green roofs, and green swales. It is also indicated that green roofs feasibility for residential areas depend on 2 characteristics: presence of flat roofs, and a minimum area of 200 square meters. In fact, the lower the slope and the rainfall intensity, the higher the water retention in green roofs (Berndtsson, 2010). However, green roofs have limited potential to control runoff as a single LID device. Enhanced outcomes occur when they are included into a management train. Conversely, green roofs could also potentially increase water pollution due to factors related to the soil material used, the hard roof material, the fertilization practices and the type of chemicals used (Berndtsson, 2010). Finally, the selection of LID structures depends on the specific characteristics of the soil, vegetation, availability of space, suitability for infiltration, among others, from a site. Modeling tools such as LID-TTT (LID treatment train tool) can be beneficial for developers to choose the best set of LID structures to have significant reductions in stormwater pollutants (Lake Simcoe Region Conservation Authority, 2016).

There are very few natural streams left in Vancouver. Using green stormwater management strategies, such as rain gardens in series can help begin to restore the natural hydrologic cycle and support habitat for birds and native animals (IRES interviewee, Forestry interviewee, 2021). As evidenced by the record-breaking rainfall and severe floods in British Columbia, many of our human engineered systems for managing stormwater are not designed to be able to handle such severe weather events. In some cases, as the IRES interviewee identified, human engineered systems have made the system more brittle by interfering with the ability of natural systems to reorganize and buffer climatic fluctuation and severe weather. Considering this, we need to design systems that mimic and utilize the natural adaptive capacity of nature to better support and benefit from the buffering and reorganizing ability of natural systems (IRES interviewee, 2021). Systems that utilize treatment trains and natural rainwater infiltration systems are an important step in moving towards restoring the adaptive potential of natural systems, can help restore the natural hydrologic cycle in urban environments, and help support bird and animal habitat.

SUDS Devices and where they can be utilised, emphasising effectiveness of water reduction and potential for retrofit (Woods-Ballard et al., 2007).

SUDS Device	Source	Site	Regional	Conveyance	Water Reduction Effectiveness Rating (Out of 10)	Potential for Retrofit
Rainwater Harvesting	✖				1	Yes
Green Roofs	✖				5	Yes
Soakaways	✖				5	Yes
Infiltration Trench	✖	✖		✖	7	Yes
Infiltration Basin		✖	✖		6	No
Filter Strip	✖				3	Yes
Sand Filter		✖	✖		2	Yes
Swales	✖	✖		✖	5	Constrained
Bioretention Devices	✖	✖			9	Yes
Pervious Pavements	✖	✖			9	Yes
Detention Basins		✖	✖		10	Yes
Ponds		✖	✖		8	Constrained
Wetlands		✖	✖	✖	3	Constrained

✖ = Suitable for installation. Blank = Installation not Possible

Table 1. LID/SUDS devices and potential for retrofitting (Maqboll et al, 2021)

3.1.4 BIO-LIDS TO ENHANCE BIODIVERSITY

REAP 3.2 establishes optimization credits to dedicate 30% of total site including the building footprint, to green spaces and provides a list of green spaces alternatives that include grass, areas with plants, vegetated roofs and walls, balcony greenery and urban agriculture areas. Because land availability is one of the most important constraints for developers, REAP 4.0 should encourage the use of green space alternatives that both function as LID for stormwater management and enhance Biodiversity through ecological plantings. It has been proven that detention basins are among the LIDs with a higher efficiency in runoff reduction for the land they take (Lashford et al., 2020). Detention basins can be in the form of bioretention systems that utilize the natural properties of soil and vegetation to remove water pollutants, detain water through evaporation, provide refuge for biodiversity, and increase the aesthetics of the site (Maqbool & Wood, 2022). Similarly, tree boxes are structures that can be retrofitted in the buildings, have a small footprint, and can be used to plant native tree species that support local biodiversity and prevent the heat island effect (Rector et al., 2013). Tree boxes are concrete structures filled with soil and planted with non-invasive trees that function as a compact bioretention and biofiltration system (Figure 4). The tree roots stimulate the uptake of nutrients that would end up in water streams otherwise as well as it decreases the quantity of water through evapotranspiration. Tree boxes are designed to capture and treat small drainage areas. On Richard Street, Metro Vancouver has installed modified tree boxes, called tree trenches, to support water infiltration and tree connectivity, which will help support both tree health and stormwater management (SALA interviewee, 2021).

