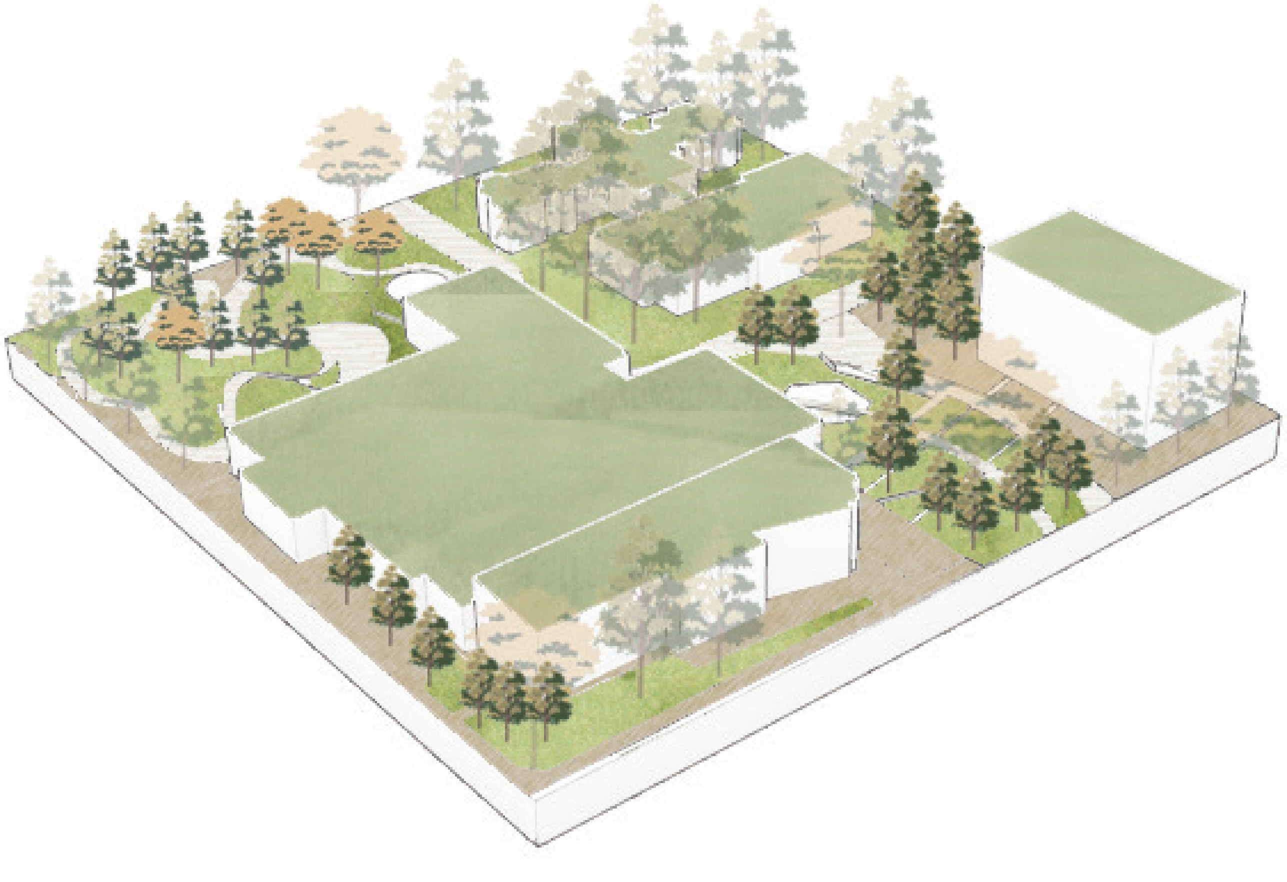
Climate resilience & well-being through neighbourhood-scale green design

A Better Practice Guide



Report prepared for the Real Estate Foundation of British Columbia and the Cascadia Urban Analytics Cooperative.

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Executive Summary

Exposure to green landscape elements benefits human health in many ways. Urban green space is also recognized as an important adaptation response to predicted changes in climate. To maximize the impacts of urban greening on our cities, planners and designers need evidence-based guidance to design and retrofit urban green spaces that maximize co-benefits for both human health and climate resilience.

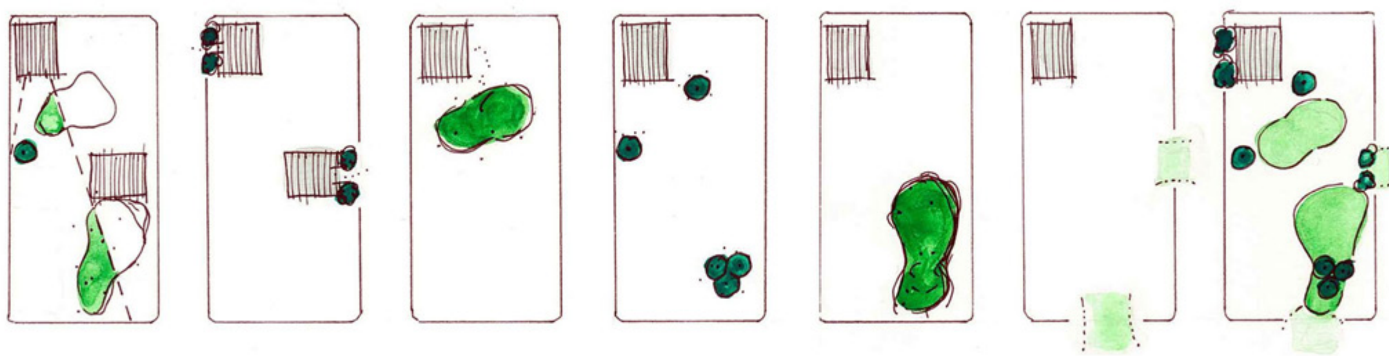
This report proposes strategies that provide strategic green space retrofits at the neighbourhood and block scale. These strategies represent a hierarchy of functional design concepts that respond to experiential qualities and physical/psychological dimensions of health, and which enhance resilience at a range of social scales from the individual to the neighbourhood.

We present a typology of eight tangible green space strategies and associated metrics to integrate climate resilience and public health co-benefits into urban green space design and planning:

1. View from within
2. Plant entrances
3. Bring nature nearby
4. Retain the mature
5. Generate diversity
6. Create refuge
7. Connect experiences
8. Optimize green infrastructure.

These strategies are introduced, and then applied to two case studies in a scenario-based exercise. The exercise provides decision-support tools through a method of assessing alternative urban greening scenarios.

We hope this work inspires you to assess and strategically plan and design the urban greenspaces in the community where you live, work, and play.



Project Testimonial

Climate change already is affecting health facilities - including hospitals and long term care homes - and services across our communities of care. In our new climate reality with more extreme heat events, longer droughts and higher wildfire risk, our health systems need an expanded network of expertise and tools to build resilience across departments and disciplines.

Our project brought together a unique constellation of academic researchers, municipal government and health facilities to develop not only practical tools, but also a compelling narrative, to help realize health and climate adaptation co-benefits at multiple scales from individual to collective, indoors to outdoors, campus to community.

The eight green design strategies are ready to be integrated, both as a set and selectively, into the complex and iterative process of planning, design and operating health facilities in our communities of care. Their co-creation involved the continuous engagement of planners and architects for their input and insights, strengthening our internal relationships and mutual understanding of how to work together to embed the strategies into our infrastructure projects. Developed with an eye to existing and emerging best practices in urban planning for health - including the Healthy Built Environment Toolkit for neighbourhood-level planning, city-wide plans to reduce urban heat island and overland flood impacts, and regional-level guidance for urban tree selection in our new climate reality - the strategies also point to the need and opportunity for expanding our networks to public health, local governments and community resilience advocates as we move towards climate resilient health facilities and health systems.

As hospitals in particular can endure as part of a community's fabric for over 100 years, and as our climate reality evolves over time, the strategies' inherent relatability and flexibility will enable fit-for-purpose application. The eight green design strategies speak to improving the everyday experiences of patients and frontline staff as they move from indoors to outdoors, from campus to the adjacent neighborhood. As such, I believe we will continue to discover opportunities for presenting the strategies to key stakeholders as part of health facility-specific "low carbon resilience" plans.

Moreover, we were encouraged by the early success of translating the project's methodology into an interactive exercise in a "lunch and learn" session. This session enabled our broader network of sustainability leaders in health care to see that having a positive impact on health, and adapting to climate change, are within their spheres of influence in their places of work, home and play.

The scale of our health and climate challenges is daunting for many people. The project has helped to demonstrate the power of inter-disciplinary problem solving, and its promise in engaging across our health system and beyond to key partners in academia and local government.

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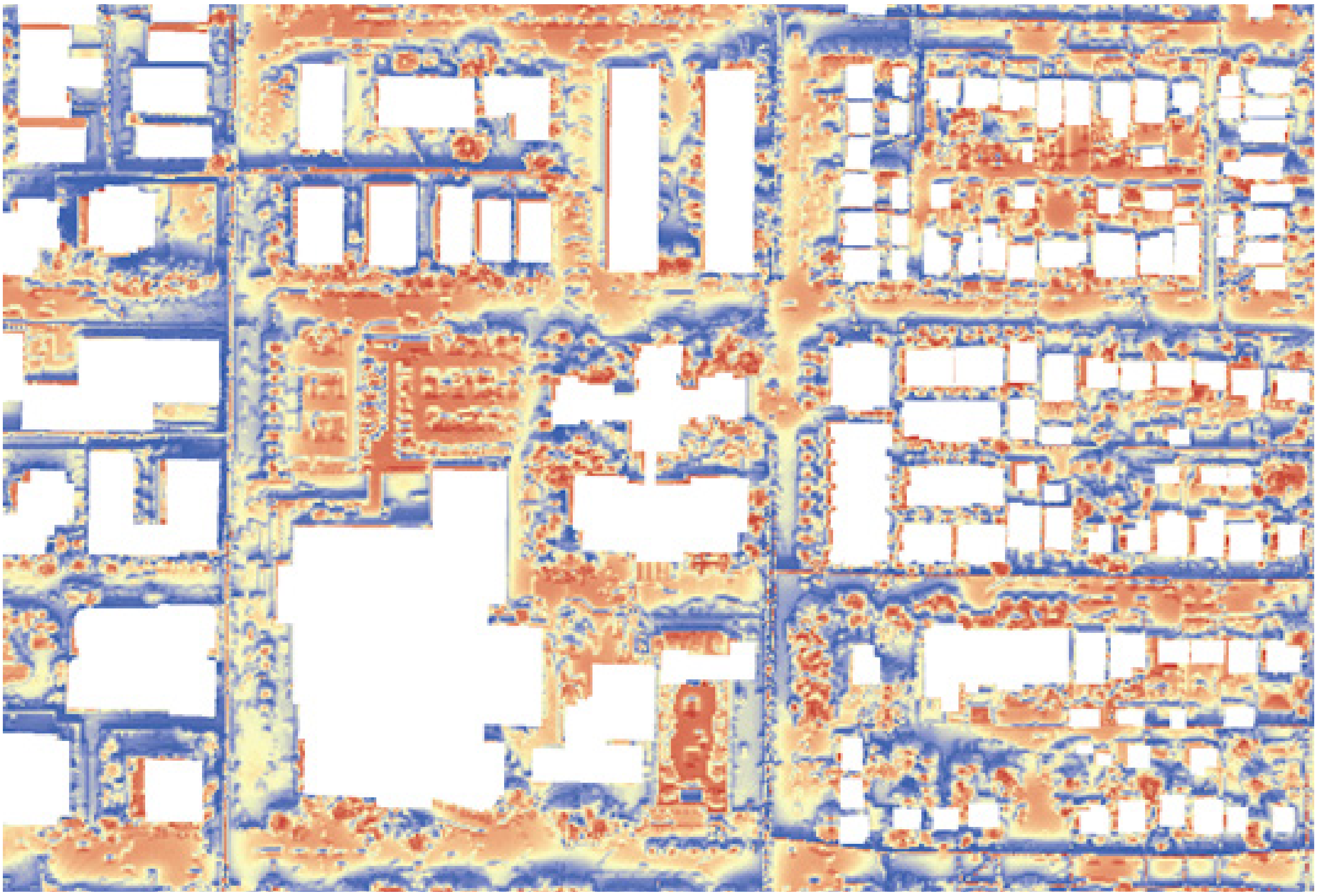
The Challenge

Our team came together through the motivations of contributing to the facilitation of healthy, climate-ready communities. Through our discussions both within the team and with stakeholders, it became apparent that despite much recent evidence on the contributions of urban greening to issues such as human well being and urban heat island impacts, little work was being done to combine the two. Also, little work was being done to translate research outcomes to practical strategies usable by local government or managers of large institutional campuses.

We formed an interdisciplinary working group of relevant expertise to shape accessible, tangible and actionable strategies to increase urban greening targeting co-benefits for human health and climate resilience. Including expertise in public health, local government, and climate research, the project team spent over a year collaboratively deliberating the strategies and metrics. This report is the result of those discussions.

Figure One: An urban heat map of a case study site. Areas in red indicate higher heat areas, while areas in blue indicate cooler areas. You can see tree shade in this image if you look closely.



Introduction

This paper proposes needed intersections between the fields of landscape architecture, urban forestry, public health, and climate change planning. Decision-support tools and clear and compelling guidance are needed to enable interdisciplinary stakeholders to apply evidence-based strategies to create, expand, or enhance urban green space in their communities. We propose design strategies and associated metrics that integrate climate resilience and public health co-benefits in urban green space design and planning.

They provide guidance to the diverse range of stakeholders necessary to champion urban forest and green space investment and design. They are adaptation measures that potentially increase environmental and human health resilience from the scale of individuals to neighbourhoods. The proposed strategies also inform future research needs in green design, particularly in local community contexts.

We present this novel typology as an opportunity to capture qualitative, tangible, and holistic aspects of green spaces as well as providing important functions, that could together appeal to a broad range of stakeholders concerned with both health and climate change adaptation. The range of stakeholders considered included: site users and general members of the public; nearby residents; onsite staff and building occupants; facility managers and maintenance workers responsible for buildings and infrastructure; and urban planners and policy-makers. The design strategies should be particularly useful to policy- and decision-makers focused on health and climate issues, as for these practitioners they may achieve two broad, relatively new and increasingly important aims at one stroke.

Figure Two: Digital rendering of a street shaded by trees. Digital tools can help visualize the impacts of urban greening for a range of audiences.

Scale

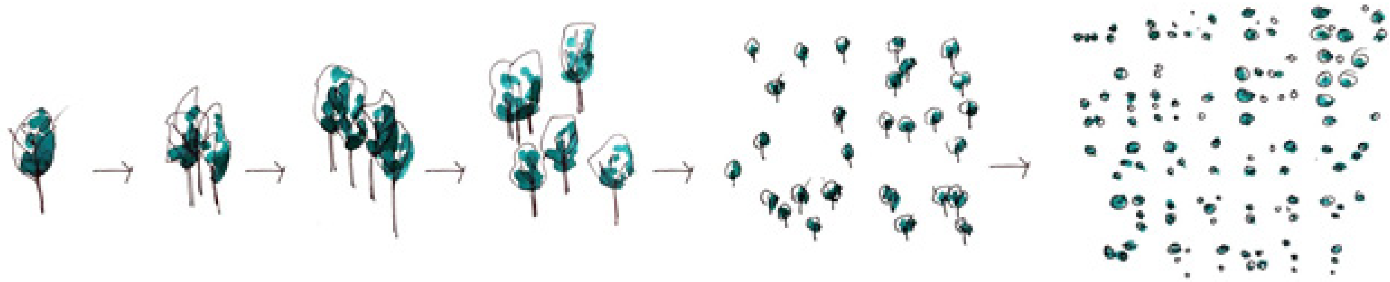


Figure Three: The scales of urban greening discussed in this report range from the individual tree to the neighbourhood.

The strategies focus on the scale of the neighbourhood block. The neighbourhood scale is an important and often missed opportunity to connect local residents with the strategies and practices of urban forestry and green space planning. At this scale, design strategies and indicators connect with tangible and realizable outcomes that directly connect to people's lives.

The scale of the neighbourhood thus represents an important social and perceptual landscape unit, but the concept and spatial extent of neighbourhood is often not clearly defined. A neighbourhood can range from a few blocks to a larger area of the city encompassing many blocks. For the purpose of this paper, we focus on what we term the 'experiential' neighbourhood: defined as a cohesive unit of about 8-12 blocks, where a 10 minute walk (800 metres) can take a person from one end of the area to the other. Residents can realistically conceptualize this scale of neighbourhood as a landscape unit, with a higher proportion of familiar social contacts and encounters, strong recognition of identity, and strong place attachment. This scale is common for campus environments such as hospitals and colleges, and has been recognized as a suitable scale for mobility and tranquility planning in residential environments, as in the superblock concept of approximately 160,000 sq metres in Barcelona (Ajuntament de Barcelona, 2014). This smaller scale of neighbourhood captures green space exposure at shorter distances, allowing for consideration of accessibility, sightlines, aesthetics, vegetation layering, and quality of green space design.

"Local communities are where humans use landscapes to make a living and contribute to their quality of life, and where they adapt landscapes to create value from landscape services or prevent loss from external pressures such as climate change"
(Opdam et al. 2013, p. 1441).

Urban Greening Strategies

The typology introduces eight types of urban greening strategies along with associated benefits and suggested metrics. For example, when conceiving an urban greening plan for your neighbourhood, you might want to consider how many buildings have green entrances, or how many mature trees are retained, or perhaps how much greenspace is connected.

The following section describes each strategy, its rationale, benefits, evidence-base, metrics for assessment, a proposed threshold or goal for performance, and opportunites to improve the approach.

Design Strategy	Anticipated Climate and Health Co-benefits
1. View from Within	• Visual biophilic experiences • Wildlife habitat and biodiversity • Stormwater mitigation
2. Plant Entrances	• Social gathering space • Orientation/navigation • Shade provisioning/cooling • Building energy savings (depending on aspect)
3. Bring Nature Nearby	• Social gathering space • Shade provisioning/cooling • Wildlife habitat provision and biodiversity • Stormwater mitigation
4. Retain the Mature	• Air filtration • Shade provisioning/cooling • Building energy savings • Carbon storage and sequestration
5. Generate Diversity	• Visual biophilic experiences • Wildlife habitat provision & biodiversity • Climate Resilience
6. Create Refuge	• Social gathering space for cohesion and enhanced social capital • Shade provisioning/cooling • Air filtration • Wildlife habitat and biodiversity
7. Connect Experiences	• Visual biophilic experiences • Shade provisioning/cooling • Wildlife habitat provision and biodiversity (e.g. ecological corridors) • Stormwater mitigation
8. Optimize Infrastructure	• UHI mitigation • Carbon storage and sequestration • Stormwater mitigation • Wildlife habitat provision and biodiversity

Table One: Urban Greening Strategies and a short list of their associated co-benefits.

NOTE: The text in this and the next sectionis based substantially on our recent publication, but modified slightly for this document: Barron, S., Nitoslawski, S., Wolf, K. L., Woo, A., Desautels, E., & Sheppard, S. R. (2019). Greening Blocks: A Conceptual Typology of Practical Design Interventions to Integrate Health and Climate Resilience Co-Benefits. International Journal of Environmental Research and Public Health, 16(21), 4241.

View from Within

Have you considered the view from within when implementing urban greening?

The **View from Within** strategy refers people's views from within buildings Whether or not they are able to see natural objects, such as trees, plants, water, or distant landforms, from the inside of a building can have an impact on health and productivity. Recent studies suggest that humans experience positive emotional responses from having views of nature. Viewing landscapes dominated by plants, flowers, trees, and other greenery can produce a significant restorative effect, even within a few minutes. Studies have shown that even 40 seconds of green roof views, for example, can improve cognitive performance and boost attention span (Lee et al. 2015). Visual access to green space and highly visible landscape features such as tall trees should therefore be included as a design strategy for health, particularly where outdoor exposure to green is not always possible. This may be the case for hospital patients confined to the indoors, schoolchildren and students who spend most of their time in the classroom, and office workers.

Considering visibility as a design strategy also promotes the creation and management of green space in less traditional spaces and at varying levels. Green roofs, vertical gardens, and green walls can play an important role in improving access to visible green space, particularly in higher-density neighbourhoods, where development occurs upwards rather than outwards, and in cities with increasingly high demand for physical space. Additionally, such biophilic building designs offer direct benefits for building efficiencies, by offering temperature moderation and energy savings. View from Within can also incorporate distant views to natural spaces such as mountains and water bodies, and ensure the sightlines are preserved or enhanced. Seasonality should be considered when implementing the View from Within strategy. Green views should be available year-round, and seasonal colour could enhance the view at certain times of the year.

Select references:
Kaplan, R. The Nature of the View from Home: Psychological Benefits. Environ. Behav. 2001, 33, 507–542.