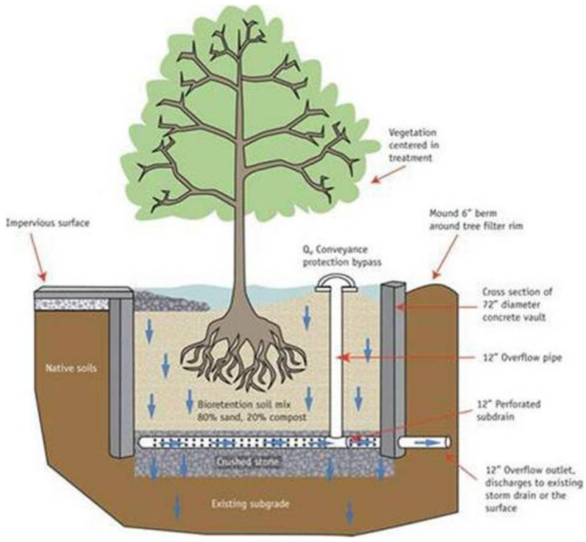

Fig 4. Structure of a tree box (Rector et al., 2013)

Furthermore, stemming from the ideas of Monberg et al (2019), designing Bio-LIDs (or Bio-SUDS the term used by the authors) that increase structural heterogeneity by adding simple materials like rocks, gravel, logs or by adding steep terrain differences can provide habitat for biodiversity in green urban areas. Structural heterogeneity can be increased even in the context of smaller size LIDs such as infiltration trenches or rain gardens, endowing a flexibility to fit these structures to any requirements of limited space uptake. However, the size of gravel and stones used can alter the composition of species able to exploit the site (Monberg et al., 2019). Adding trees to rain gardens create sun and shade microhabitats and having loose material and fine organic matter create microhabitats for insect species that exploit this resource (Fig 5.).

Infiltration Trenches

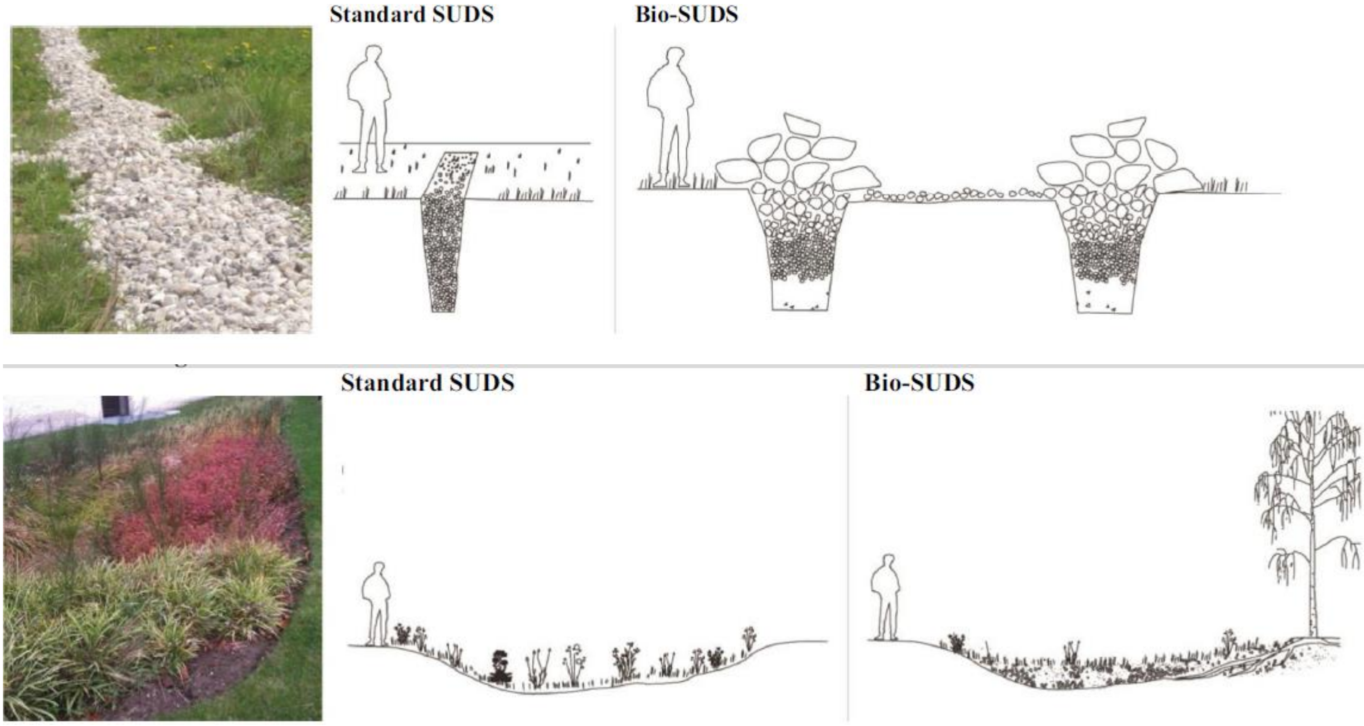

Fig 5. Redesigning Low Impact Developments (LID) to Bio-LIDs (Monberg et al., 2019)