Lee, K.E.; Williams, K.J.H.; Sargent, L.D.; Williams, N.S.G.; Johnson, K.A. 40-Second Green Roof Views Sustain Attention: The Role of Micro-Breaks in Attention Restoration. J. Environ. Psychol. 2015, 42, 182–189

View from Within diagram

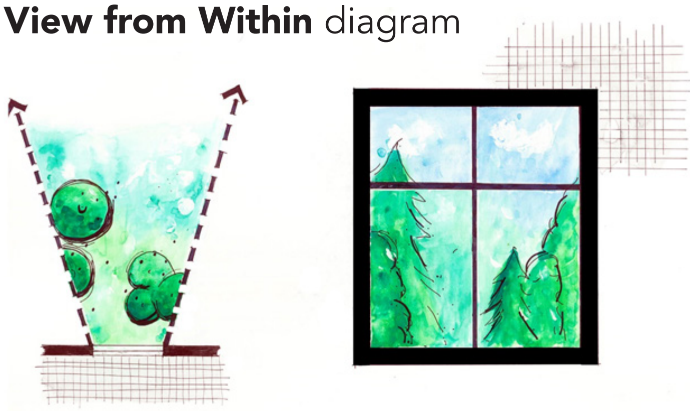


Figure Four: When discussing urban greening solutions, consider the view from within a building.

Metric:

In order maintain a uniform way to assess the amount of green which can be seen from the windows of a building, grey/green analysis of the view of the windows can be used.

The floors from which the views should be assessed is based on the height of the building.

Google Earth Pro allows a viewer to enter a modelled building. If 3D models of your neighbourhood's buildings are available on Google Earth, you can virtually enter the building and take photos at the appropriate floors.

Once the view is calibrated, only the height and the direction for the view is changed to capture views from all facades and various heights. The angle of the view is not changed.

Screengrabs from buildings and facades can then be opened in software such as Adobe Photoshop. Using the magic wand tool, all green pixels can be selected and the number recorded. The same can be done for all of the blue pixels that form the sky.

The green grey percentage of the view that we used for our calculations was the number of green pixels divided by the total sumber of pixels minus the number of sky pixels times one hundred.

The result is the % of green in the picture without the sky. Removing the sky removes some of the noise in the calculations.

Goal:

The team consensus was to aim for at least 30% green visible in all the views captured for the study.

Taking it a step further:

Since each view is different and distant views of landscape elements such as waterbodies, mountains can greatly enhance a view, having a qualitative measure of the view might be beneficial. This could be in the form of a description of the elements and the quality of the elements seen from views of windows. Example of descriptions could be snow capped mountains in the distance, view of the ocean or lake, views of healthy lush forests. It would also be ideal to bring in elements of biodiversity in the natural landscape elements seen from the windows.

Figure 5: Google Earth screengrab (Left) and a photograph of the view looking in the same direction from floor 3 (right)

STRATEGY
2

Plant Entrances

Green entrances create opportunity for all building visitors to experience some nature in their day. Do your entrances have a welcoming green frame?

The **Plant Entrances** strategy refers to the presence of green, which may include trees or other vegetation, at building or site entrances or exterior doorways. Having green elements in close proximity to site or building entrances serves multiple purposes. Depending on the location of the building entrance and vegetation, trees can provide shade, cooling effects, and subsequent energy savings. Building entrances are high-traffic areas as well as social spaces, drawing occupants to the outdoors as well as welcoming occupants inside. The presence of vegetation at building or site entrances ensures that all users are exposed to the associated green benefits as they enter and exit.

The presence of green space at entrances is not a commonly used metric in green space or urban forest evaluation. When applied appropriately, however, smaller-scale strategies such as these are generally more feasible compared to larger scale strategies in terms of financial, legal, and other resource constraints. Concerns about safety and security should be considered when designing plantings near entrances to ensure that the spaces created feel welcoming to all members of society.

Select references:
Kuo, F.E. Social Aspects of Urban Forestry: The Role of Arboriculture in a Healthy Social Ecology. J. Arboric. 2003, 29, 148–155.

Ryan, C. Eco-Acupuncture: Designing and Facilitating Pathways for Urban Transformation, for a Resilient Low-Carbon Future. J. Clean. Prod. 2013, 50, 189–199.

Unt, A.; Bell, S. The Impact of Small-Scale Design Interventions on the Behaviour Patterns of the Users of an Urban Wasteland. Urban For. Urban Green. 2014, 13, 121–135.

Plant Entrances diagram

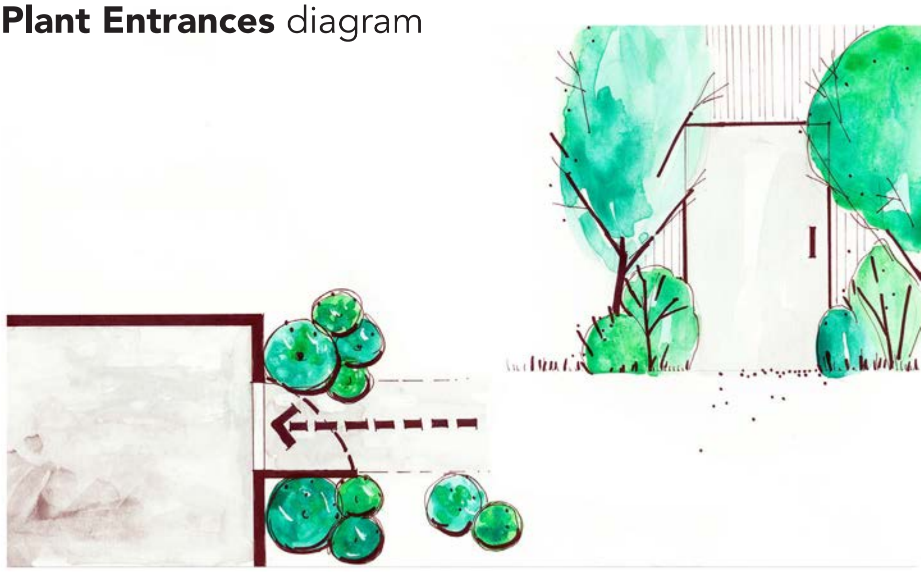


Figure Six: Plants near entrances make them part of a person's daily experience. They can have an impact on the entry and exit transitions when entering or leaving a hospital.

Metric:

The percentage of green to grey around the entrances in plan view can be used to assess how green the entrance is. The area assessed around the entrance depends on the physical size and amount of people using the entrance. For our case studies, the area of assessment for a well-used, larger entrance was a rectangular shape the size of 20m by 40m. The area of assessment for smaller, less used entrances was 10m by 20m. Orthophotos were used to identify the green elements (such as trees, shrubs, and pervious surfaces) and grey elements (impervious surfaces such as paved surfaces). Using the Adobe Photoshop magic wand function, all of the green elements were selected and number of pixels recorded.

The final calculation would be:
green/grey % = # of green pixels/ # total pixels in entrance assessment box *100

Goal:

The aim is to get the lowest ranking entrances (those with a lower green/grey ratio) to include more green. Through team consensus, a target of fifty percent green within the measured entrance area was chosen for our case studies.

Taking a step further:

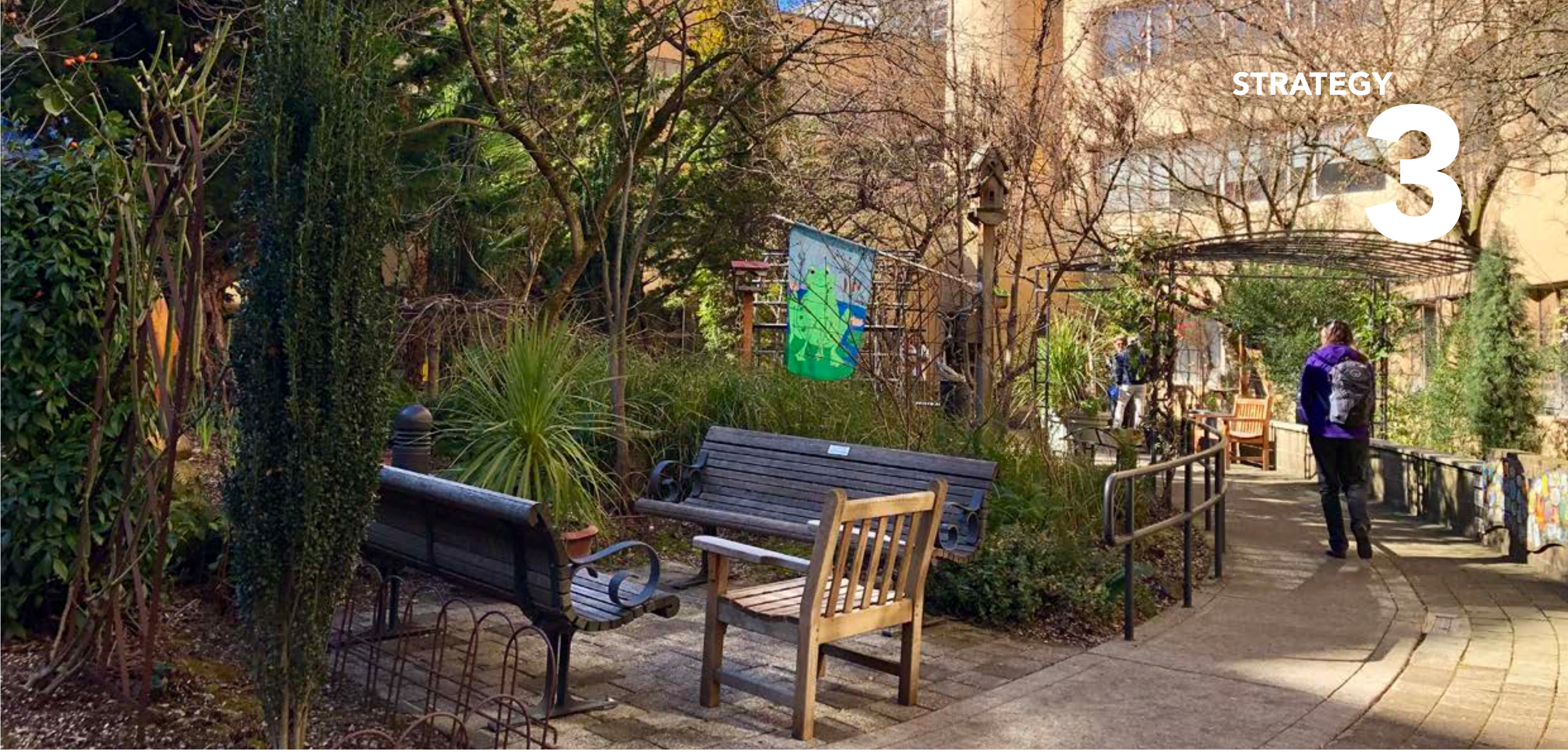
A simple measurement does not capture the experiential quality of the entrance. To do this, one could include a description of the experience of walking through an entrance to add a qualitative component for assessment. Write 3 evocative lines about the entrance experience to include in your assessment for an empirical and experiential assessment.

Inspiration

Figures Seven & Eight: Inspiration images of planted entrances.

Vo Trong Nghia Architects Naman Retreat Entrance

https://www.realestate-tokyo.com/rent/B0001462/atago-green-hills-forest-tower/#lg=1&slide=1



Bring Nature Nearby

Not everyone can travel to a park or garden. Are there spaces near your building that can provide an opportunity to relax surrounded by plants?

The **Bring Nature Nearby** strategy refers to the presence of green within close proximity of all neighbourhood dwellers, regardless of demographic, cultural or socio-economic conditions. Example may include "pocket parks" and linear greenways. Exposure to green space, along with its associated benefits, has been shown to correlate with demographic and socio-economic conditions, often noted as disparities in availability of parks and trees in underserved communities. It is vital for urban forest managers to ensure that all community members have equal access opportunity to the physical and psychological benefits provided by urban trees.

Vertical distance to green space is an interesting issue to consider. Do urban dwellers who live twelve storeys up experience fewer green benefits compared to those living on the ground floor, due to the time it takes to reach a certain amount of green? Do building users respond similarly to nature placed on multiple floors in biophilic buildings compared to ground plane landscapes? Larger cities are becoming increasingly dense, and residential high rises are prevalent in areas with higher demand for physical space and rising housing costs. It is therefore essential to develop and test green space indicators that account for changes in city demographics and urban planning trends.

Select references:
Cordoza, M.; Ulrich, R.S.; Manulik, B.J.; Gardiner, S.K.; Fitzpatrick, P.S.; Hazen, T.M.; Mirka, A.; Perkins, R.S. Impact of Nurses Taking Daily Work Breaks in a Hospital Garden on Burnout. Am. J. Crit. Care 2018, 27, 508–512.

Dadvand, P.; de Nazelle, A.; Triguero-Mas, M.; Schembari, A.; Cirach, M.; Amoly, E.; Francesco, F.; Basagaña, X.; Ostro, B.; Nieuwenhuijsen, M. Surrounding greenness and exposure to air pollution during pregnancy: An analysis of personal monitoring data. Environ. Health Perspect. 2012, 120, 1286–1290.

Donovan, G.H.; Michael, Y.L.; Butry, D.T.; Sullivan, A.D.; Chase, J.M. Urban trees and the risk of poor birth outcomes. Health Place 2011, 17, 390–393.

Bring Nature Nearby diagram

Figure Nine: Ensuring occupiable greenspace is near entrances to high use buildings makes nature exposure opportunities accessible for more people.

Metric:

The metric used for the nearby greenspace strategy is the amount of time it takes to walk to the closest green space. Nearby green space is defined as a spot of green at least 10mx10m in size with public access that has space to sit. Examples may include pocket parks, linear greenways, and roof gardens. In a hospital setting, this greenspace could be used by patients, their families, and the healthcare staff that use the health campus.

Travel time includes waiting for an elevator, elevator travel time to the floor with green space, and walking from the elevator to the green space. To maintain simplicity in our calculations, all elevators are assumed to be at the centre of buildings.

Assumed speeds:

- Waiting time for elevators: 45 s
- Time to walk from Elevator to exit: 10 s
- Travel time for elevators: 2 s/floor
- Walking speed: 0.5 m/s

Goal:

The goal is to minimize travel time through addition of green space within building boundaries (green roofs) or very close to the entrance with minimal road crossings. A suggested travel time of 2 minutes or less was used in our case studies, which provided a reasonable goal at the neighbourhood scale.

Taking a step further:

Include other perceived barriers for travel to nearby space. Examples include the perceived high barrier of crossing a road, a steep sloping path, or stairs to get to the green space. These all serve as high barriers for people with mobility challenges.

Inspiration

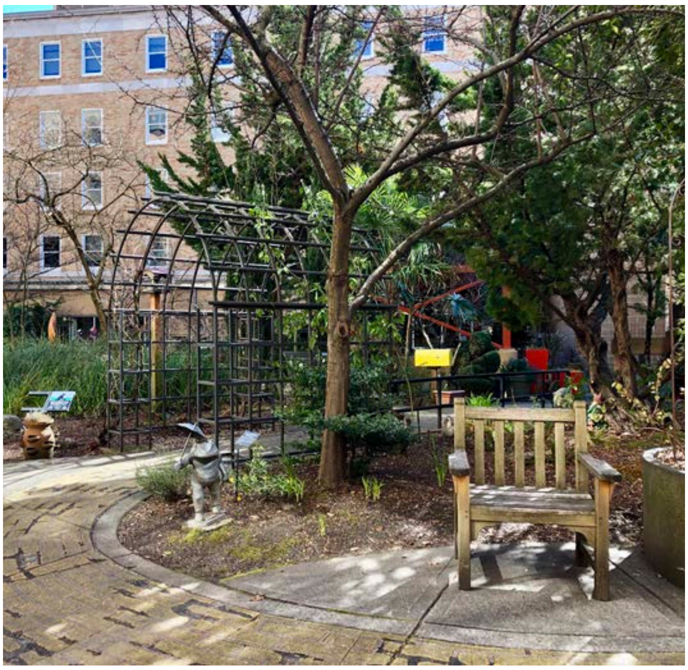


Figure Ten: The children's garden at Legacy Emanual Hospital in Portland, Oregon provides a space to get fresh air and spend time in nature within 2 minutes of most rooms.Photo courtesy of Sophie Nitoslawski.

Retain the Mature

Large trees provide aesthetic and emotional benefit to people. When designing a landscape, have you retained mature trees?

The **Retain the Mature** strategy refers to paying attention to the size and structure of trees comprising a green space. Given the benefits provided by big trees, these spaces could be designed around a "heritage" or "legacy" tree. Age diversity is important, particularly along city streets, to ensure that many trees are not removed simultaneously at the end of their lifespan, along with their associated benefits. In the context of climate mitigation, one large tree sequesters and stores more carbon than a smaller one. In terms of adaptation, a big, mature tree is also generally understood to provide more benefits compared to one of a smaller stature, such as more shade, greater energy savings, and air quality improvements.

Select references:
Wolf, K.L. Trees and business district preferences: A case study of Athens, Georgia, US. J. Arboric. 2004, 30, 336–346.

Jim, C.Y. Urban Heritage Trees: Natural-Cultural Significance Informing Management and Conservation. In Greening Cities: Forms and Functions; Tan, P.Y., Jim, C.Y., Eds.; Advances in 21st Century Human Settlements; Springer: Singapore, 2017; pp. 279–305.

Schroeder, H.; Flannigan, J.; Coles, R. Residents' Attitudes toward Street Trees in the UK and US Communities. Arboric. Urban For. 2006, 32, 236.

Retain the Mature diagram

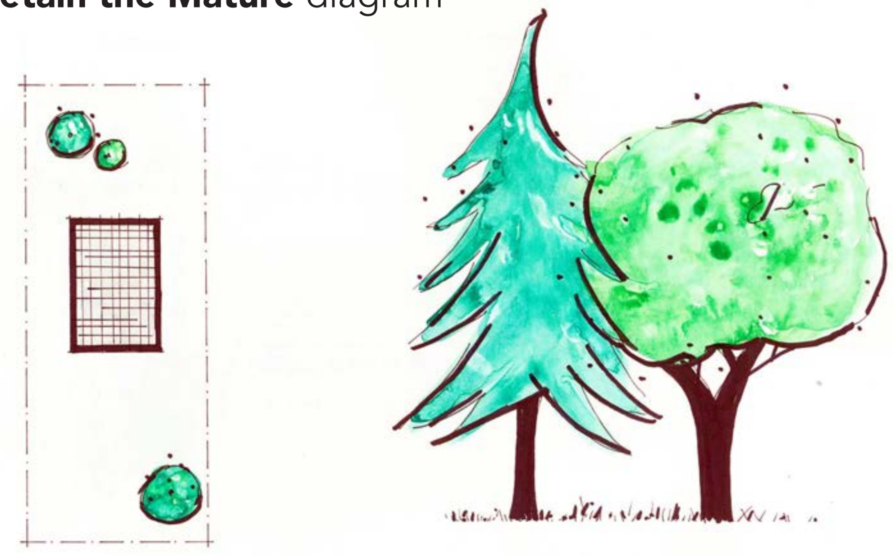


Figure Eleven: Large trees provide more ecosystem services and often more aesthetic benefits than smaller trees.

Metric:

The metric used for the retain mature trees strategy is the percent of mature trees compared to the total number of trees.

Our project defined mature trees as any tree with the height greater than 15m. We acknowledge that not all mature trees have a height greater than 15m. However, we identified trees using LiDAR, where height and the canopy cover of the trees are the key data points. This criteria allows for easy replicability and data acquisition.

Goal:

The goal is to maximise the number of mature trees in the area. We set a minimum target of 30% of the total number of trees being greater than 15m in height. By planting more trees in the present and not cutting the trees down, the sites will have more mature trees in the future.

Taking a step further:

To support the LiDAR data, one could also include a field inventory which would more accurately determine all the mature trees on the site.

Inspiration

Figure Twelve: Large trees can shade entire streets, but need to be carefully managed with new climate realities.

Generate Diversity

A more diverse urban forest will be more resilient to pests and diseases. Have you measured diversity in your greenspaces?

The **Generate Diversity** strategy refers to ensuring that a diversity in species of trees and plants is provided within a green space. Species diversity is crucial to urban forest functioning, resilience to pests and disease, and to the enhancement of green benefits. Research has shown that greater species richness is an important mitigator of environmental stressors, including tree pests and disease. The presence of native tree species has been shown to promote the establishment of other native organisms, such as insects and birds, increasing the ecological integrity of urban forest ecosystems. Many are widely used in assessing the quality of an urban green space, namely naturalness and ecological integrity (e.g., representation of native species), the number and representation of species present, Other qualitative indicators such as perceived safety and green design aesthetics relate to the diversity of planted landscapes.

Select references:
Shanahan, D.F.; Lin, B.B.; Bush, R.; Gaston, K.J.; Dean, J.H.; Barber, E.; Fuller, R.A. Toward improved public health outcomes from urban nature. Am. J. Public Health 2015, 105, 470–477.

Rudd, H.; Vala, J.; Schaefer, V. Importance of backyard habitat in a comprehensive biodiversity conservation strategy: A connectivity analysis of urban green spaces. Restor. Ecol. 2002, 10, 368–375.

Generate Diversity diagram

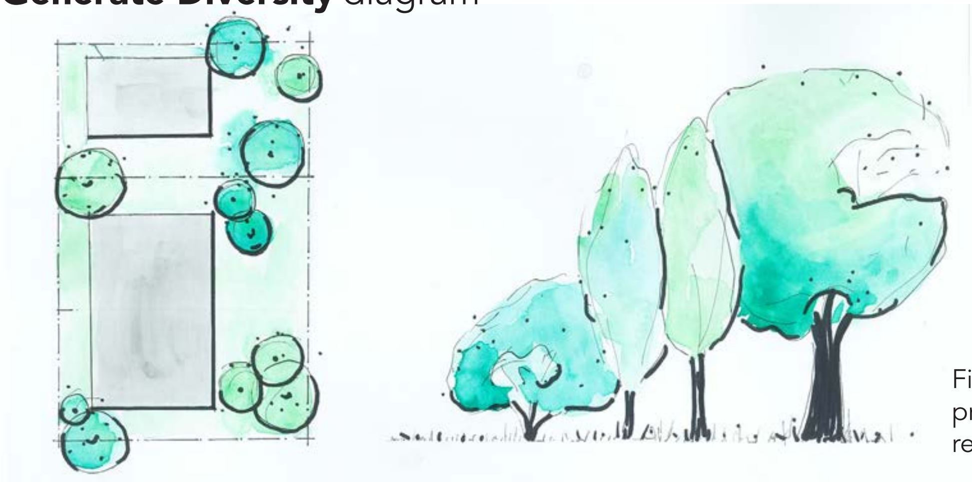


Figure Thirteen: Diverse trees provide aesthetic benefits and some resilience to climate impacts.

Metric:

The metric for diversity is the relative distribution of tree species, the heights of the trees and their collective ecosystem services.

In order to assess this, a tree inventory needs to be done fo the site. The data can then be input into free software, such as i-Tree eco v.6 which will provide calculations and graphs for your area. Data collected during inventory includes the height, canopy, species and dbh of the tree.

Goal:

The site should have trees that are diverse with varied species. General guidelines for diversity suggest that no more than 30 percent of trees come from one family, no more than 20 percent from one genus, and no more than 10 percent from one species. Some cities have chosen even higher targets for diversity. Select for trees that are resilient to climate change and low on allergenicity.

Taking a step further:

Consider age, size, and genetic diversity, and consider each species ability to survive in future climate realities. In Metro Vancouver, a species database of climate resilient species can be found here:
http://www.metrovancouver.org/services/regional-planning/PlanningPublications/UFA_UrbanTreesList.pdf

Inspiration

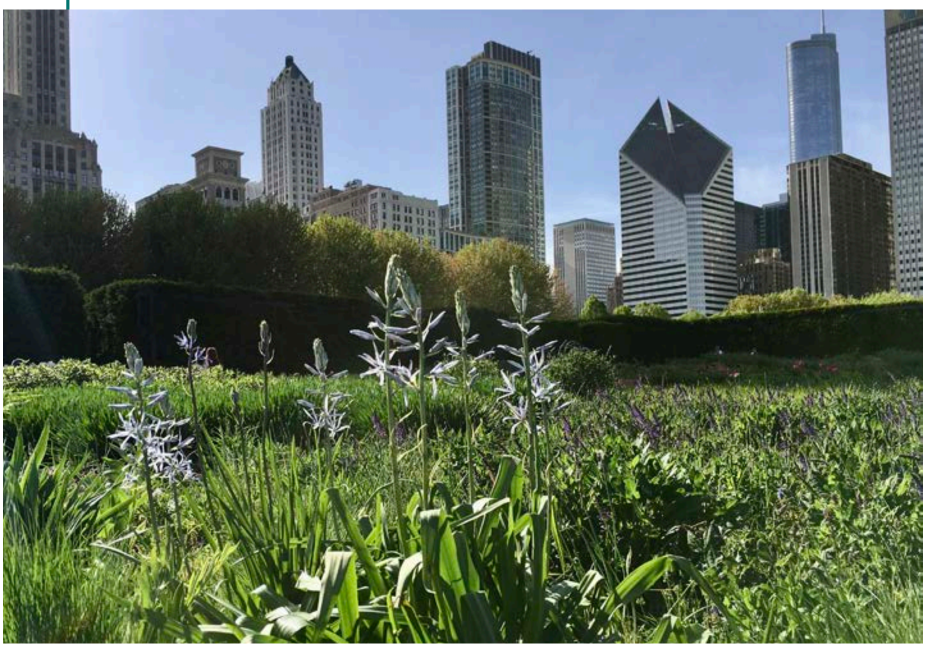


Figure Fourteen: Urban biodiversity is an important climate resilience strategy with high aesthetic benefits.

Create Refuge

Can green shade accommodate the population of an area during an extreme heat event?

The **Create Refuge** strategy refers to the presence of "cool spots" where neighbourhood dwellers can find protective temperatures during extreme heat events. An example would be a stand of trees with sufficient diversity in size and structure for shade and cooling through evapotranspiration. Urban areas are increasingly subjected to the effects of climate change. Extreme heat events may compound the impact of the more general urban heat island effect, prompting municipal researchers and practitioners to recognize the importance of urban green in mitigating higher temperatures. Creating refuge allows urban dwellers to access public and green spaces in warmer temperatures, and can mitigate associated health risks.

We include another novel metric, namely the number of people that a cool refuge can accommodate at once. The focus on people provides a tangible and accessible metric, and can be calculated as a percentage based on the total population that might have access to a particular refuge or series of green spaces. The tree selection for the trees that make the refuge spots are important too. Urban Forest planners might what to opt for trees with dense canopy and low allerginicity factors. Adding a deciduous, dense canopy refuge spot of the south side of the buildings could insulate the building from direct sunlight in the summer and contribute to energy savings.

Select references:

Wu, Z.; Kong, F.; Wang, Y.; Sun, R.; Chen, L. The impact of greenspace on thermal comfort in a residential quarter of Beijing, China. Int. J. Environ. Res. Public Health 2016, 13, 1217.

Lee, H.; Mayer, H.; Chen, L. Contribution of trees and grasslands to the mitigation of human heat stress in a residential district of Freiburg, Southwest Germany. Landsc. Urban Plan. 2016, 148, 37–50.

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Morakinyo, T.E.; Kong, L.; Lau, K.K.L.; Yuan, C.; Ng, E. A study on the impact of shadow-cast and tree species on in-canyon and neighborhood's thermal comfort. Build. Environ. 2017, 115, 1–17.

Create Refuge diagram

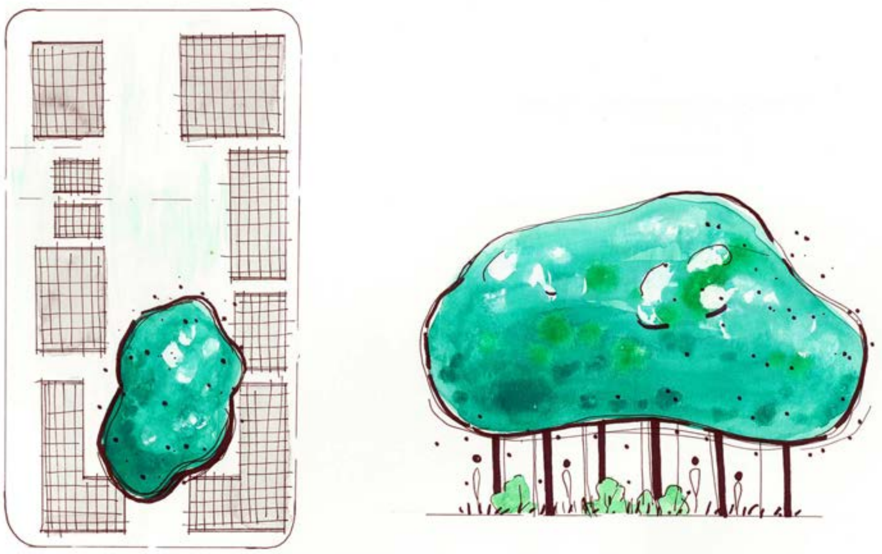


Figure Fifteen: Green refuge provides welcome relief from some urban heat events.

Metric:

The metric used for refuge space is the number of people that can be accommodated under a tree. We assumed that a person would use 1.5m X 1.5m of space under a tree. This would allow for sitting, standing, accommodate wheelchairs, and even hospital beds where necessary. This space should provide enough personal space from other individuals under the tree.

We define refuge space as anything with a canopy greater than 30 m in diameter that has no underlying bush, allowing people to occupy the shade. LiDAR data can be used to identify such refuge areas. Using LiDAR data, you can isolate individual trees and categorise them based on their height. Areas under trees with heights greater than 10 m with no tree/ bush under the canopy create refuge spots.

If the refuge area comprises street trees in a residential neighbourhood, with the refuge space in front off a private home, we called them second grade refuge cover. In second grade refuge cover, people would be standing on private lawns or within private gardens for shade.

The number of people under refuge space= Canopy cover of the space (m2)/ (1.5mx1.5m). During disaster events such as an extreme heat wave accompanied by loss of electricity to a building, more people can be accommodated by reducing the personal space used by one person.

Goal:

To maximise the number of people that can be accommodate by increasing number of quality refuge spots.

Taking it a step further:

You may also want to ground truth all the refuge spots identified by LiDAR by doing a field inventory. You may also designate these spots as refuge spots and to make sure the area under it remains unoccupied by cars/ shrubs etc. It maybe helpful to have certain spots with paved surfaces under the refuge to allow for people with all abilities to access them.

The tree selection for the trees that make the refuge spots are important too. Trees with dense canopy and low allerginicity factors would make better refuge spots.

Strategic placement of refuge spots close to entrances make them easy to access, and also contribute to the green experience of the entrance. Adding a deciduous, dense canopy refuge spot along the south side of buildings could insulate the building from direct sunlight in the summer and contribute to energy savings.

Connect Experiences

Can people walk continuously along a shaded pathway?

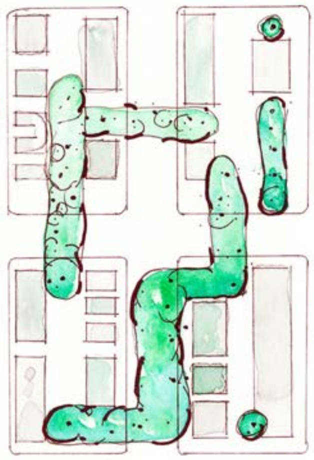
The **Connect Experiences** strategy refers to continuous greenery along a street or other transit path, meant to encourage active transit and other forms of physical activity. Routes with sufficient trees, vegetation, and open space can serve as an escape from urban stresses like noise, traffic, and pollution. Green corridors or roads can provide ready access to and between public open spaces, including green spaces. Evidence has also shown that the presence of greenery encourages physical activity; in fact, the presence of street-level green space may positively correlate with increased time spent walking. People in dense urban environments are also more incentivized to walk to their destination when street trees are planted closer together. Urban streets have the potential to provide a space for both transportation walking, to reach a destination, as well as recreational walking for pleasure, stress relief, and other health reasons.
We therefore propose green space connectivity as a design strategy, particularly given its close relationship with accessibility to green benefits. Trees in particular arrangements (e.g. tree-lined paths) can create more accessible and aesthetically pleasing areas for pedestrian traffic; these 'shadeways' also create cooler walking and cycling routes during extreme heat events. While accessibility measures should ensure that all community members have equal opportunity for green exposure, connectivity design strategies are meant to layer this with additional physical activity and active transit through green strategies.

Select References:
Groome, D. Green Corridors': A Discussion of a Planning Concept. Landsc. Urban Plan. 1990, 19, 383–387.

Lu, Y.; Sarkar, C.; Xiao, Y. The Effect of Street-Level Greenery on Walking Behavior: Evidence from Hong Kong. Soc. Sci. Med. 2018, 208, 41–49.

Langenheim, N.; White, M.; Tapper, N.; Livesley, S.J.; Ramirez-Lovering, D. Right tree, right place, right time: A visual-functional design approach to select and place trees for optimal shade benefit to commuting pedestrians. Sustain. Cities Soc. 2020, 52, 101816.

Connect Experiences diagram



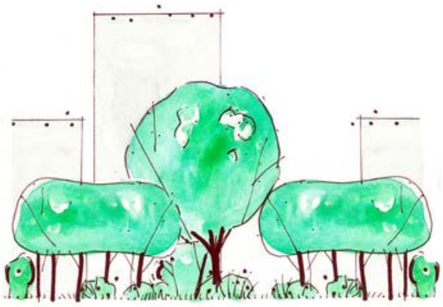


Figure Sixteen: Connected greenspaces and green shaded routes can make non-motorized transportation more attractive.

Metric:

The metric for connect experiences is the % of green corridors in your neighbourhood. A green corridor is defined as a movement corridor with canopy over head and eye level greenery along at least one side of it.

Goal:

The goal is to have all of the major non-motorized movement corridors green. Having some shaded way along all the movement corridors within the site and along all the roads and paths leading up to the site from public transit stops and major roadways.

Taking it a step further:

Consider connectivity of soil, canopy, and the quality of experience in connected landscapes.

Inspiration

Figure Seventeen: A green path with eye-level green and overhead green promotes active restorative experiences.

Optimize Green Infrastructure

Have you left room for enough green, permeable spaces to manage stormwater and cool the air?

The **Optimize Green Infrastructure** strategy refers to ensuring that you have sufficient canopy cover and other green infrastructure services to support a healthy and resilient living environment. In response to human health, having enough vegetation to filter the air can help mitigate air pollution, noise pollution, and visual stressors that can detract from wellbeing. From a climate change perspective, urban heat islands can be mitigated with sufficient tree canopy and vegetation to provide shade and evapotranspiration. Recent research suggests aiming for 40 percent canopy cover: a study focused on urban heat islands suggests that areas with canopy cover greater than 40 percent had significantly reduced daytime air temperatures, in another study, subjects reported increased stress reduction up to about 40 percent canopy cover.

While the recent studies cited above suggest a quantity to aim for, more research and context-specific exploration would be needed to create a specific target for a given neighbourhood. Generally, those living in environments with more high-quality green space tend to report better physical and mental health outcomes.

It should be noted, though, that while green space provides important benefits, increasing green space within neighbourhoods has been associated with negative impacts, such as gentrification. Nonetheless, recent modeling studies emphasize the importance of measuring daily accessed greenery, rather than relying on top-down remote sensing (such as canopy cover), as the two measurements may not be equivalent in conveying a city resident's experience. While overall tree canopy and green space should be considered when planning or designing a community's blocks, our typology suggests the need for future research that aligns landscape vegetation assessments with block-level experience.

Select references:
Ziter, C.D.; Pedersen, E.J.; Kucharik, C.J.; Turner, M.G. Scale-Dependent Interactions between Tree Canopy Cover and Impervious Surfaces Reduce Daytime Urban Heat during Summer. Proc. Natl. Acad. Sci. USA 2019, 116, 7575–7580.

Jiang, B.; Li, D.; Larsen, L.; Sullivan, W.C. A Dose-Response Curve Describing the Relationship between Urban Tree Cover Density and Self-Reported Stress Recovery. Environ. Behav. 2016, 48, 607–629.

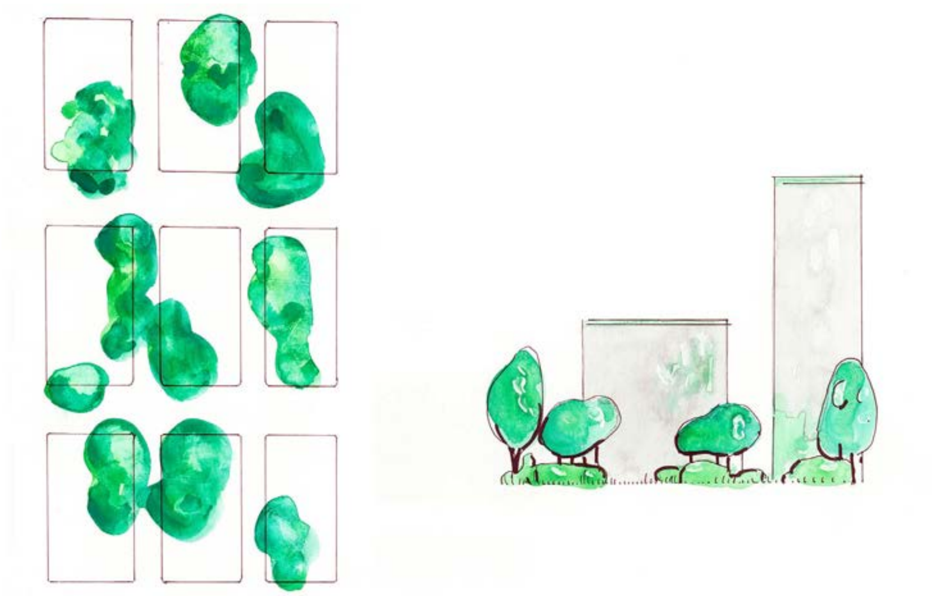


Figure Eighteen: Adding up all of the other interventions, it is important to assess if you have enough green to help your neighbourhood face climate realities.

Metric:
Canopy cover is commonly used to evaluate a city's urban forest and is often used as a proxy for urban forest quantity. Tree canopy cover is comprised of all trees making up the urban forest, as highlighted in Figure X. Many cities set tree canopy targets to guide urban forest decision-making and management. Higher rates of tree canopy cover in a neighbourhood is associated with higher potential for climate adaptation. For example, greater canopy cover would have greater heat island mitigation through increased shade and evapotranspiration. It is also associated with human health benefits, such as better pregnancy outcomes in neighbourhoods with higher tree canopy cover.

Goal:
Canopy cover goals should align with the bioregion of your neighbourhood. In some cases, a high canopy cover might not reflect the regional realities of the environment. For example, a high canopy would not make sense in a desert landscape.

For our case studies, we chose a goal of 40% canopy cover.

Taking it a step further:
Leaf area index and quality of treed landscape should also be considered.

Inspiration

Figure Ninteen: Large trees and permeable surfaces help absorb stormwater, putting less pressure on engineered systems.

How to Create & Assess Urban Greening Scenarios

Scenarios are a useful way to test and assess the urban greening strategies. By gathering data of existing conditions and looking for opportunities to green, a team can explore a neighbourhood to determine where additional trees and plants can be planted.

The following pages describes the resources needed and the steps to develop and assess the scenarios, to ensure that the new plants and trees are in optimal locations for health and climate resilience co-benefits.

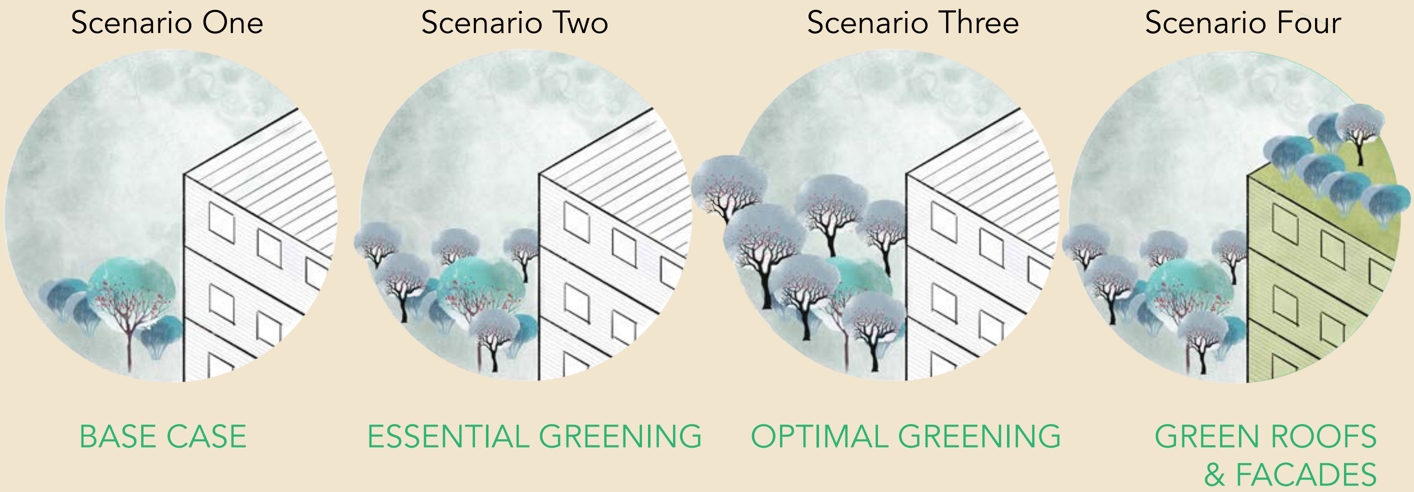


Figure Twenty: Diagram of urban greening scenarios.

Resources needed:

- ArcGIS software
- Tree measuring equipment: DBH tapes, clinometer, laser rangefinder, eslon tape, tree identification guides.
- Recent aerial photography of your site
- LiDAR data of site *if available*
- Tree inventory of site *if available*
- Information about any planned development for the site

Step One: Do an inventory of existing trees.

An inventory of existing trees allows you to understand your assets. The inventory will tell you important information, such as the existing species diversity planted in your area and some of the ecosystem services provided by the urban forest. At a minimum, the inventory should note the species, height, trunk diameter, and canopy width of the trees.