3.2 BIODIVERSITY

3.2.1 IMPORTANCE OF BIODIVERSITY AND BIODIVERSITY IN UBC

The Government of Canada defines biodiversity as “the variety of living species and ecosystems on Earth and the ecological processes of which they are part.” Biodiversity includes the variety of insects, mammals, birds, plants, etc., within our environment that is closely related to human life. Biodiversity helps to maintain ecosystem functions and to build system resilience (Lohbeck et al., 2016). For example, it ensures the healthy functions of the food web; plants can help purify air pollution; animals are used as the symbol of nations, etc. (Shaw, 2018). Currently, there are more than 1 million species that are facing the risk of extinction (Shaw, 2018), indicating the urgency and significance of conservation actions on biodiversity. According to the government of Canada, causes of degradation in biodiversity include habitat loss, the spread of non-native species, climate change, pollution, and overconsumption. To mitigate this degradation process and restore biodiversity, actions are needed in multi-aspects.

UBC engages in biodiversity conservation as “its Campus as a Living Laboratory”, in many actions. There is a “Campus Urban Biodiversity Strategic (CUBS) Plan” guiding activities to enhance campus biodiversity. Campus Biodiversity Initiative: Research and Demonstration (CBIRD) platform provides opportunity, research results and projects details about biodiversity. Building biodiversity in residential areas is a bridge between humans and nature that emphasizes the relationships between the social and ecological. It is a way to enhance the human living environment, conserve and restore natural health, and support community sustainability and resilience. REAP “guides the development of all residential neighborhood buildings planned for the UBC Vancouver campus”, including biodiversity as a critical component in the assessment process.

In REAP 3.2, there are three preconditions to increase biodiversity in residential building projects. The first precondition is ecological planting. The requirements are made on planted species selection to ensure low maintenance, energy efficiency, suitability for the local environment and climate, and wildlife benefits (UBC, 2020). Human activities like illumination can have considerable impacts on the environment, vegetation, and wildlife and lead to energy consumption. Therefore, the second precondition is to reduce light pollution. REAP 3.2 considers that the illumination should not exceed the requirement from Illuminating Engineering Society (IES). Wildlife like birds is another component of biodiversity. In UBC, given the number of 10,000 birds' deaths due to collisions per year, the third precondition is to design the buildings in a bird-friendly way, specifically, avoiding birds' in-flight collisions on glass and windows (Ryan, 2019). UBC Bird Friendly Design Guidelines for Buildings and CSA A460:19 is available as standard. The buildings can gain credits on biodiversity once the basic requirements are met and have additional positive achievements. For example, 30% of the total site area as green space can earn 2 credits. Developing a landscape maintenance plan, increasing native planting, and pollinator gardens can earn 3 credits.

However, there are some potential aspects that are missed in the biodiversity section like mitigation on negative impacts of building construction, emphasis on structural planting of native and edible species, and adding cultural ecosystem services to the residents. These aspects can largely support biodiversity under sustainable, resilient, and climate-adaptive considerations.

3.2.2 MITIGATE BIODIVERSITY LOSS IN BUILDING CONSTRUCTION

Land-use change is one of the most direct causes that drive biodiversity loss by influencing soil productivity, wildlife habitat, directly reducing species diversity. As stated on the website of REAP: "Compared to standard residential buildings, REAP ensures lower consumption of water, energy, and resources, and higher-quality indoor environments and construction practices.", construction is also a key part in REAP. However, REAP 3.2 only mentioned construction in the section of "Material and Resources" and "Health and Wellbeing" and missed in the section of "Biodiversity" and "Water" that this report focused on. Environmental damage and influence on biodiversity generated from building construction can happen before, during, and after construction, and the impacts can be mitigated under regulations targeting each process. Possible impacts include the destruction of wildlife habitat, pollution to air and water, hydrological impacts, fragmentation on habitat (Ferguson, 2020). Many of these impacts are also related to other aspects in REAP like stormwater management. For example, construction can lead to soil compaction that influences biodiversity related to soil quality as well as the rainwater infiltration process. Also, improper construction practices can negatively impact climate change that influence community resilience.