For a smaller area of multiple city blocks, a complete inventory can be completed in approximately a week by two qualified urban foresters. At an hourly rate of $40, this equates to about $3,200 or less.

Ideally, these new trees can be spatially located in GIS software. This will enable additional measurements, and allow you to visualize the existing urban forest.

Once complete, this existing inventory can be used as a 'baseline' scenario.

Figure Twenty One: A tree inventory is an important step in building data to create informed scenarios, or verifying existing data sets.

Step Two: Look for locations suitable for 'essential greening'.

Once the inventory is complete, it is time to start planning your future forest. Many cities have up to date aerial photography that can be used, along with site visits, to find locations within your site that are ideal for 'essential greening.' These are marginal spaces that are currently under-utilized, perhaps covered in under-used concrete. The images below show under-utilized spaces suitable for 'easy greening.'

Once these are determined, use software such as GIS to locate new trees in these areas. Be mindful of the future space requirements of new trees. An additional column in a spreadsheet is an easy way to note the new trees, and keep track of the new trees you are planting.

Once complete, the list and map of new trees and their locations can form the base for a second future scenario.

Figure Twenty Two: Diagram showing greeing options (in red) for sample site.

Step Three:

Now that you have identified the essential greening, it is time to make more difficult decisions about the urban forest. There are a number of choices and trade-offs to be made at this point. An additional two or three scenarios allow you to explore these options. The paragraphs below suggest some ideas for how this could be done. Keep in mind that all sites/blocks/neighbourhoods are unique, so some of these might not apply and others might be more relevant.

Canopy Cover
A major decision for future scenarios is how 'green' you want the future area to be. One way to determine scenarios is to use tree canopy cover as a proxy for greenness. You could choose to divide the scenarios based on the percent canopy cover that they represent. For example, the existing area might have 20 percent canopy cover, and the next scenarios could have 30, 40 and 50 percent cover respectively.

Climate Resilience
Another consideration is climate resilience. How can trees and green space help communities face uncertain futures? Options such as shading buildings for cooling in summer, or buffering from winter winds, can help reduce building energy demand. Trees and green spaces can infiltrate storm water during storms, reducing loads on existing systems. They also play a small role in filtering air pollutants. To help make choices for climate resilience, inform yourself of projected climate impacts in your area.

Carbon Mitigation
Trees and green spaces can play a role in sequestering and storing carbon in the urban environment. Large, mature trees play an exponentially higher role in sequestering and storing carbon than young trees. Carbon is also stored in healthy soil, so when planning a scenario for carbon mitigation, be sure to maximize soil area.

Human Well-being
Urban green spaces play a role in the daily health and well-being of urban residents. Desiging a scenario to maximize human well-being might include ensuring equal access to quality greenspace, connecting green spaces to encourage physical activity, or locating greenspaces in a way to maximize social interaction. It should also consider aesthetic qualities or features of a place.

Wildness & Biodiversity
The degree of wildness is another parameter for making design decisions. As a general rule of thumb, some species require larger patches of green for habitat, so you could look to create large areas of greenspace (>5 ha) within or near to your site. When thinking about wildness, look for opportunities to create patches of trees and also ways to increase connectivity of trees and soil to allow for mobility by multiple species.

Step Four:

Bringing it all together

With the above considerations in mind – be creative in designing urban greening scenarios that maximize one or more of the above considerations. Options could include creating one large central green area, or dispersing greenspaces throughout your site. Be sure that the two final scenarios are distinct enough to clearly communicate different decision paths. Remember – these are scenarios, not final plans!

Once you have made decisions for the next few scenarios, be sure to locate the new trees on a map and list them in a spread sheet. These two inputs will be required for the next step: Measuring Urban Greening Scenarios. The next pages outline a process used to create and measure urban greening scenarios for two case study neighbourhoods.

Figure Twenty Three: Four unique scenarios for a small park: A - Essential greening, B - Climate mitigation, C - Wildness & Biodiversity, D - Human Well-being.

Scenario case studies

To test the eight design strategies, two health campuses are picked and four scenarios were created to show the various permutation combinations of green infrastructure that can be leveraged to showcase the way the strategies play out on ground. The two sites have different specializations, are highly visited and have new construction planned which serve as a good opportunity to intervene and present green infrastructure solutions to accompany the new installations.

The spatial scope for the scenarios are what we define as experiential neighbourhood, which is the health campus and one city block surrounding it.

All the greening in the scenarios are done within the health campus boundary assuming that the health campus will have the authority to plant trees within land owned by them as compared to city land or private property.

Figure Twenty Four: Urban greening scenario for a case study neighbourhood.

Scenario case studies

Scenario 1: Base case

Scenario 1 is a representation of the current situation of the health campus neighbourhood. In order to create the scenario, we gathered data on existing trees, pervious surfaces, solar radiation, landuse, and building uses.

Data Category	Specific data
Land use of experiential neighborhood	Commercial, residential, health campus
Green cover	Pervious ground and crown cover
Health campus details	Building footprints, 3D models, Entrances, building use, popular movement corridors
Tree ownership	Private, public or owned by health campus
Solar Radiation	Used the solar radiation tool on Arc GIS

Table Two: Resources required to create and assess urban greening scenarios.

The data was used to describe the baseline conditions and the context within which the other scenerios may be built. Scenario 1 was assessed against the eight design strategies using the methodology described earlier.

Following assessment, the results of each design strategy was overlaid to identify three zones of essential greening for each campus.

Scenario 2: Essential greening

This scenario builds on Scenario 1 and aims to green the three zones identified in Scenario 1 through the addition of strategically planted trees. The trees are placed to increase its impact on multiple strategies. For example: a tree was placed in an essential zone such that it contributed to visible green, entrance green, connected green and overall green. This scenario embodies the essential greening option mentioned in the previous section.

Scenario 3: Optimal greening

This scenario builds on Scenario 2 to increase assessment scores for the green design strategies through on-ground greening. It includes more radical solutions such as road closures, larger trees, and increased pervious ground surfaces.

Scenario 4: Green roof and green facade

This scenario also builds on Scenario 2 to increase assessment scores for the green design strategies through addition of green roofs and green facades. Green facades are located to increase plant survival, and green roofs proposed are less intense (i.e. no trees) to increase feasibility.

Case study 1: Acute Care Centre

The Acute Care Facility is a major hospital for patients in critical condition. Primary users of this facility are healthcare staff, patients, and their families. The site has multiple buildings with varying uses ranging from offices, critical care buildings, specialized care buildings, and teaching buildings. The buildings also range in size from low-rise (4 floors high), mid-rise (9 floors high) and high-rise (14 floors high). There are commercial blocks with public trees on the north side and residential blocks with private trees on the south side. The neighborhood as a whole has about 16% canopy cover.

The acute care center is for patients who are mostly confined to the bed, so the results of the 'View from within' strategy were given priority. The three essential greening zones were chosen to increase visual green for patients and staff.

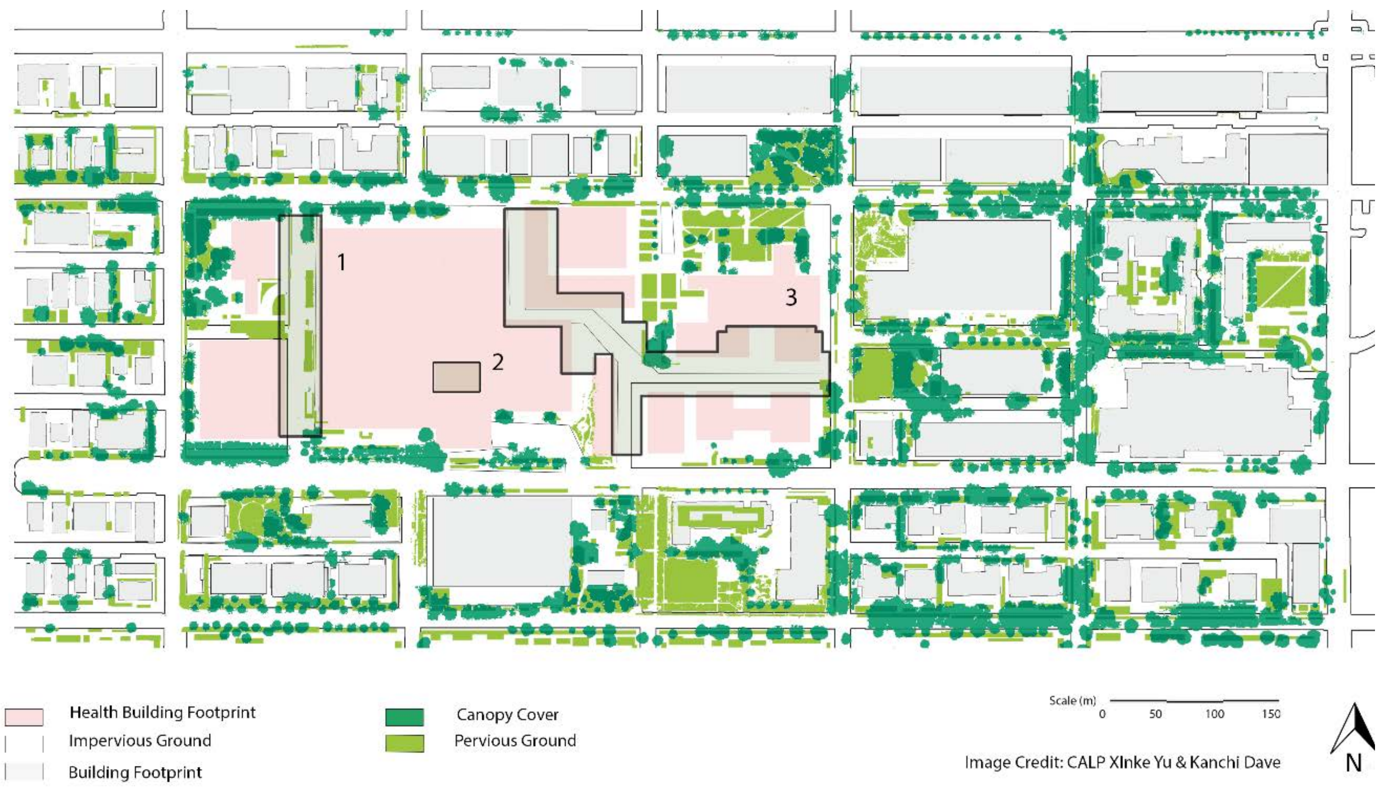


Figure Twenty Five: Three essential greening zones identified through Scenario 1 for the Acute Care Facility. All three zones are within the campus boundary. Zone 1 and 3 are high movement corridors with little to no green infrastructure, zone 2 roof space on either side of 2 clinical towers that is bare and thus reducing the visible green from the windows of the two towers that face each other.

STRATEGY ONE: View from Within

Since there are multiple buildings in the Acute Care Facility which would result in many redundant calculations, three high-use buildings were selected for measurement. These buildings are a proxy for the whole campus as they are evenly distributed across the campus, and have varied building heights and various uses. They include a new mid-sized office building, a critical in-patient high-rise building with two towers, and an older low-rise teaching building. The clinical towers holds the highest daytime population, including patients in critical care. Views from this building were prioritized.

For more detailed calculations, views that do not overlap and have the lowers green percentarge were chosen for each building. The calculations for these selected views were used as a proxy for other views.

The resulting views chosen for the scenarios are: Clinical tower 2 west high floor, Clinical tower 1 east high floor, Office building east top floor, Clinical tower 1 lower west and east.

		% of green viewed from N,S,W,E of building			
Buildings	Average % of green seen from all directions for floor	North %	South %	West %	East %
Higher (9th floor)					
Mid size office bldg	37	51	73	22	4
Clinical tower 1	14	9.8	42	4	2
Clinical tower 2	18	13	45	3	12
Average % green for each direction		25	53	10	6

Lower (3rd floor)					
Mid size office bldg	47	6	100	90	5
Clinical tower 1	25	3	96	3	0
Clinical tower 2	12	9	36	1	1
Small teaching bldg	36	65	0	19	62
Average % green for each direction		21	58	25	17

Table Three: On average for the base case, the views with the lowest green percentage for the higher floors are to the east and west of the buildings. The lowest green views for the lower floors were the east and north facing with the clinical towers having the least green of the views.

STRATEGY ONE: View from Within

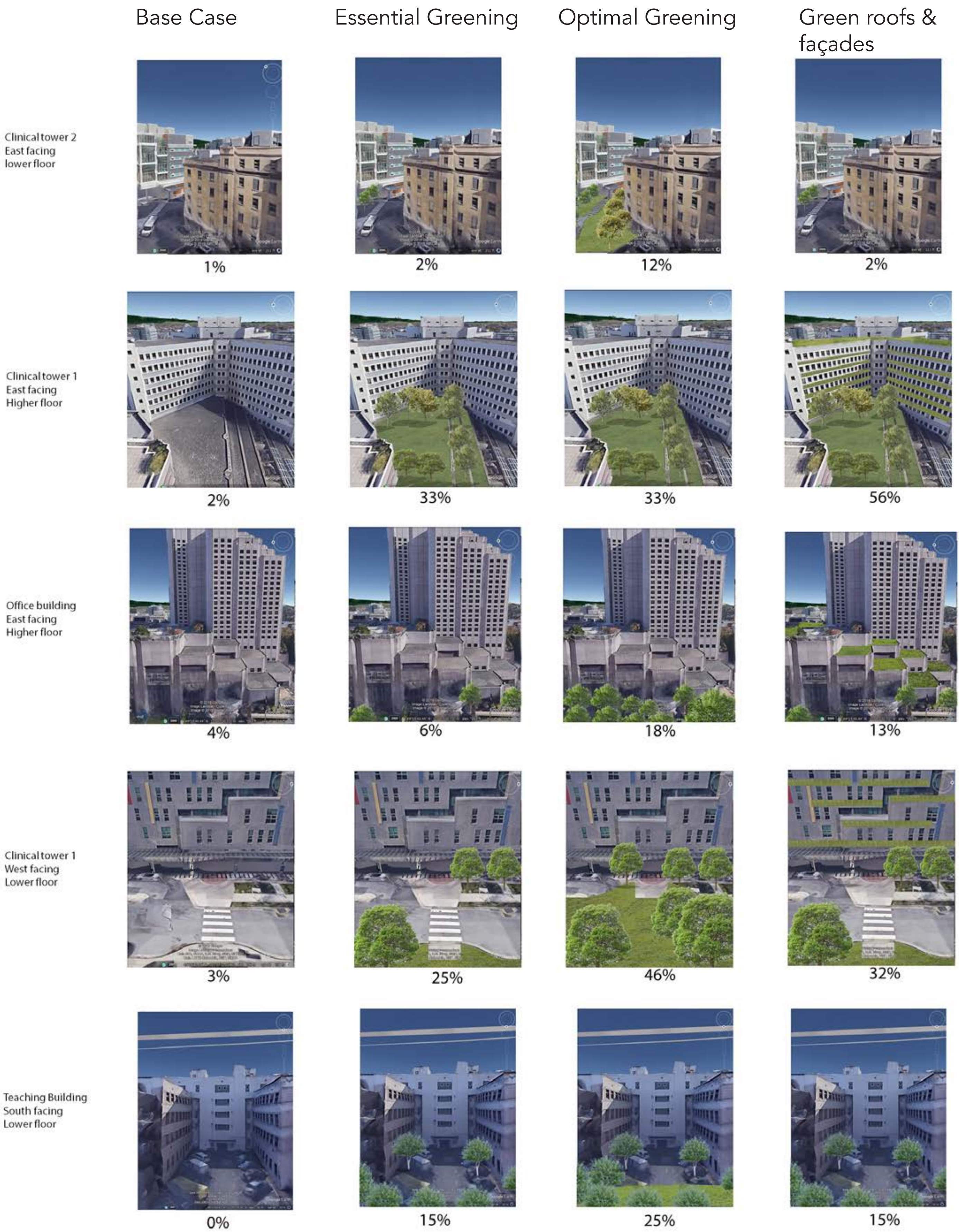


Figure Twenty Six: The views chosen for scenario building are: Clinical tower 2 west high floor, Clinical tower 1 east high floor, Office building east top floor, Clinical tower 1 lower west and east. In most cases the optimal greening increases visual greening more than green roofs.

STRATEGY TWO: Plant entrances

The facility has 17 total entrances. The area of assessment for entrance number 5, 6, 8 are larger since they are physically larger in size and serve as main entrances which will have the largest and most varied population using them. The smaller entrances are generally used by healthcare staff.

Entrance	Building type	Users
1	Residential care building	Health care staff, inpatients and families
2, 3	Office building and clinics	Health care staff, outpatients and families
4, **5, 6**, 7, **8,**9	Critical Care tower and building	Health care staff, in patients and families
10, 11	Residential care	Health care staff, inpatients and families
15	Specialized care building	Health care staff, outpatients and families
12, 13, 14, 16, 17	Teaching and office buildings	Health care staff

Table Four: Entrance details and users of the buildings.

In the basecase scenario, entrances numbered 3, 4, 7, 9, 14, 16 score the lowest in green percentage. Entrance 3 and 4 are high priority since they are along high movement corridors. Entrance 7 is underground and hence left out of the scenario development. Entrances 9 and 14 are back entrances are used by fewer people. Entrance 16 is an entrance to one of the ancillary buildings. The popular main entrances that are most frequented by patients and families already have a fair amount of entrance green at this facility.

Entrance number	green space %		
	Base Case	Essential Greening	Optimal Greening
1	88	88	88
2	60	60	60
3	3.6	78	78
4	13.5	78	78
5	49.9	49.9	49.9
6	41	41	41
7	0	0	0
8	20.9	20.9	40
9	5	30.7	30.7
10	24.6	24.6	40
11	63	63	80
12	0	0	70
13	30.4	30.4	30.4
14	0	38.1	100
15	9	9	69
16	5	5	5
17	62.5	62.5	62.5

Table Five: The % of green of the building entrances in the Acute Care Facility.

STRATEGY TWO: Plant entrances

The essential greening scenario increases the green in the lowest ranking entrances including 3,4,9 and 14. The scenario increased green to 30% for 80% of the entrances. The optimal greening scenario increased this to nearly 90% of entrances having at least 30% green.

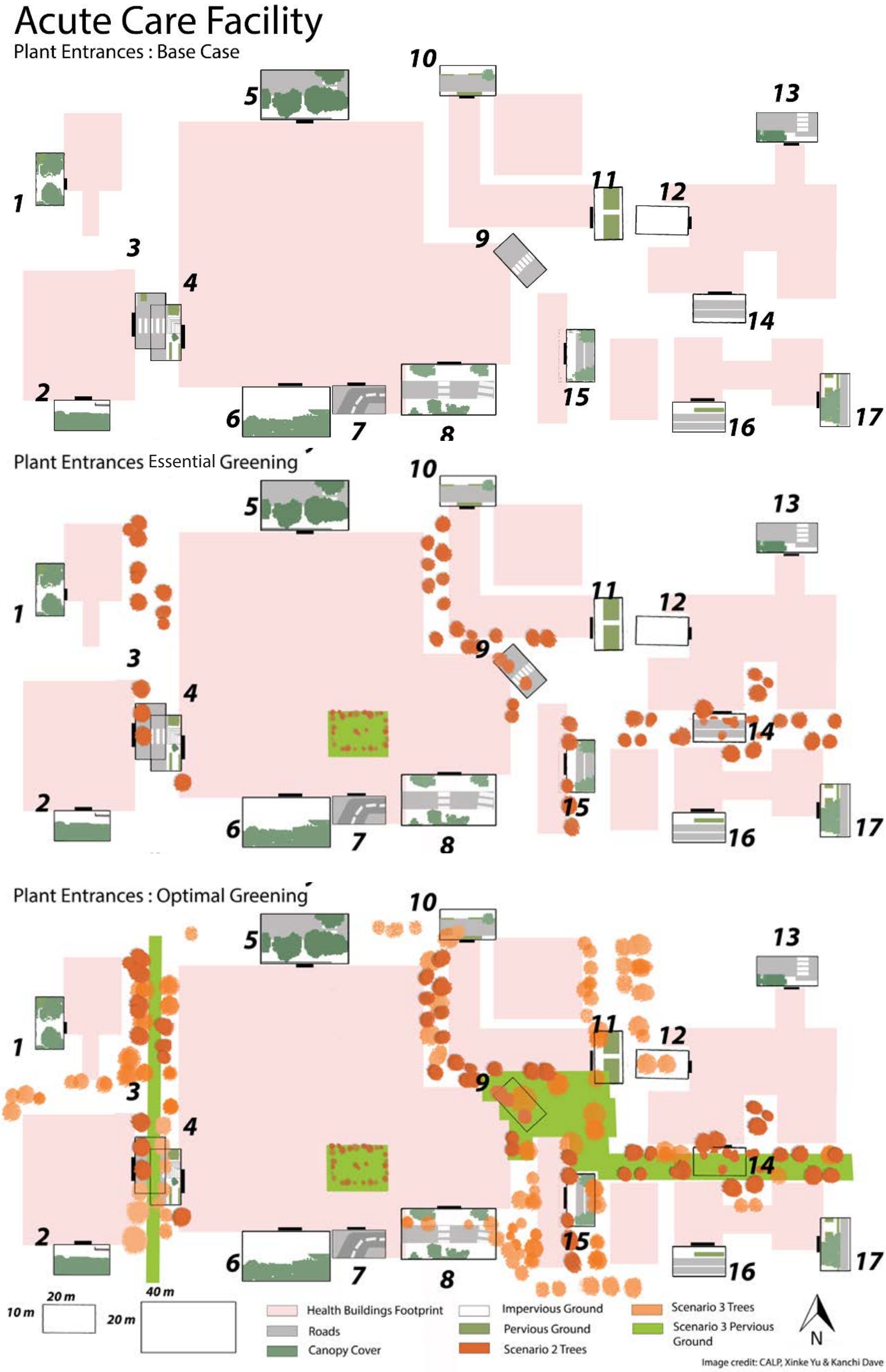


Figure Twenty Seven: Plan view visualization showing the green space at the 17 numbered entrances to the acute care buildings.

STRATEGY THREE: Nearby Greenspace

Since there are multiple buildings in the Acute Care Facility, we picked three buildings spread well across the campus, with varied building heights, and use. These are used as proxy for the whole campus. The three buildings included a new mid sized office building, a critical in-patent high rise and an old low rise teaching building (the same three buildings used for the 'View from within' strategy).

Building	Time required (in seconds)			
	Base case	Essential greening	Optimal greening	Green roofs & facades
Mid size office bldg	40-103	40-103	20-83	40-103
Clinical tower 1	50-125	50-125	20-95	10-77
Clinical tower 2	210-273	210-273	50-113	10-67
Small teaching bldg	20-71	20-71	20-71	20-71

Table Six: The time required to access greenspace for each of the three buildings, over each of the four scenarios.

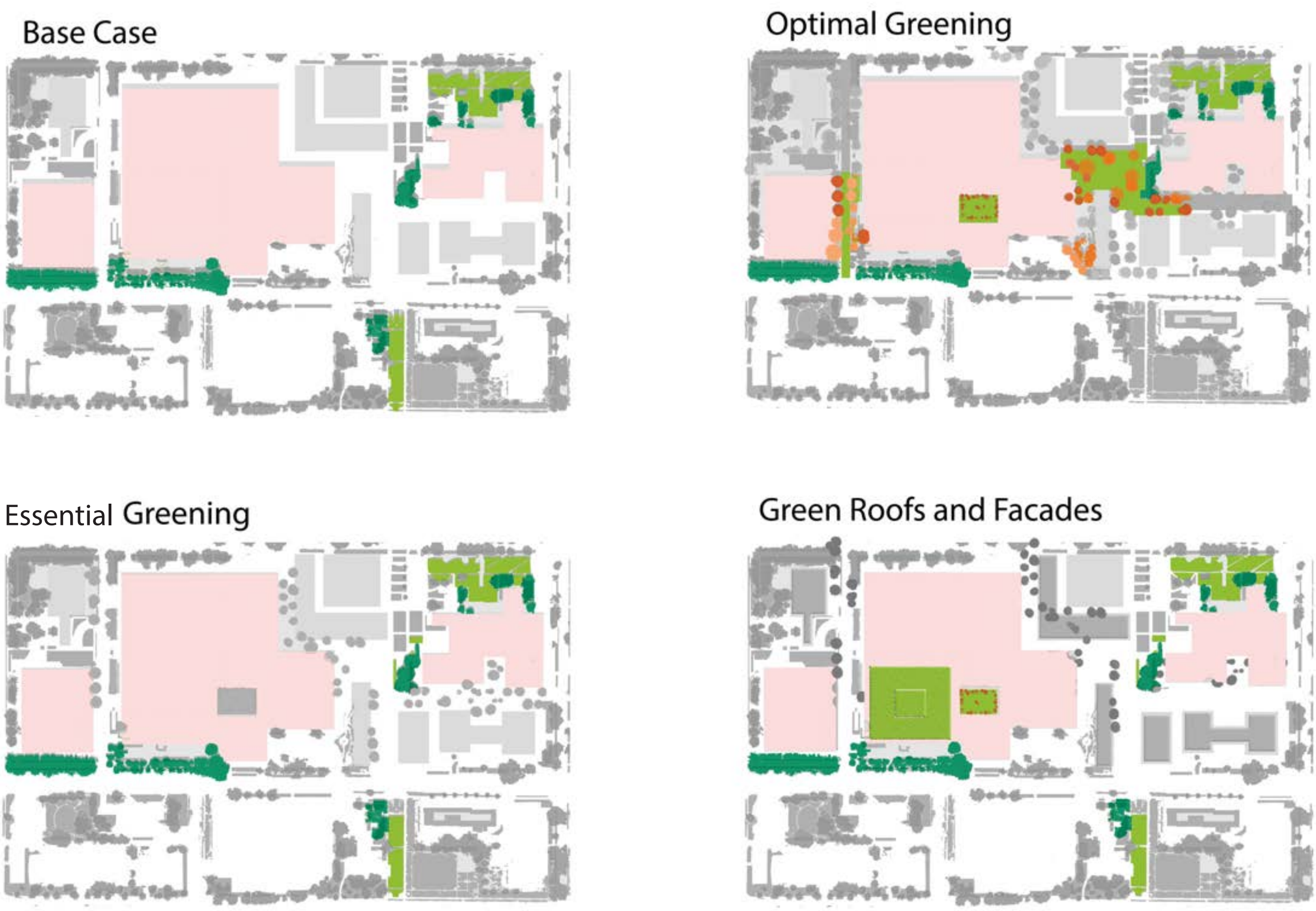


Figure Twenty Eight: Plan view visualization showing the nearby greenspace added for each of the scenarios.

STRATEGY FOUR: Retain the Mature

Thirty-nine percent of the total number of trees on the Acute Care Facility campus are mature trees (greater than 15 m in height). This is well within our set goal of having at least 30% of the trees being mature. The majority of the trees are currently medium sized, with a height of around 10 - 15m.

Due to the addition of more small and medium sized trees in the future scenarios, the percentage of mature trees is reduced in the short-term until the new trees grow to maturity.

Additonaly future mature trees are strategically placed to reduce the direct solar radiation to ground in areas with high exposure to solar radiation.

	Base Case	Essential Greening	Optimal Greening	Green Roofs and Facades
% of trees that are mature	39	31	27	31

Table Seven: Mature tree percentages for each of the scenarios.

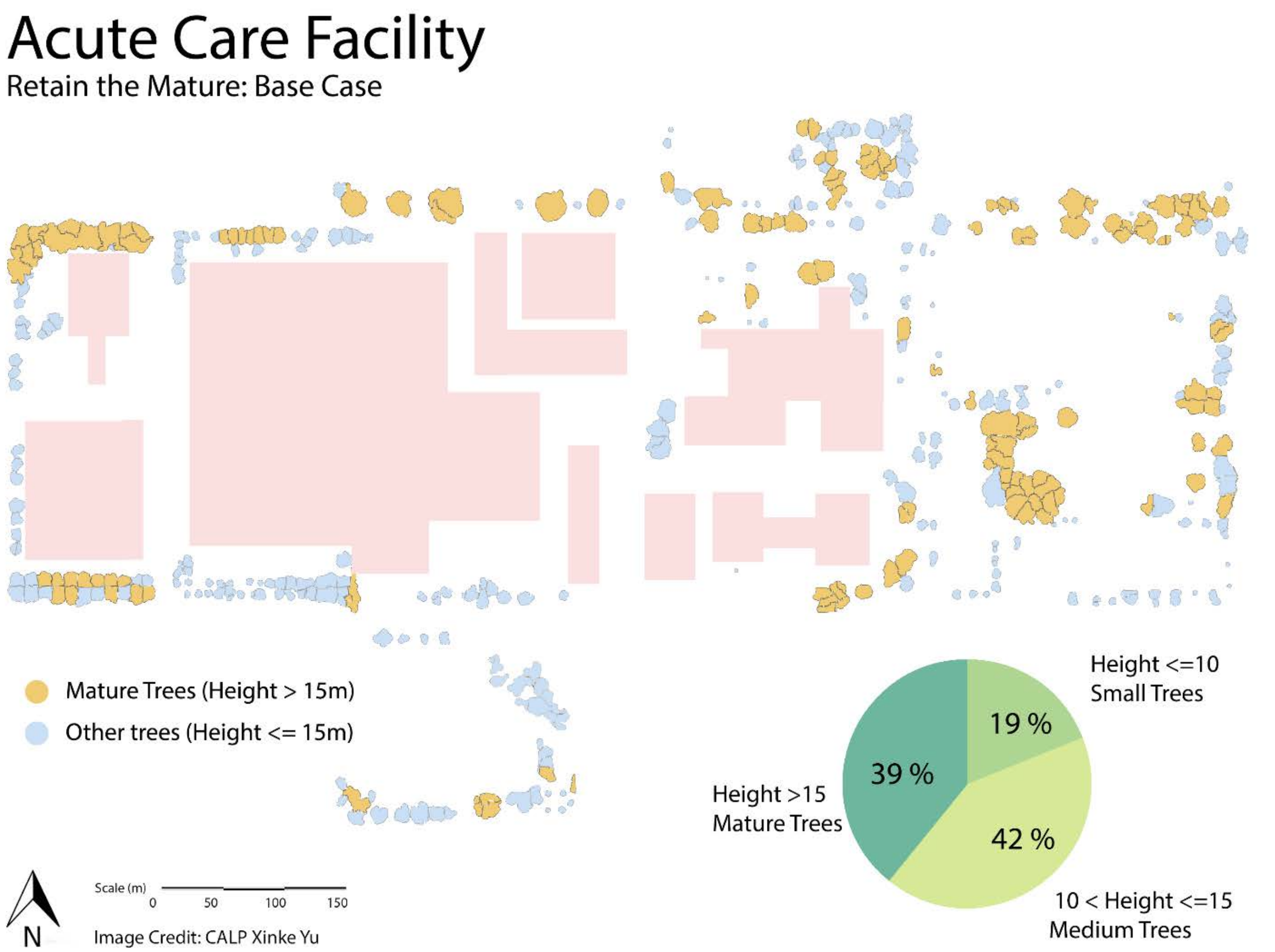


Figure Twenty Nine: Existing mature trees within the facilty.

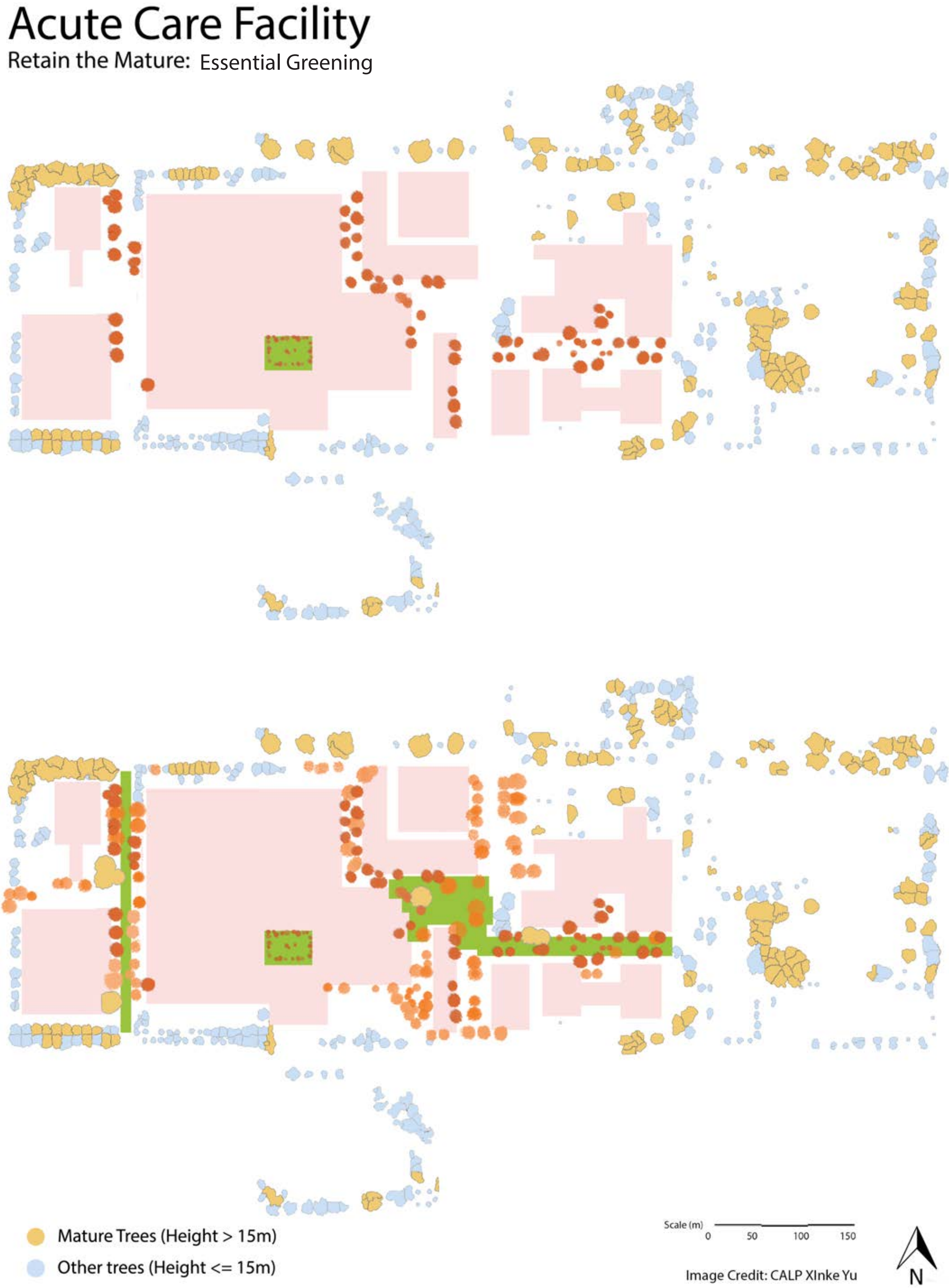
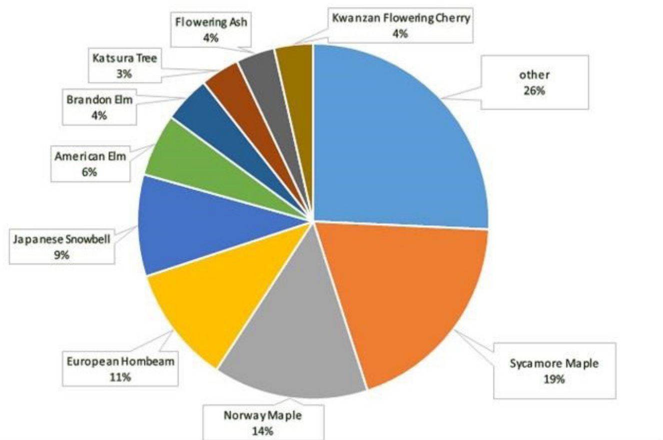


Figure Thirty: The Essential Greening and Optimal Greening scenarios with additional trees planted. Note: The final scenario is not drawn because trees are not planted on greenroofs.

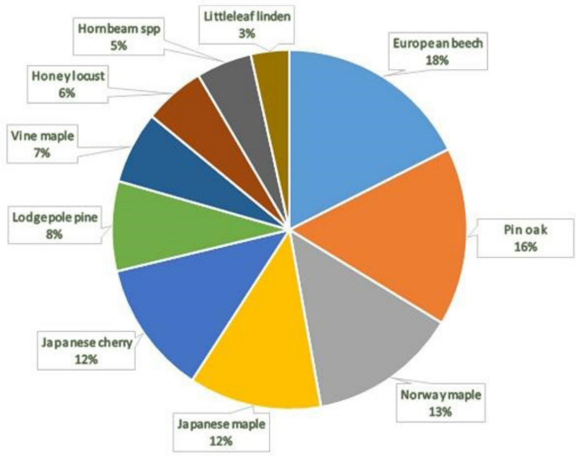
STRATEGY FIVE: Generate Diversity

Maple trees are the most commonly planted genus of trees on the campus. General guidelines for diversity suggest that no more than 30 percent of trees come from one family, no more than 20 percent from one genus, and no more than 10 percent from one species. Some cities have chosen even higher targets for diversity. The diagrams below show the distribution of species for public trees in the neighbourhood (left side) and private trees within the facility (right side).

Public trees in neighbourhood



Private trees in facility



Most common species of trees:


Sycamore Maple ***19%***


Norway Maple ***14%***


European Hornbeam ***11%***

Most common species of trees:


European beech ***18 %***


Pin oak ***16 %***


Norway maple ***13 %***

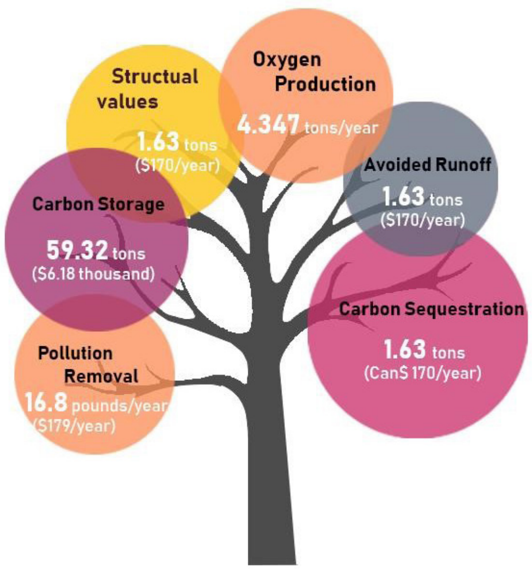


Figure Thirty One: i-Tree Eco provides a rough estimation of the benefits provided by trees for a range of different ecosystem services. This figure shows the services provided by the existing trees in the Acute care centre.

STRATEGY SIX: Create Refuge

The refuge capacity of the facility for the Basecase scenario is 9500 people. The estimated daytime population of the campus is 15,000. However, the majority of these refuge spots are placed around the periphery of the campus, making it difficult for people with low mobility to reach them. Most of the refuge is under public trees rather than being facility-owned trees. The disadvantage of using public trees is that their shade can fall onto private property. Private property is subtracted from our calculations, but included in the diagram to show that they may be used in an emergency.

The newly-planted small trees in Scenario 2 don't provide sufficent refuge cover on their own. Only trees added close to existing big clumps of canopy were included into the refuge category for this scenario.

	Base Case	Essential Greening	Optimal Greening	Green Roofs and Facades
Number of people that can be accommodated in refuge spots	9500	9600	10000	9600

Table Eight: Number of people accomodated by refuge spaces for each scenario.

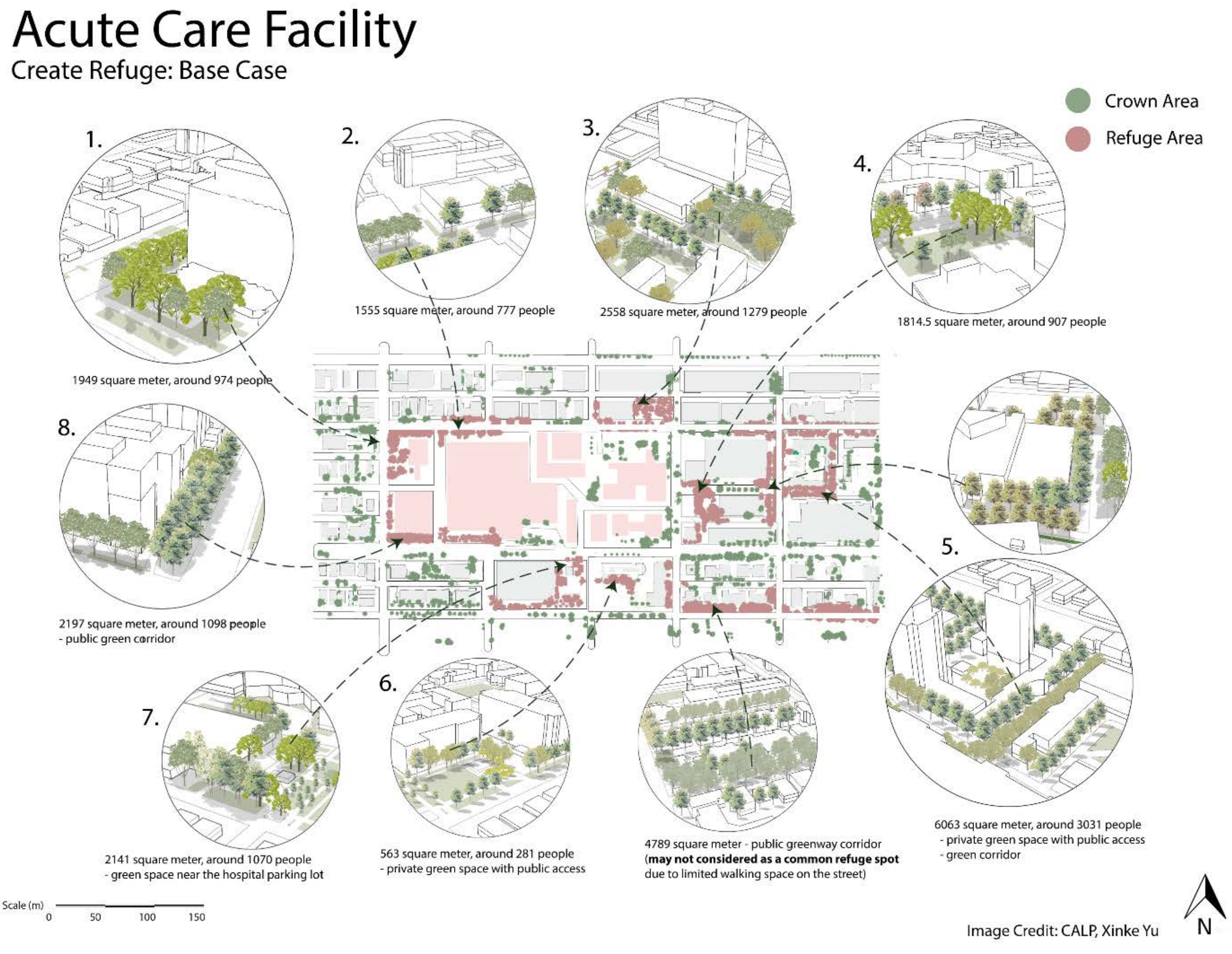


Figure Thirty Two: Refuge spaces around the facility.