Mitigation actions can focus on preventing unnecessary damage and planning for future recovery. A concept called "biodiversity offsets" can be considered and implemented to compensate for the loss of biodiversity resulting from a construction project (Bull, 2013). Currently, the city of Ottawa has developed a "Protocol for Wildlife Protection during Construction" (2015) to reduce the impacts of construction on wildlife. The city of Vancouver does not have a similar document yet, but the protocol for Ottawa can be a reference.

The following suggestions are made according to Canadian Wildlife Federation (CWF) (Ferguson, 2020) and City of Ottawa. Before construction, according to "Canada's Species at Risk Act and Migratory Birds Convention Act", it's required to protect certain species and their habitats. First is to determine a proper time for clearing site and construction as many species can be sensitive to certain time windows through the year like hatching period. After that, Evaluation of the construction areas should be required to inspect any wildlife living in the construction areas, properly move their nests, and avoid construction if the construction areas are key and irreplaceable habitats to endangered species. Pre-stressing is a proper practice to encourage wildlife to leave the construction sites, and different practices are recommended according to different species. During construction, it's important to avoid attracting wildlife to the construction areas and prevent the diffusion of pollutants. Actions can be taken like draining or blocking the polluted water sources and avoiding tempting organic wastes like food and garbage. After construction, when the damage and influence on local biodiversity is inevitable, biodiversity offsets are crucial to compensate for the loss of biodiversity (International Union for Conservation of Nature, 2021). Actions can be taken like replanting native species and rebuilding habitats.

Soils have a natural capacity to infiltrate and hold rainwater; however, in urban settings soils are highly compacted and have lost much of their water storage capacity (Forestry interviewee, 2021). Using methods outlined in, Soil profile rebuilding: Rehabilitating compacted urban soils in place (Day & Chen, 2021), compacted soils can be rehabilitated to regain their natural water storage capacity. The process of rehabilitating the soil happens after construction and includes adding organic matter, loosening the upper 24" of topsoil using a backhoe, replacing the topsoil layer with the original soil from the site, and planting woody plants, trees, and/or shrubs which will colonize the site with roots (approximately 10 years), increase organic content in the soil, and help restore the soil's physical structure. This technique benefits natural stormwater infiltration and supports tree growth, carbon sequestration, and urban biodiversity (Day & Chen, 2021; Forestry interviewee, 2021).

3.2.3 CONNECTING CULTURAL ECOSYSTEM SERVICES TO BIODIVERSITY

Cultural ecosystem services include recreational, aesthetic, cultural heritage, and educational values. When we try to improve biodiversity, it's possible to promote cultural ecosystem services at the same time to boost the outcome. A good option can be creating a community garden in the residential building area. Also, by doing so, it's possible to increase community resilience and climate adaptivity.

Until 2021, there are more than 110 community gardens in Vancouver now according to the City of Vancouver. According to the American Community Garden Association, a community garden is a piece of land gardened by a group of people that can grow flowers, vegetation, and fruits. It's clear that a community garden tightly links people with nature while providing multiple benefits. From the human perspective, some benefits include providing recreational activity, providing fresh and healthy food, improving residence mental and physical health, and improving residences' basic knowledge of plants, which directly improve human health and wellbeing. What's more, community gardens in residential areas are helpful for educational purposes for the young generation (Lovell et al., 2014). "The best way to ensure that the new generation understands and appreciates the value of ecosystems and biodiversity is to enable and encourage the exploration of nature on the doorstep, regardless of where they live" (Nature Trust of British Columbia, 2021). Community gardens can also provide environmental benefits like better air quality, water-saving, system resilience and increasing biodiversity. Specifically, domestic greywater and rainwater can be used for irrigation of the community garden. Another example, community gardens provide fresh food to the residents so that they increase food security. According to the definition of resilience from Folke (2006), this enhancement in food security is a performance of community resilience.

Furthermore, SES are complex and adaptive. Besides evolution, knowledge growth can change the response pattern of the system. Community gardens are a direct way for people to learn about the environment, the ecosystem, the actors in the SES besides humans, and all the benefits generated from the system. Through better understanding these concepts, people can adaptively change their ways of living with nature in a more sustainable and resilient direction.

However, community gardens can have negative impacts to both humans and the environment like excessive use of chemicals (Lovell, 2014). Therefore, it is necessary to consider the negative possibilities when designing and setting the community gardens. Providing recommendations on species selection to increase the management considerations on stormwater management and climate adaptation, regulating invasive species plantation, limiting the usage of chemicals are feasible options in governing community gardens. Regulations on equity to the residence accessibility can also be considered during community garden management.