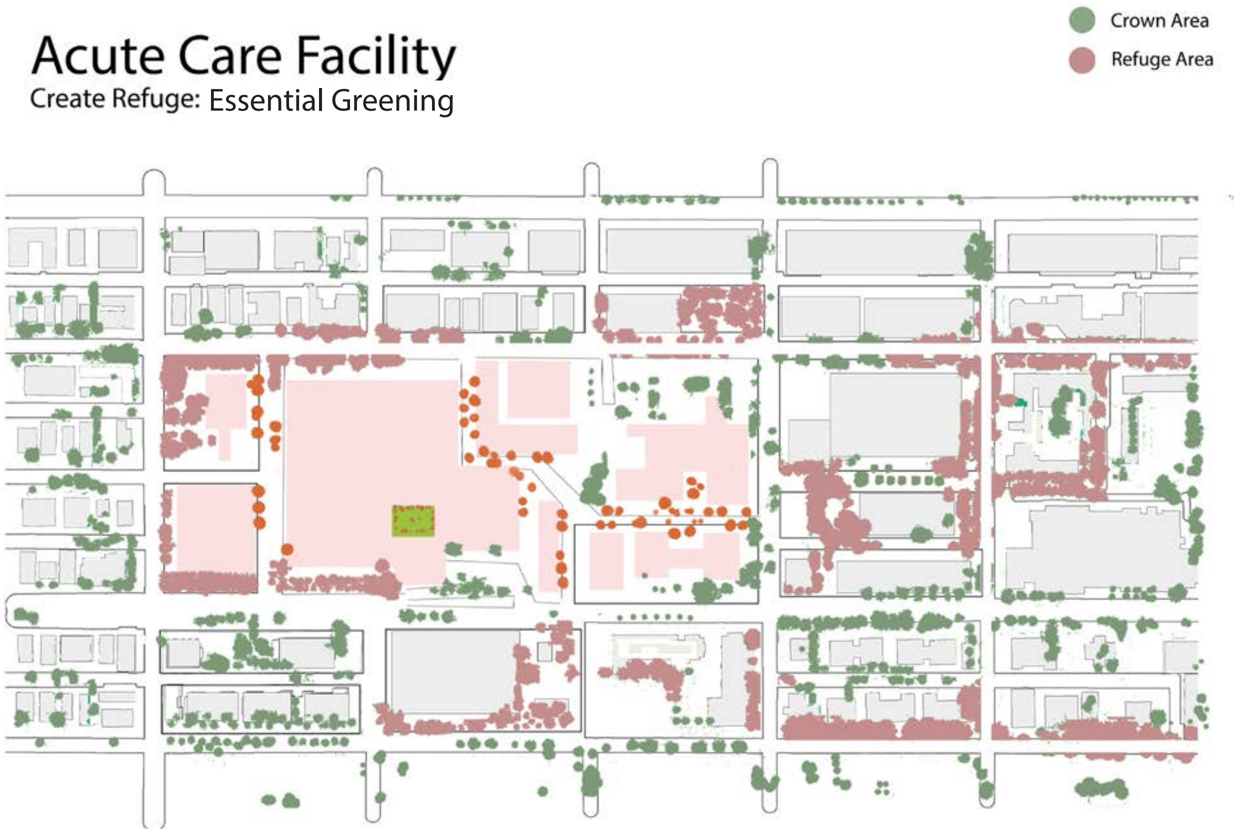


Figure Thirty Three: Refuge spaces around the facility. for the Essential Greening scenario

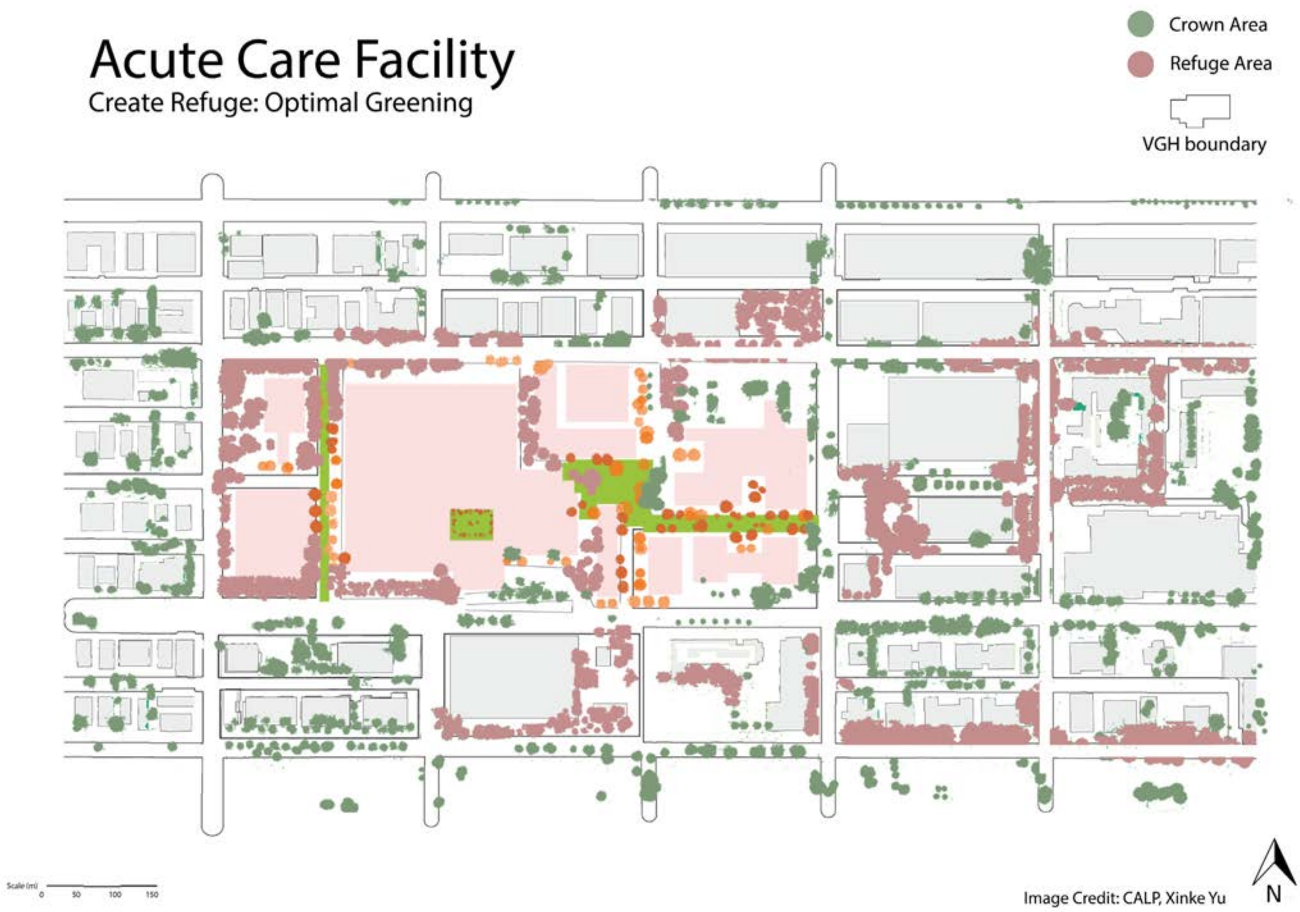


Figure Thirty Four: Refuge spaces around the facility. for the Optimal Greening scenario

STRATEGY SEVEN: Connect Experiences

Nearly sixty percent of movement corridors in and around the health campus are connected with continuous canopy or eye level greenery. However, all of these connected corridors are on the perimeter of the campus. There are few connected green pathways within the campus, and none that connect the main buildings of the campus.

The Essential and Optimal greening scenario allows for greening of the major movement corridors within the campus. Additional green corridors should promote low carbon mobility options, a key strategy for carbon mitigation.

	Base Case	Essential Greening	Optimal Greening	Green roofs and facade
% connected pathways	57%	68%	73%	68%

Table Nine: The percentage of pathways with connected green corridors for each scenario.

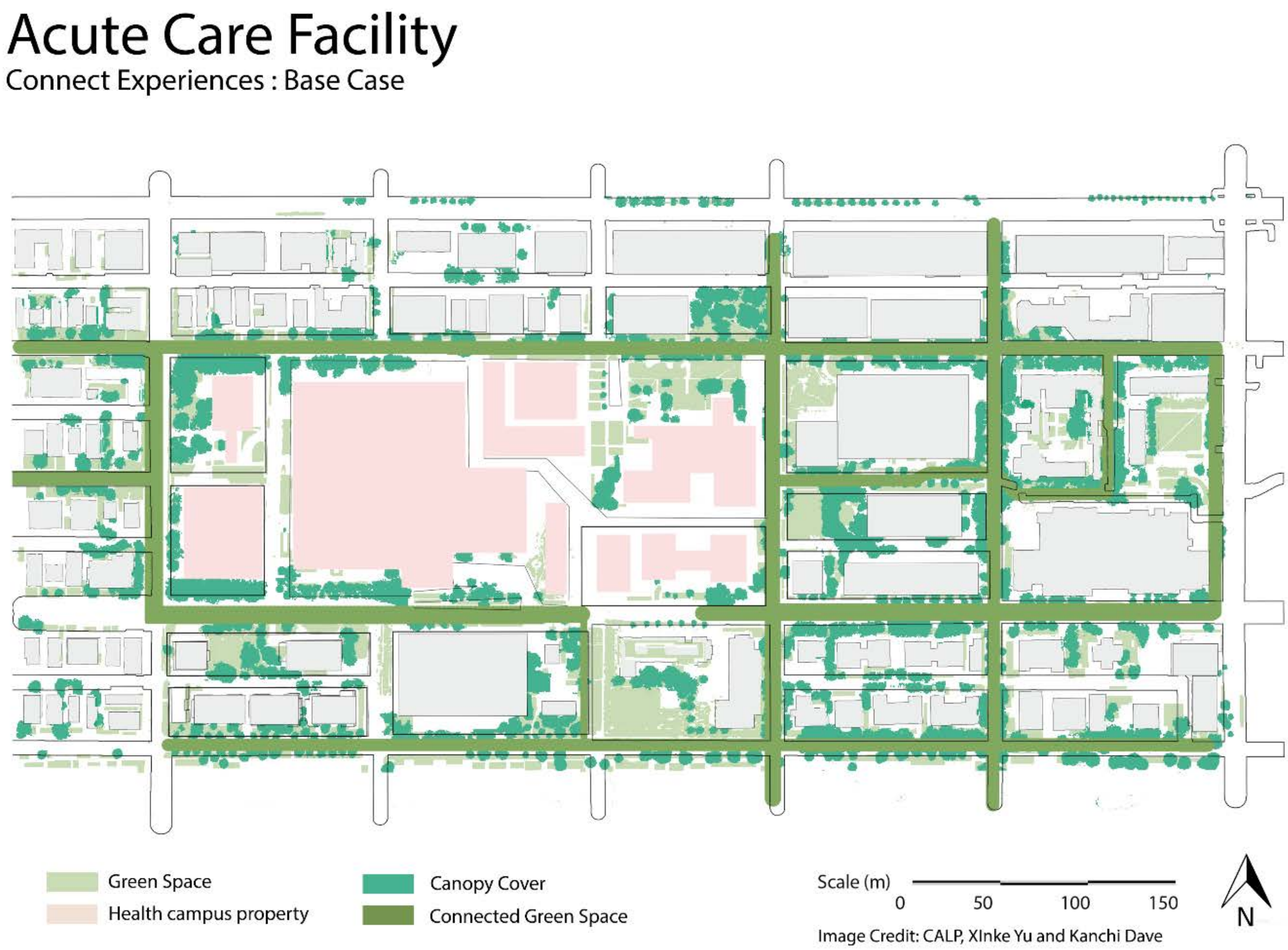


Figure Thirty Five: Connected movement corridors in the Base Case scenario

STRATEGY SEVEN: Connect Experiences

Connect Experiences : Essential Greening

Figure Thirty Six: Connected movement corridors in the Essential greening scenario

Connect Experiences : Optimal Greening

Figure Thirty Seven: The connected green corridors for the Optimal greening scenario.

STRATEGY EIGHT: Optimize Green Infrastructure

The overall canopy cover of the experiential neighbourhood is 16%, with about 1/3rd of the trees being owned by the campus itself. In this scenario exercise, all the new trees are added to the facility campus itself, meaning the overall canopy cover of the experiential neighbourhood cannot increase significantly.

	Base Case	Essential Greening	Optimal Greening	Green roofs and facades
% canopy cover	16%	17%	19%	17%
% pervious ground	9%	9%	10%	18%

Table Ten: The percentage of canopy cover and pervious ground changing through the 4 scenarios. Optimal greening has the highest canopy cover while adding green roofs would increase the pervious ground cover. All the scenarios still fall short of the 40% canopy cover goal.

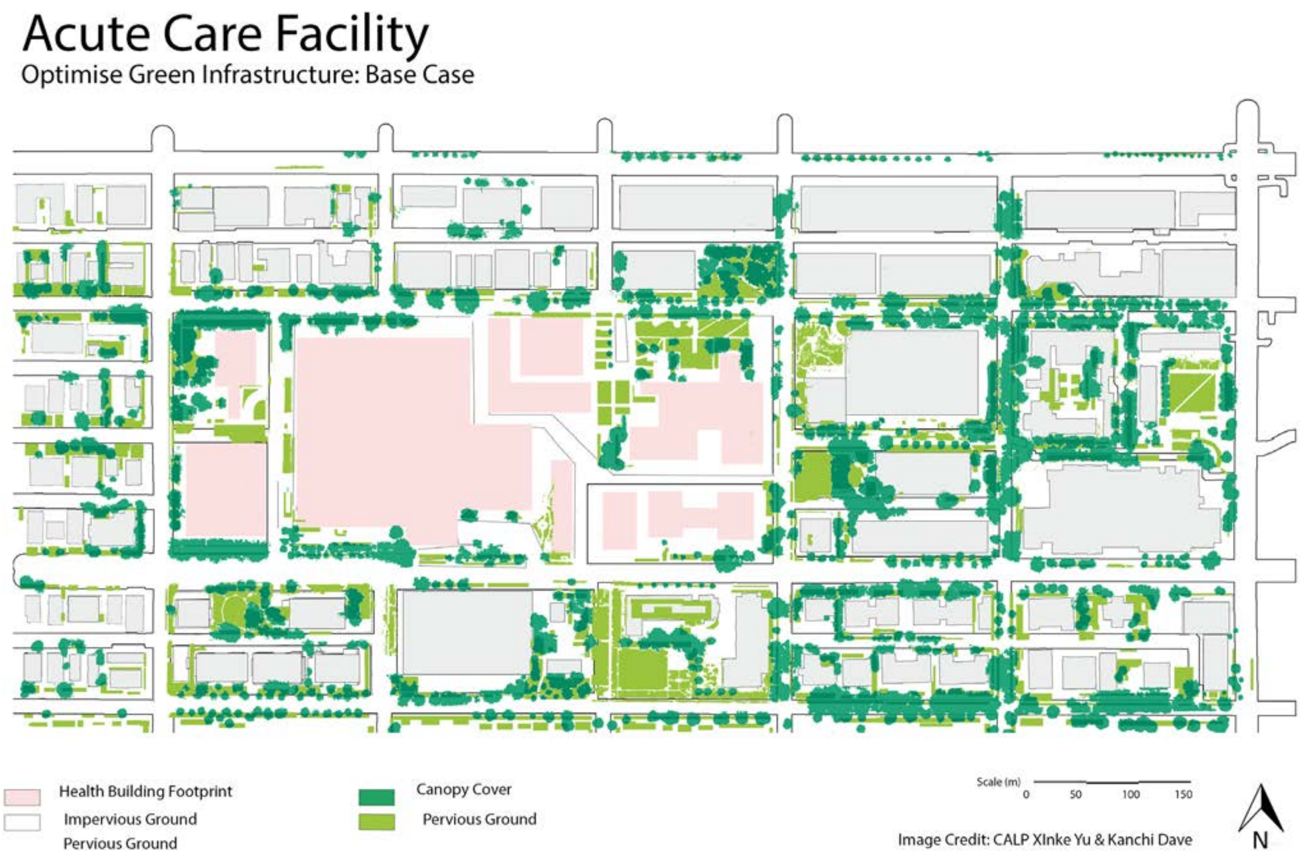


Figure Thirty Eight: Plan view of the Base Case scenario showing existing canopy cover and permeable surfaces.

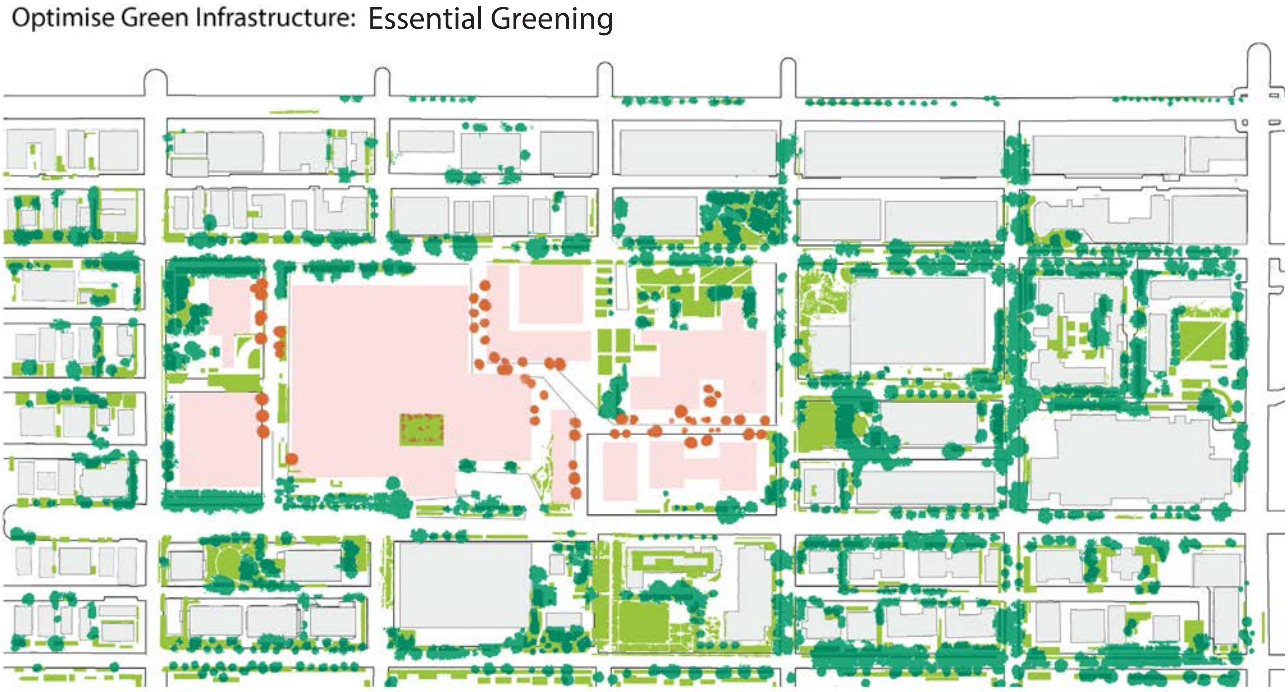


Figure Thirty Nine: Plan view of the Essential greening scenario showing new trees along major movement corridors.