3.2.2 SPECIES LIST CONSIDERING BUILDING DIVERSITY, RESILIENCE AND CLIMATE ADAPTATION

Increasing the percentage and amount of native and edible species in the areas of residential buildings is another option to increase community biodiversity. Besides biodiversity, efforts should be made towards resilience and climate adaptation as well. REAP 3.2 mentions planting species as a credit and emphasizes food gardens. However, a SES contains both human and other agents like wildlife (Dwiartama & Rosin, 2014); therefore, edible plants that can serve not only humans but also wildlife like birds and small mammals should be considered as well. In this way, biodiversity and community resilience are not only improved from vegetation varieties and human food security but also the restoration of wildlife habitats and resilience of interactions between all actors in a SES. Among these native and edible species, species with a broad niche are preferable, such as drought-tolerant plants. Because they need less maintenance and less water, they can better adapt to climate change and the increasing frequency of extreme heat and frequent drought. An Urban Tree List for Metro Vancouver in a Changing Climate (2016) and Grow Green guide (2017) provided by Metro Vancouver can be a reference for species selection.

Expert interviewees shared different perspectives on the value of planting native species in the context of climate change. The SALA Interviewee identified that many species, including native species, may not fare well under projected climatic scenarios in the Vancouver area (SALA Interviewee). However, as the IRES Interviewee identified, it may be important to continue planting native species even when they may not be projected to be the best suited to future environmental conditions to help support the genetic diversity and seed-base of the population and give them time to adjust ranges and adapt to new climatic conditions. Furthermore, through supplemental watering we may be able to support these important native species through periods of drought in summer. If they have access to water, many species can be quite resilient to heat (IRES interviewee). Using captured rainwater or filtered greywater to supplement the needs of native species in periods of drought could both support the survival of native species and support efficient water usage on campus.

To better support biodiversity and habitat, we need to identify target species and provide habitat that serves specific life histories and needs - foraging, nesting, resting, etc. Creating structural diversity in urban green spaces is important to support diverse 3-dimensional habitat. Structural diversity refers to plantings that occupy different spatial niches, which can be achieved through planting trees, shrubs, and herbs (SALA Interviewee). By developing strategies that are tailored to specific species of concern, we will be able to support a diverse range of species more effectively on campus.

To meet the requirements mentioned above, here is a list of plants that could be considered in the residential areas according to the guide and documents provided by Metro Vancouver.

	√ ▲ ■ ◯ ☆	√ ■ ◯ ☆	√▲◯☆	▲ ■ ◯ ☆	■ ◯ ☆	▲◯☆
Shurbs	dull Oregon grape; tall mahonia; Saskatoom; Tall mahonia; Jostabeery; evergreen huckleberry; salal;	creeping Mahonia; red flowering currant	Goji berry;	jalapeño; Bell pepper; German Chamomile; Goumi;	Hansa rose; Rose of Sharon; Hidcote lavender; strawberry tree; Charity hybrid mahonia;	blueberry
Trees				Cornelian cherry;	Akebono; Akenbono daybreak; sourwood	dward apple; Hawthorn; hybird serviceberry;
Herbs	kinnikinnick;	micro clover; Whitley's speedwell; bird's-eye speedwell; Berggarten sage; culinary sage; yarrow;	Solomon's Seal; wild strawberry	English thyme; cardoon; creeping rosemary Prostratus	Cambridge cranesbill; New Zealand bur; pink pussy toes; chamomile; white clover	Creeping Taiwan Bramble; straberry; parsnip; rosemary

Table 2. Species list that considers preferable characteristics and structural diversity: Native √, Edible ▲, Drought tolerant ■, Support birds ◯, support bees ☆

Species that are native and have all the other features like dull Oregon grape may be top choices, because native species have less negative potential to local SES while non-native species can have unexpected, complex, and surprise feedback according to the shrimp introduction study (Spencer et al., 1991). However, since native species may not adapt to the changing climate, we also list some non-native species with preferable characteristics. Planting species whether for green space or community garden can be selected based on this table. Also, the drought-tolerant species that support both birds and bees are usually species with flowers, which can provide cultural ecosystem services. Berries such as blueberries, raspberries, and some food bearing trees grow well in the Vancouver climate but aren't typically planted in public green spaces. There is a good opportunity to plant more edible species, but these efforts need to be accompanied with training and support for workers responsible for caring for these spaces (SALA Interviewee).