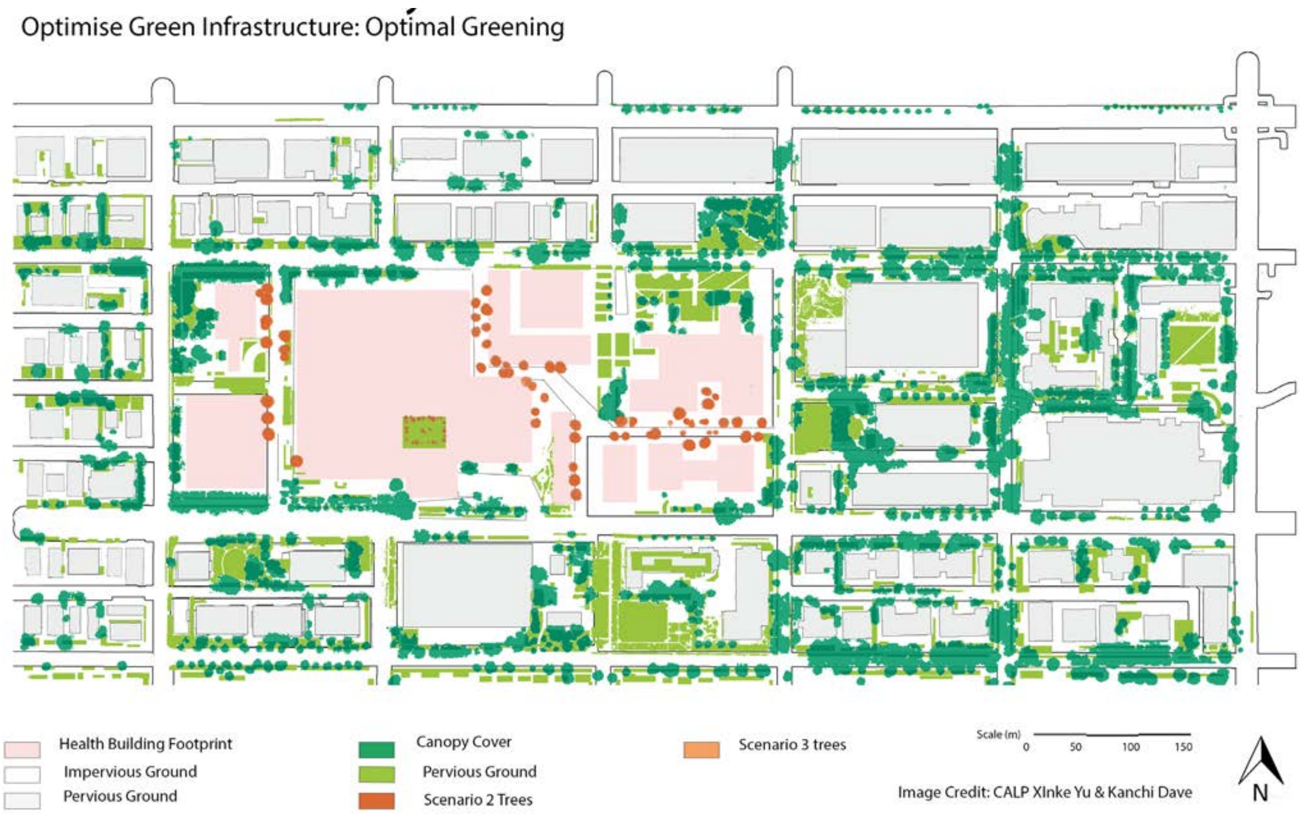


Figure Forty: Plan view of the Optimal greening scenario showing the closure of close of two streets to create green corridors in order to create quality nearby green space within the campus.

CONCLUSION

The preceeding pages show how applying the design strategies through their sequential pathways each contribute to the human wellbeing and climate-readiness of the facility. By measuring the base case, adding essential greenspaces to meet goals, and visualizing optimal greening strategies both on the ground and on roofs and facades, the scenarios provide guidance to help decison-making about new green spaces within and around the facility.

The concluding figure (below) shows how each strategy is improved through the scenarios.

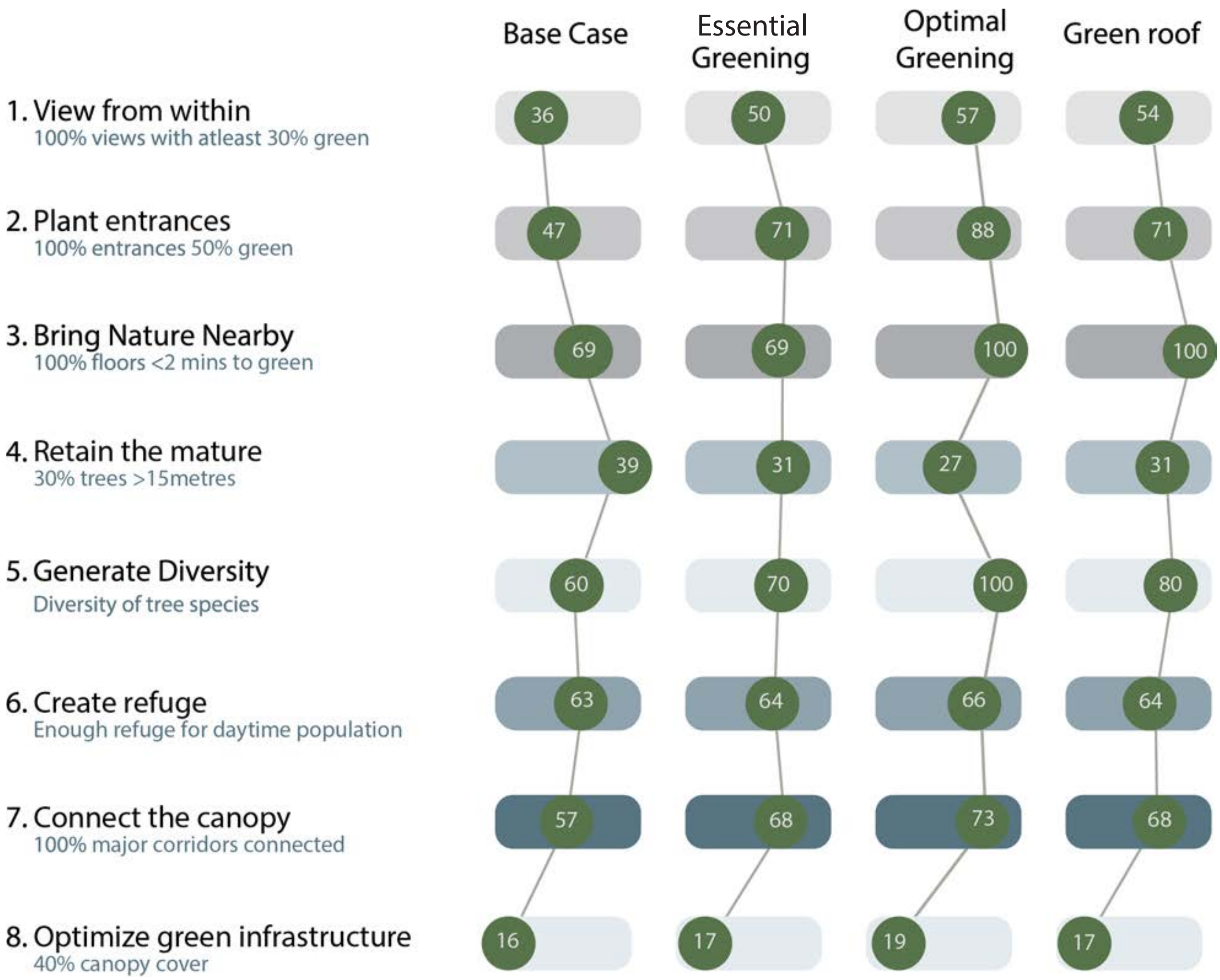
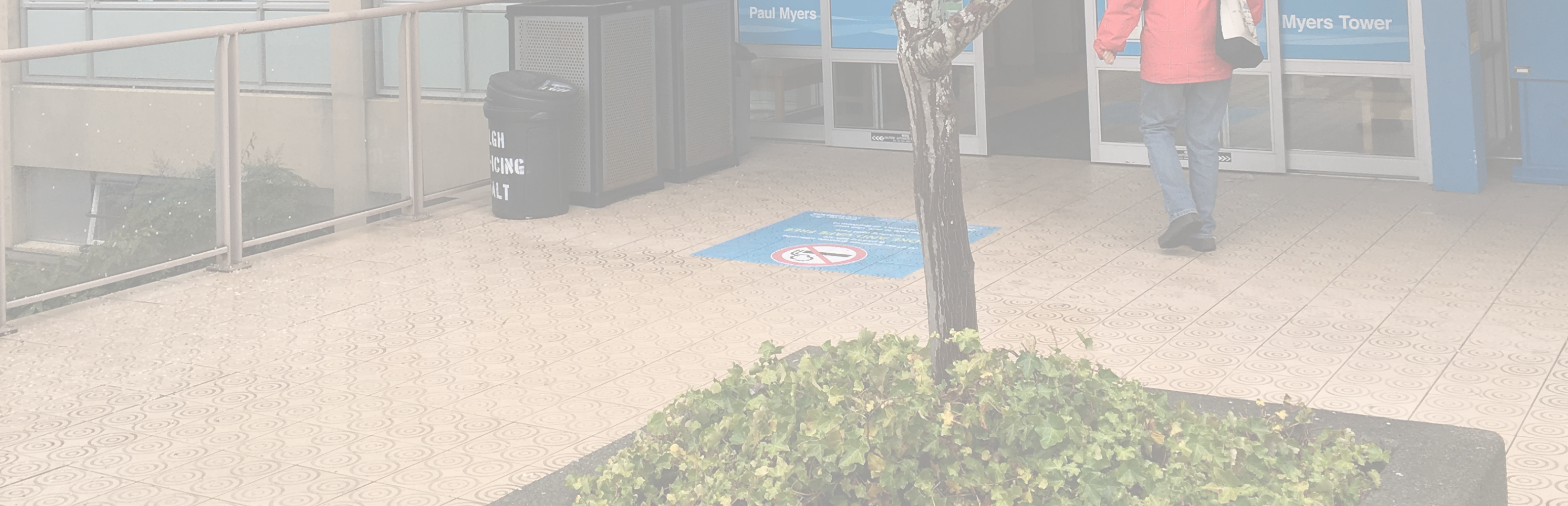


Figure Forty One: Image showing the summary results of all the scenarios for all the eight design results. The goals are given in blue below the design principles. Optimal greening has the best results of all the scenarios for the eight deign principles. The mature trees strategy is temporatily low while new trees grow to maturity.



Case study 2: Regional Care Centre

The Regional Care Facility is made up of three buildings. These include a high-rise main clinical building primarily for in-patients, a mid-rise office building that houses clinics and offices of doctors, and a low-rise residential long-term care building. East of the facility is a residential neighbourhood, while west of the faciltiy is a commercial neighbourhood. As Figure Forty Two (below) clearly shows, there is more tree cover in the residential zone than in the commercial zone. Fifty-six percent of the trees in the neighbourhood are privately owned, 30% publicly owned and 13% owned by the facility.

The Regional Care Centre is for patients with higher mobility and higher need for horticultural therapy than the acute care facilty. The strategies of nearby green, connected green, and refuge green were given more preference in this case study.

Figure Forty Two : Current conditions in the case study neighbourhood. The neighbourhood shows a clear green shift from west to east.

STRATEGY ONE: View from Within

In the Base case scenario, higher and lower floors with west-facing views for the clinical and office buildings have the lowest green space. The clinical building has the lowest green views while the residential long term care building has the greenest views.

Since there are so many views, and the impact of the strategies will be similar for views facing the same direction, only views that do not overlap and have the lowest green percentage were selected for scenario development. The calculations below can serve as a proxy for all the other views.

Entrance	Building type	Users
1, 2, 3, 4	Critical Care tower and building	Health care staff, out patients and families
5,6	Long term Residential care	Health care staff, inpatients and families
7	Office building and clinics	Health care staff, out patients and families

Table Eleven: A summary of the main buildings and their users for the second case study.

		% of green viewed from N,S,W,E of building			
Buildings	Average % of green seen from all directions for floor	North %	South %	West %	East %
Higher (9th floor)					
Clinical centre	21	18	44.8	6.9	14.5
Office Building	34	46	46.9	4.2	39
Average % green for each direction		32	46	6	27
Lower (3rd floor)					
Medical Centre	37	28.7	60	14.4	46.6
office bldg	32	39.4	34.7	1.7	51
residential care bldg	60	82	39	77	41
Average % green for each direction		50	45	31	46

Table Twelve: Existing views from the buildings and the percentage green they each contain.

STRATEGY ONE: View from Within

The views chosen for scenario building are: clinical building east, north high floor and north lower floor, and office building west high and low

Figure Forty Three: For views that do not have roofs, the Optimal greening scenario has the highest visual greening potential. Green roofs do a great job at greening views that are largely comprised of rooftops.

STRATEGY TWO: Plant entrances

The facility has seven total entrances. The area of assessment for entrances number 3, 6, 7 are larger since they are physically larger in size and serve as main entrances. The smaller entrances are used by fewer people on a daily basis.

In the Base case, entrances 1, 2, and 7 have the lowest green percentage. While the Essential greening does not add much green to the entrances, Optimal greening adds enough green to entrances 6 and 7 tobring 70% of the entrance to above 30% greenery.

Entrance number	green space %		
	Base Case	Essential Greening	Optimal Greening
1	17	17	17
2	14.3	14.3	14.3
3	60.8	60.8	80
4	41	41	60
5	97	97	97
6	28	28	80
7	8	8	40

Table Thirteen: The seven entrances and thier measured greenspace in three scenarios.

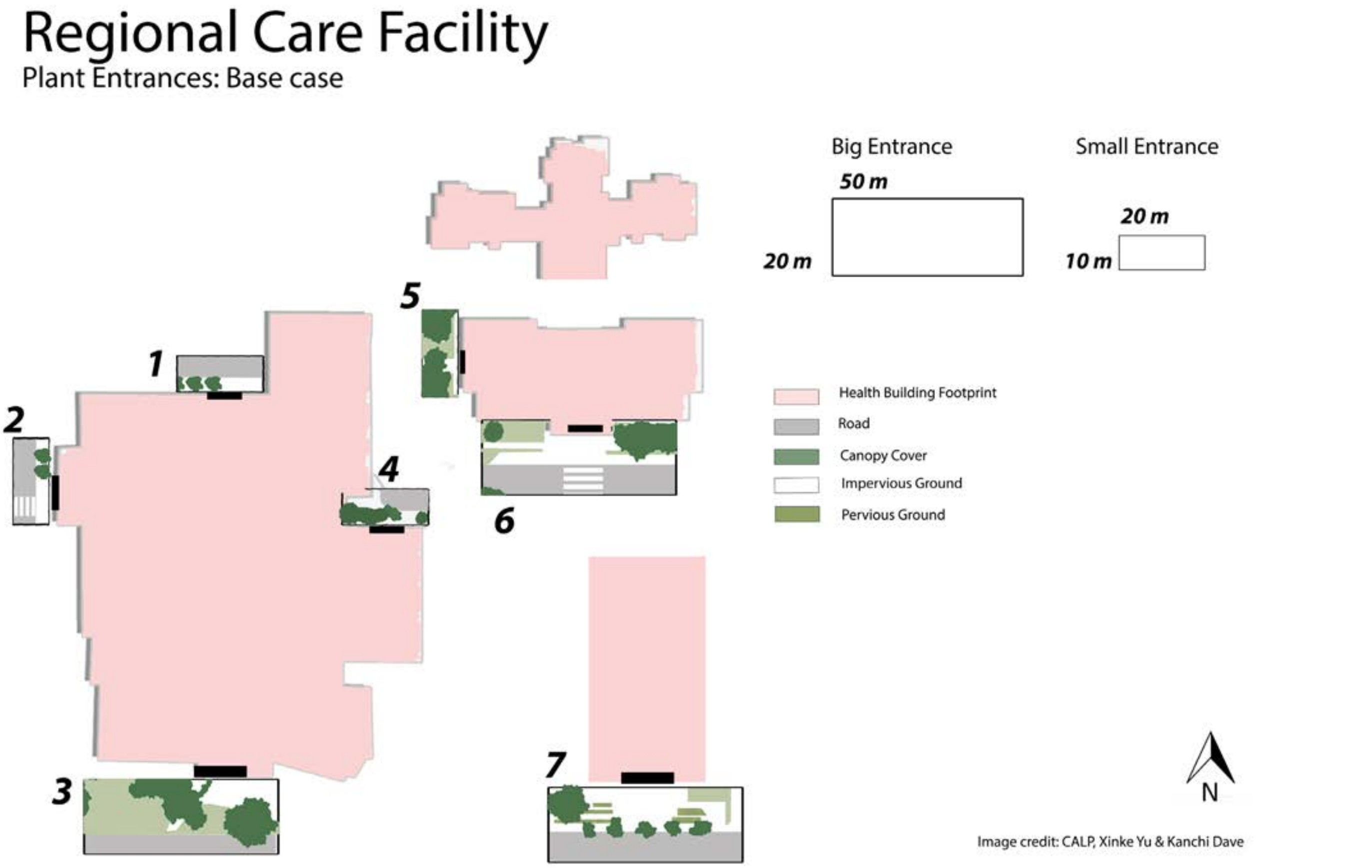


Figure Forty Four: The existing green around entrances for the Regional Care Facility. As you can see, the area of assessment for entrances 3, 6, and 7 are larger because they serve as main entrances for the facility.

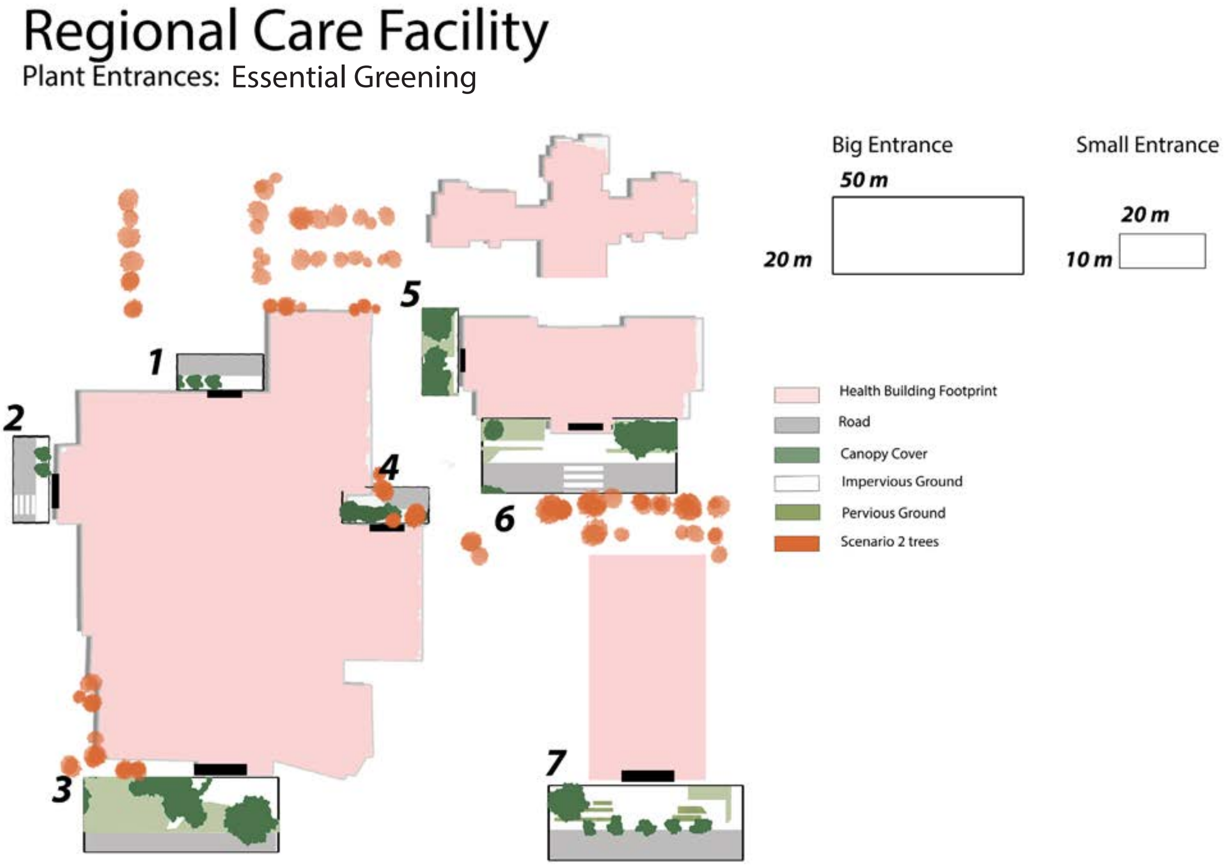


Figure Forty Five: Additional green was added to entrance four in this scenario.