3.3 CLIMATE ADAPTATION

Climate adaptation is a key piece in the REAP system and a major category in which credits can be accumulated. All REAP buildings must be built to meet the requirements for weather data for both the 2020s (present weather conditions) and to accommodate the 2050s (future weather conditions) (UBC, 2020; PCIC, 2021). There are four conditions that should be met under this category: Climate Ready Thermal Comfort Modelling (CA P1), Climate Ready Energy Efficient Design (CA 1.1), Enhanced Resiliency (CA 1.2), and On-Site Backup Power (CA 1.3). Of these four preconditions, the Enhanced Resiliency precondition is the area in which the most connection to both the Rainwater and Biodiversity areas. The Enhanced Resilience precondition is worth up to 3 points, where resilience in relation to building code is defined as "the ability of a system to anticipate, absorb, accommodate, or recover from the effects of an event or stress in a timely and efficient manner. The way in which a building adapts to an event or ongoing stress depends on several factors, including its location, design, operations, and maintenance" (BC Housing, 2019). To fulfill the requirements under the Enhanced Resiliency precondition, REAP buildings must "Achieve appropriate design strategies from the Mobilizing Building Adaptation and Resilience (MBAR) papers" (UBC, 2020). However, under the Enhanced Resiliency credit, REAP states that there are no current resilience strategies being adopted while stressing the importance of having these strategies be cost-effective (UBC, 2020). MBAR's design strategy papers are in-depth comprehensive documents detailing the various site, design, cost spectrum, and operation strategies for four key areas: Air Quality, Fire at the Urban Interface, Heat Wave, and Power Outages and Emergencies. After an extensive review of the four papers, multiple alliances with both Rainwater and Biodiversity can be identified as well as their community benefits and alignments. The following table below describes these connections (BC Housing; a, b, c, d).

MBAR Strategies	**Air Quality** (BC Housing, a)	**Fires** (BC Housing, b)	**Heat Wave** (BC Housing, c)	**Power Outages & Emergencies** (BC Housing, d)
Design Strategies	Mesh screens to prevent wildlife from entering buildings	Water fixtures easily accessible to building occupants	Water fixtures easily accessible to building occupants Plant deciduous and native vegetation along south, east, and west facing walls	Water fixtures easily accessible to building occupants Rainwater or greywater harvesting as non-potable water

Table 3. MBAR design strategies (BC Housing; a, b, c, d)

There are numerous community and ecological benefits from establishing these linked strategies. First, and most important to note, by strategically planting deciduous and native vegetation by south, east, and west facing windows, buildings will benefit in three ways; in the summer months by acting as external shading when all foliage is still present, in the winter months by allowing sunlight through when all foliage has fallen, and finally, as an added form of absorption of storm and rainwater if captured. This design strategy also falls into accordance with the Climate Ready Energy Efficient Design credit where an emphasis on establishing thermal comfort without the use of mechanical systems is imperative. According to the BC Housing Energy Step Code and MBAR, planting external vegetation not only reduces local temperatures outside buildings but is also one of the most cost-friendly options for infrastructure (Strebly, 2019; BC Housing, c).

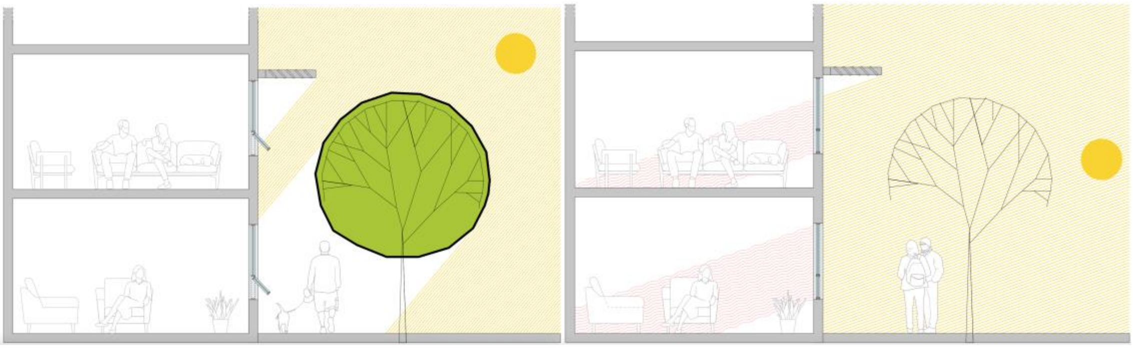

Fig 6. Summer Winter (Strebly, 2019)

The next precondition to note is Climate Ready Thermal Comfort Modelling. This precondition requires residential buildings to achieve thermal comfort through design strategies that compliment current temperatures as well as an appropriate approach for future (2050) temperatures (UBC, 2020). Summer months (May to September) are of most importance to consider as temperatures are predicted to increase dramatically by 2050 and buildings are already experiencing overheating (PCIC, 2021). The credit with the most opportunity for points is the Climate Ready Energy Efficient Design, which focuses on the implementation of infrastructure to minimize reliance on energy consuming appliances to achieve thermal comfort. Under the Climate Ready Energy Efficient Design credit, much consideration is placed on Passive Design code which includes but is not limited to external shading, reduced window to wall ratio, building shape and orientation, roof materials, and insulation materials to facilitate a cooler environment in warmer months (UBC, 2020).

Another design feature that should be considered for improved Climate Adaptation, like integrating deciduous trees as a means of passively cooling residential spaces, increasing biodiversity, and aiding with the absorption of rainwater are green roofs and living walls. Upon analysis of REAP 3.2, both green roofs and living walls are mentioned in the On-Site Rainwater Management (W 2.1) credit as a recommended strategy as well as in the biodiversity section under Site Green Space credit (BIO 2.1) where "30% of the total site area (including the building footprint) must be dedicated to green space" (UBC, 2020). The Rainwater Management credit states that installing green roofs aid with reducing runoff stormwater and water retention while the biodiversity credit suggests that green roofs provide healthy habitats for wildlife as well as increasing biodiversity (UBC, 2020). UBC's Centre for Interactive Research on Sustainability (CIRS) built in 2011 employs both a green roof as well as a living wall. The roof is cited as a rainwater management strategy and is home to native flora and fauna while the living wall is used for solar shading with a similar summer to winter method as external tree planting (UBC Sustainability Initiative, 2016).

> 'It (the green roof) is planted with native plants designed to provide habitat for local animals and insects and is an important part of the water management strategy for the building… The roof reduces stormwater runoff by absorbing and utilizing the rain falling on it as irrigation. The living wall provides solar shading for the western façade that is both passive and dynamic, as the leaves of the vines change color throughout the year and fall in winter.' (UBC Sustainability Initiative, 2016)

Structural support should be used when planting green walls to keep vines off buildings. Effort should be taken to provide green passive shading on the west side of buildings to mitigate solar heating. Trees are effective for 2-3 story buildings but aren't effective at shading taller buildings; green walls are therefore a great option for taller buildings or space limited sites. Metro Vancouver mandated that 50% of buildings in Olympic Village needed green walls. This mandate was highly effective and resulted in over 50% of buildings with green roofs, some of which have been around for 20 years. UBC has been slow to build green roofs on campus but there has been a lot of evidence supporting the effectiveness of green roofs both structurally and in supporting stormwater mitigation (SALA interviewee).

It is important to note that, neither green nor living roofs are mentioned in any of the Climate Adaptation literature for REAP 3.2. On top of the previously stated benefits that come with installing green roofs, they also provide large potential to improve enhanced thermal comfort for residents via cooling. Studies have shown that green roofs have major cooling effects for both interior and exterior environments (Dong, 2020; La Roche, 2020). Although green roofs can help support biodiversity and store some water but aren't effective in capturing severe stormwater and can be expensive and effort intensive to maintain (IRES interviewee). Although green roofs are currently being employed on the UBC campus, incorporating green roofs as a means of meeting the requirements for future REAP certified residential buildings under the Climate Adaptation preconditions as well as the Biodiversity and Rainwater Management areas could be highly beneficial on multiple scales and the overall wellbeing of their inhabitants both human and non-human.

The final credit is also worth up to 3 points is On Site Backup Power where protection of infrastructure prevents black outs from occurring. This includes protecting water supply, the security system, the heating system, and any other electrical componentry that may be affected in the event of a grid level power outage (UBC, 2020). This credit, although important, has no observable connections to Biodiversity nor Rainwater Management and will therefore not be discussed in detail.

4. CONCLUSION

Guiding Principles:

Informed by our literature review and interviews with UBC faculty, we have identified some guiding principles to consider when implementing the existing REAP 3.2 policy and designing REAP 4.0. Firstly, it is important to identify the target outcomes and work backwards to design strategies. For example, to increase biodiversity on campus it is important to identify which species we are targeting, identify their specific habitat needs, and design green spaces that support those specific needs (Forestry interviewee, 2021; SALA interviewee, 2021). While the REAP policy is a useful credit and guide, it does not provide the guidance and contextual information that may be needed to effectively identify or implement appropriate design strategies on a case-by-case basis. Increasing transparency and providing avenues through the planning and design process for consultation with experts may be important if we want these strategies to be applied effectively (Forestry interviewee, 2021). Furthermore, for strategies to be long lasting and effective, we need to provide adequate training, resources, and personnel to support and care for these projects. For instance, to support structurally diverse or edible plantings, workers will need to be trained in how to manage these systems (SALA interviewee, 2021).

We want to encourage UBC and developers to be creative in implementing the REAP policy. In urban landscapes, we often see repeating landscape forms due to lengthy permitting processes and institutionalized design standards (Forestry interviewee, 2021); however, these configurations may not be the most effective at managing stormwater, biodiversity, or climate adaptation. A small ring of green space around a building does not provide adequate habitat for most species. If we are serious about increasing biodiversity and climate change resilience on campus, many of the standard planting techniques will need to be changed. For instance, we might consider reorienting buildings within lots to allow for a larger green space, or small refugia, that can provide suitable habitat for plants and animals and support stormwater mitigation (Forestry interviewee, 2021). REAP 4.0 could develop a credit that supports habitat connectivity by allotting credit to structurally diverse green spaces that are built in proximity to other green spaces in neighboring lots and that consider the larger hydrologic and ecological networks of the neighborhood. There may be push back from residents for some of these design strategies since 3-dimensional planting and rewilded spaces typically appear messier and are not familiar forms in urban environments (SALA interviewee). This reiterates the importance of the educational credits within REAP 3.2 that help educate residents about sustainability standards and their ecological environment, which can help grow support for these projects and change the culture surrounding what is valued in urban green spaces. Synergistic efforts are needed to effectively support the implementation and longevity of the strategies outlined in this report and increase climate resiliency for both humans and non-humans on campus.

4.1 FUTURE RESEARCH

1. Eco-gentrification is a concern with green building initiatives through the increase in property values and displacement of existing, lower-income residents (Rice, 2020) Studies have found that green buildings result in low upfront costs but large premiums (Jeddi Yeganeh, 2019) and only 40% of LEED for Neighborhood Development provide affordable housing options (Szibbo, 2016). It is important that REAP policy considers ways to increase access to affordable green housing on the UBC campus to ensure equitable access to green, sustainable spaces and support climate justice initiatives on campus. As UBC works towards building climate resilience, it is imperative that policies such as REAP consider for what and for whom resilience serves (Cote & Nightingale, 2012).

2. Resilience thinking as the main paradigm to plan flood-resilient cities needs to be further implemented. Plans and policies related to LID, and stormwater management should be in a way that are flexible, collaborative, innovative and integrated, yet these characteristics could easily be lacking from local and national level planning documents. There is a discrepancy between the attitudes and behaviors of academics in the flood resilience literature who predict overarching benefits of implementing LIDs and the degree in which these expectations reflect in the social-economic realities of planning. There need to be further studies analyzing how institutional factors might constrain the effective use of LID strategies, for example the lack of legislative backing, the power awarded to private commercial interests, and the severe lack of resources in local authorities (Potter & Vilcan, 2020). Sustainability strategies need to have institutional support, without it, resilience thinking will continue to be an "aspirational" goal and not a means towards sustainability.

3. Building community and environmental resilience for the residential building should always think about inclusivity and equity. For example, study shows that community gardens sometimes lead to concerns of inequity. Exclusion of some residents and inequitable access to community garden resources are some common possibilities (Lovell et al., 2014). It is critical as we develop these sustainable systems to consider how to provide equitable access to these spaces and their benefits.

4. Biodiversity offsets are an important concept that addresses how we might compensate for the loss of local biodiversity through construction and disturbance. More guidance and credits can be made based on this concept. At the same time, the compensation can be considered not only for biodiversity but also for other social and ecological components in the SES, including water and resources management and climate adaptation.

5. Human-wildlife conflicts and interactions can impact community resilience and sustainability. In SES, the relationships between humans and other actors are complex, and there exists both positive and negative relationships. The bird-friendly building code is a good example of preventing negative interactions between humans and birds. However, studies should not only focus on birds but also other wildlife like small mammals. Studies should not only consider the impacts to wildlife but also impacts to human health, safety, and property. Wildlife that seeks for shelters and foods in residential buildings can damage the building and bring potential risks to residents (City of Ottawa, 2015), these conflicts may increase through aims to increase biodiversity around REAP buildings. These conflicts and interactions can lead to unexpected outcomes. Future research can focus on wildlife-proofing measures as building proactive practice instead of remedial measures.

Through employing strategies that link biodiversity, stormwater mitigation, and climate adaptation, REAP 4.0 will be better suited to deal with the present and future challenges of climate change and support climate resiliency on campus.

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