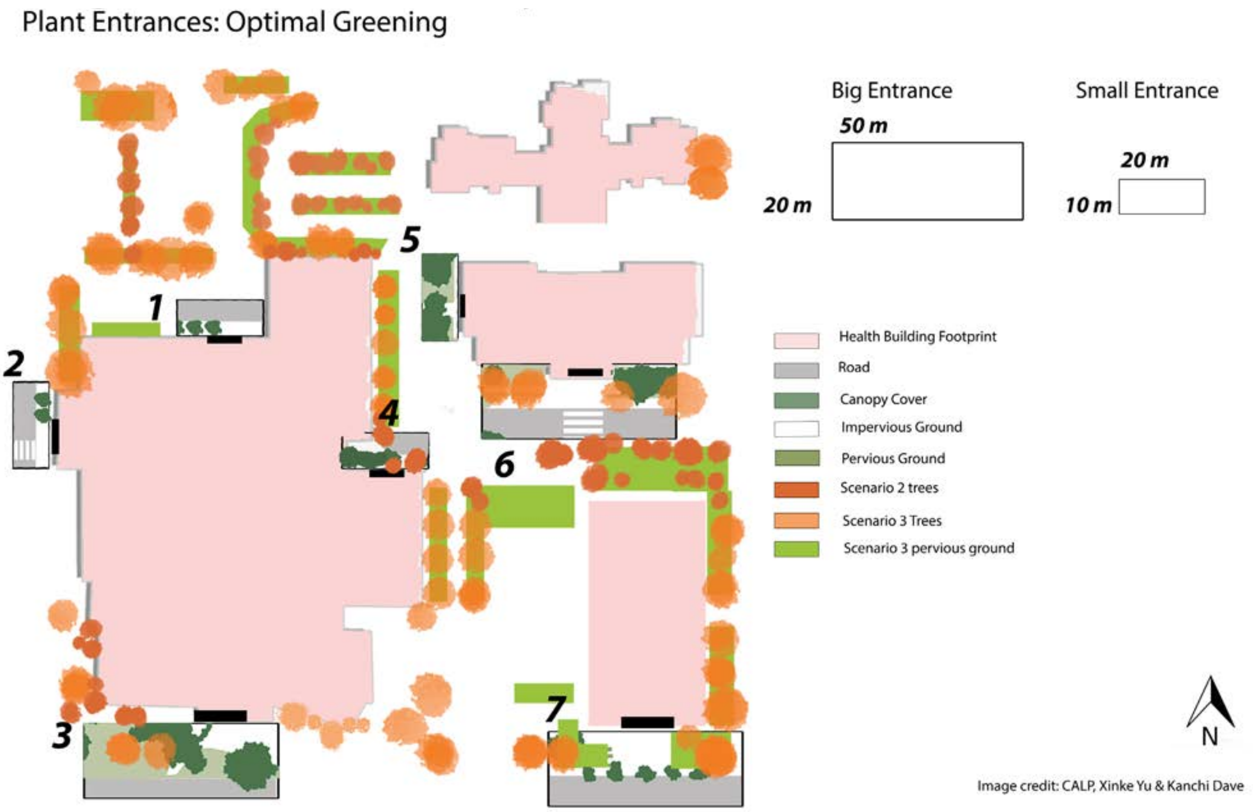


Figure Forty Six: Entrances 3, 4, 6, and 7 benefit from additonal green in the Optimal greening scenario.

STRATEGY THREE: Nearby Greenspace

We measured all three buildings in the Regional Care Facility. The results, in Table Fourteen below, show that the office building and clinical centre both have longer distances to nearby greenspace.

Building	Time required			
	Base case	Essential greening	Optimal greening	Greenroofs and facades
Clinical Centre	390-453	30-93	30-93	30-93
Office Bldg	204-255	174-225	10-61	10-61
Residential Care Bldg	20-71	20-71	20-71	20-71

Table Fourteen: The range of time in seconds it takes to get to nearby quality green space for each of the buildings. Optimal Greening reduced the time by making quality green space close to the buildings. The residential care building already has nearby green integrated into the site design.

Image Credit: CALP, Xinke Yu and Kanchi Dave

Figure Forty Seven: Additional nearby greenspace for each of the scenarios.

STRATEGY FOUR: Retain the Mature

Thirty percent of the total number of trees on the Regional Care Facility campus are mature trees (greater than 15 m in height). This meets our set goal of having at least 30% of the trees be mature. The majority of the trees are currently medium sized, with a height of around 10m- 15m.

However due to the addition of newly planted small trees, percentage of mature trees goes down to 23% until they grow to maturity.

	Base Case	Essential Greening	Optimal Greening	Green Roofs and Facades
% of trees that are mature	30	24	23	24

Table Fifteen: Newly planted trees reduce the overall percentage of mature trees temporarily until they grow to maturity. This is a reminder than continuous tree planting programs are important in establishing an age diverse tree community.

Figure Forty Eight: Existing mature trees in the neighbourhood. You can clearly see that new development in the west has removed all mature trees.

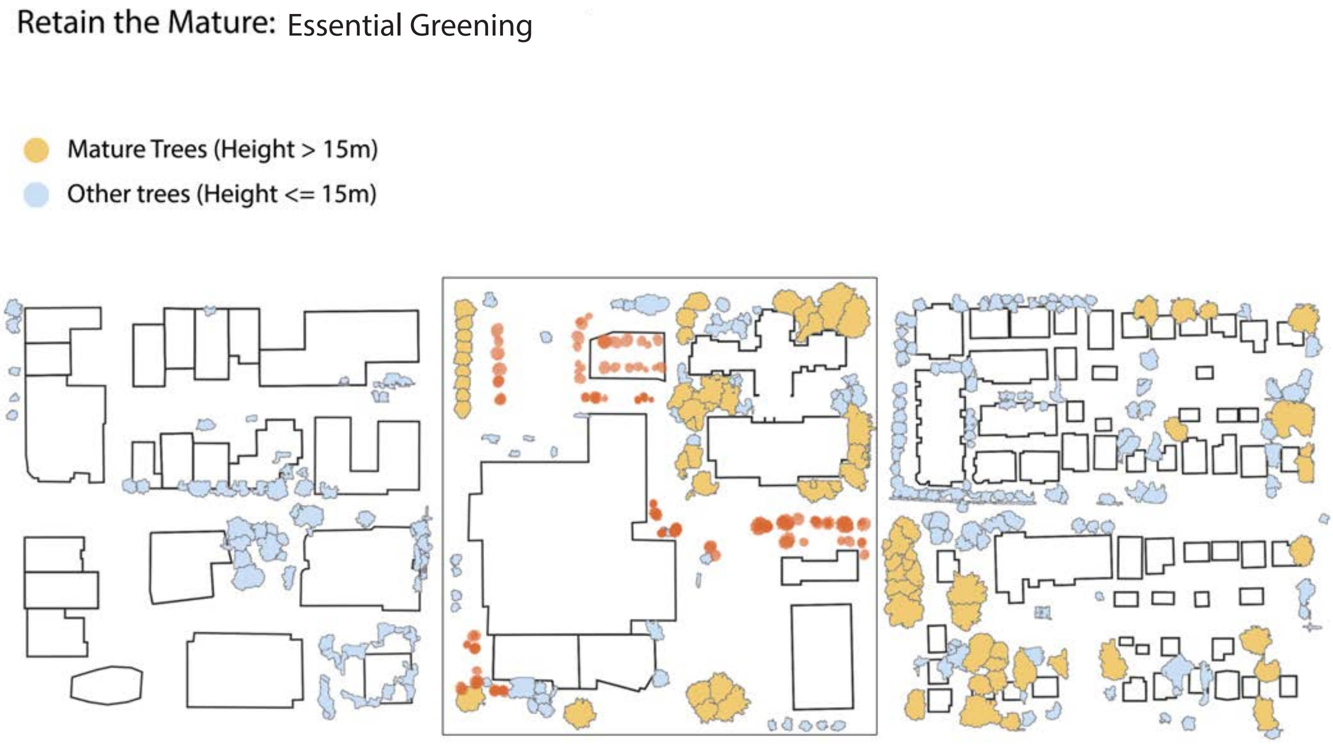


Figure Forty Nine: Newly planted trees in the Essential greening scenario that will eventually contribute to the percentage of mature trees.

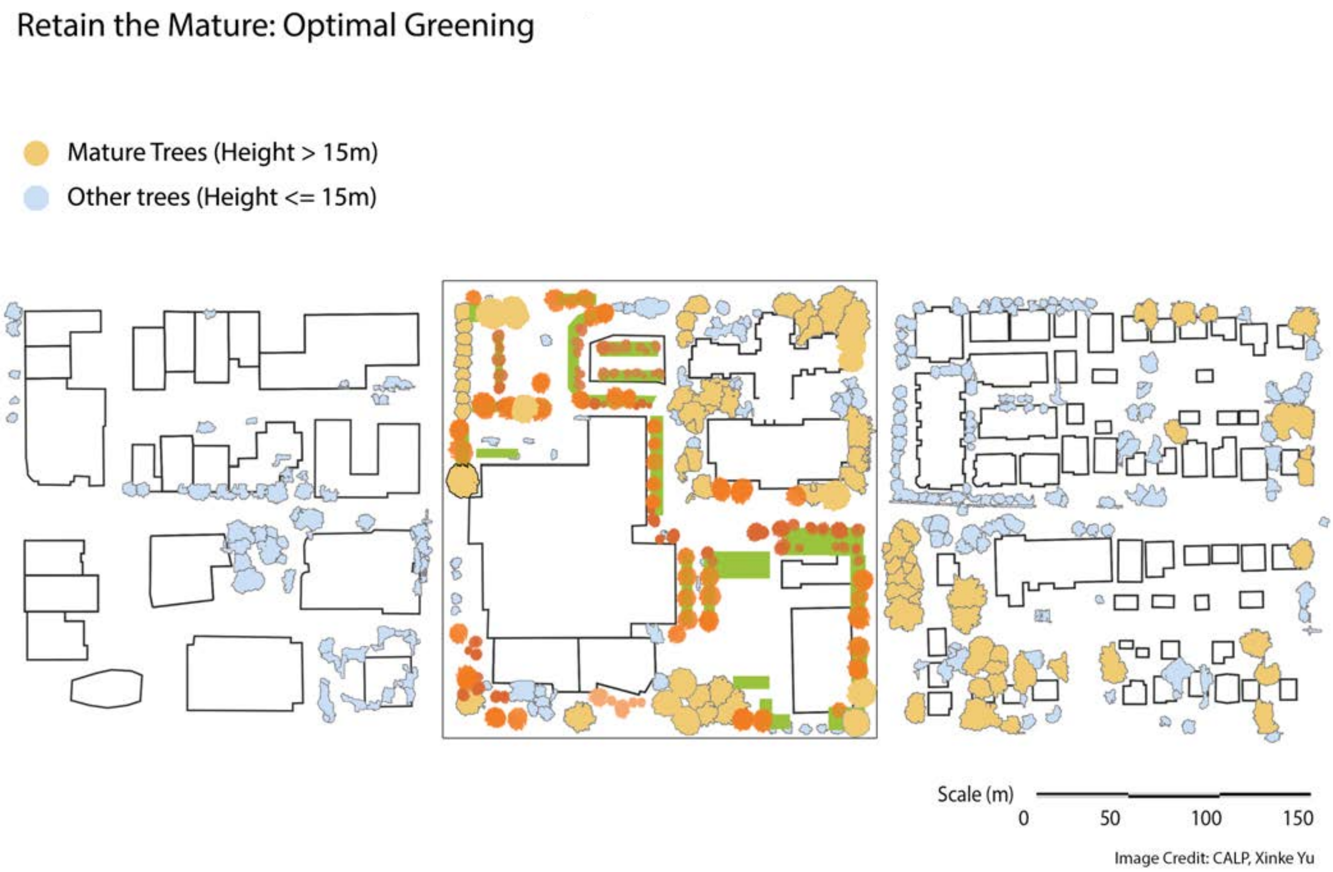
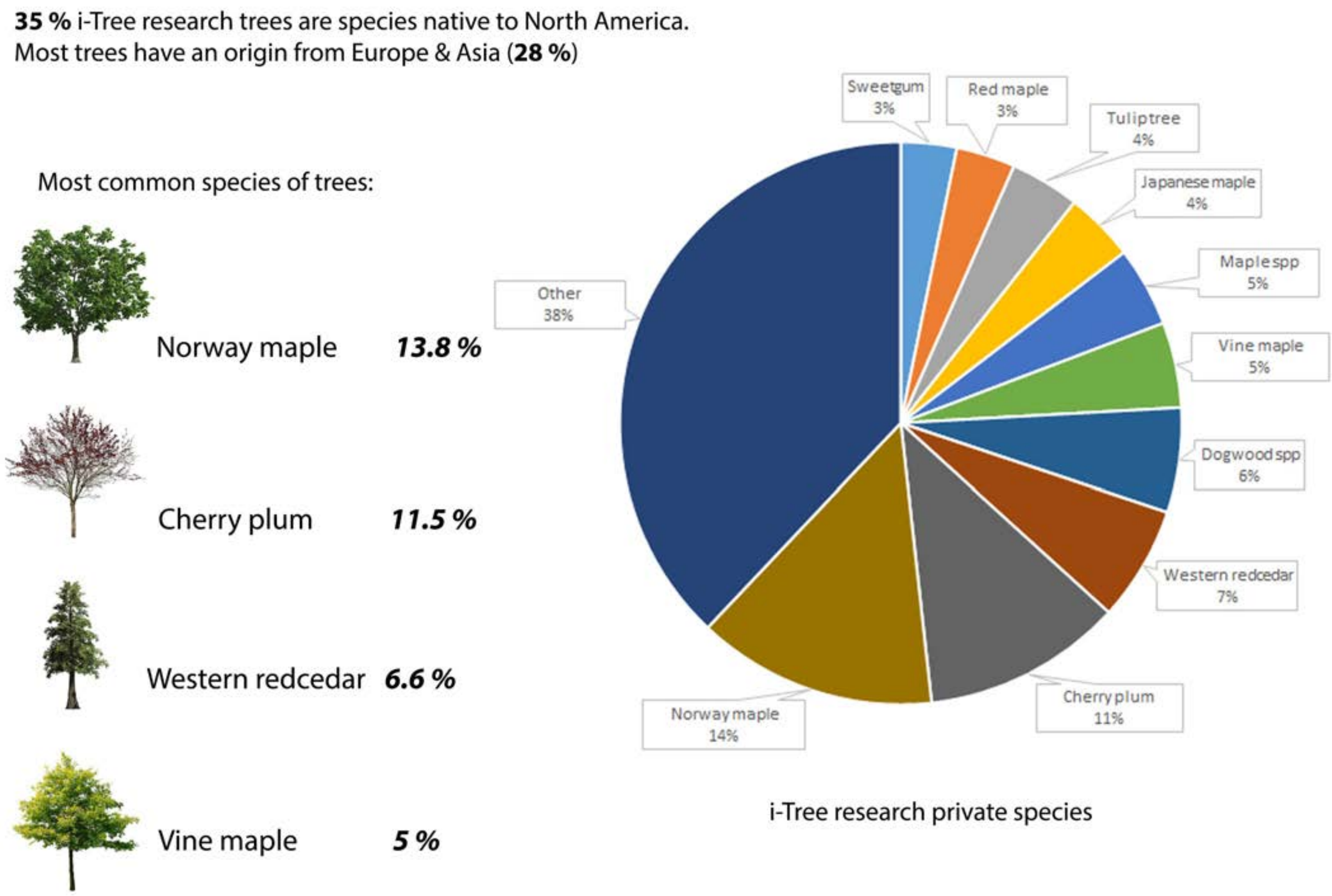


Figure Fifty: Newly planted trees in the Optimal greening scenario that will eventually contribute to the percentage of mature trees.

STRATEGY FIVE: Generate Diversity

All trees on the north, south, east, west block of the regional health campus and within the health campus itself were inventoried. The most commonly planted tree species in this area are maple trees.



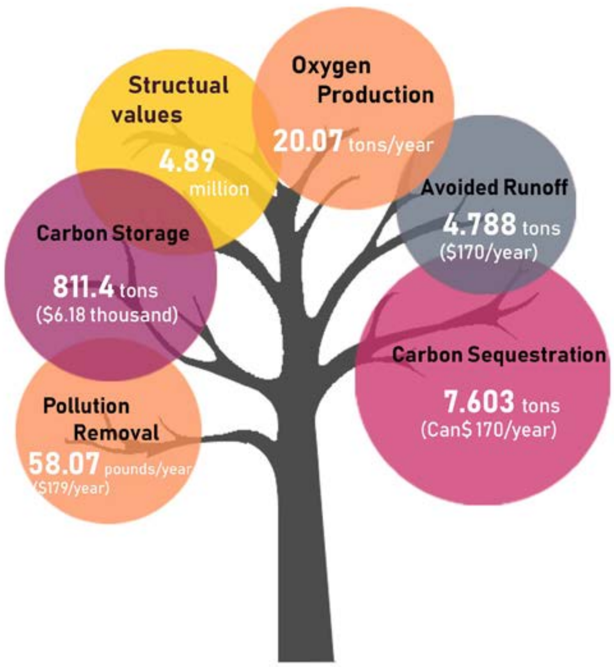


Figure Fifty One: i-Tree Eco provides a rough estimation of the benefits provided by trees for a range of different ecosystem services. This figure shows the services provided by the existing trees in the Regional care centre.

STRATEGY SIX: Create Refuge

The refuge capacity of the facility is currenlty 2000 people. The estimated daytime population of the facility is about 5000 people. Some of the assessed refuge spaces are along roads or a short walk away from the campus, which makes them less accessible for those with low mobility. The large canopy cover surrounding the long term residential care building serves as an ideal refuge spot within the campus boundary. All the scenarios aim at creating such a spot at other sites around campus. The optimal greening scenario adds refuge spot for another 1000 people.

	Base Case	Essential Greening	Optimal Greening	Green roofs and facades
Number of people that can be accommodated in refuge spots	2000	2100	3000	2100

Table Sixteen: The number of people who can be accomodated under tree canopy in each scenario.

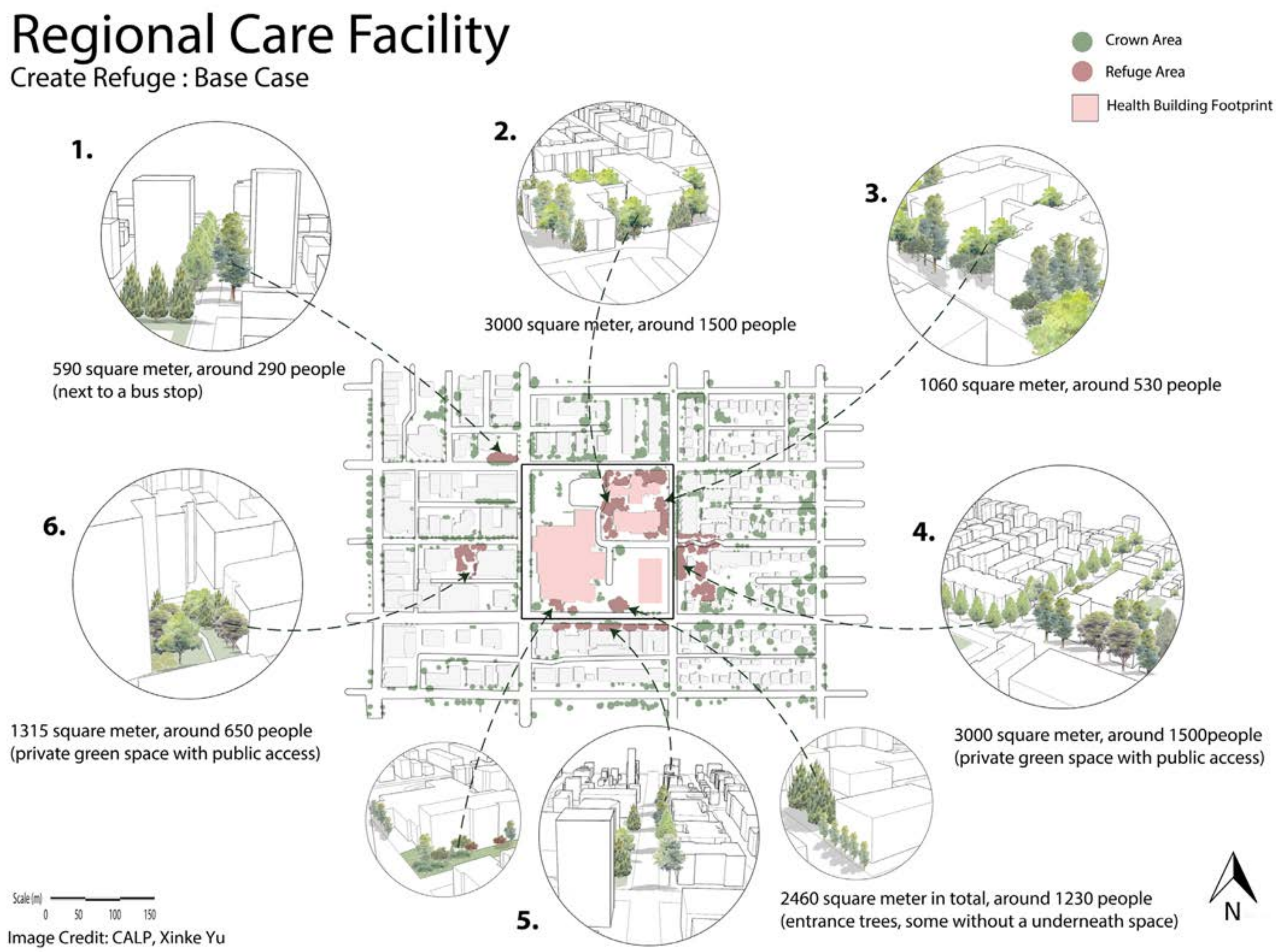


Figure Fifty Two: A diagram of the locations and quality of refuge space within and surrounding the Regional Care Facility.

STRATEGY SIX: Create Refuge

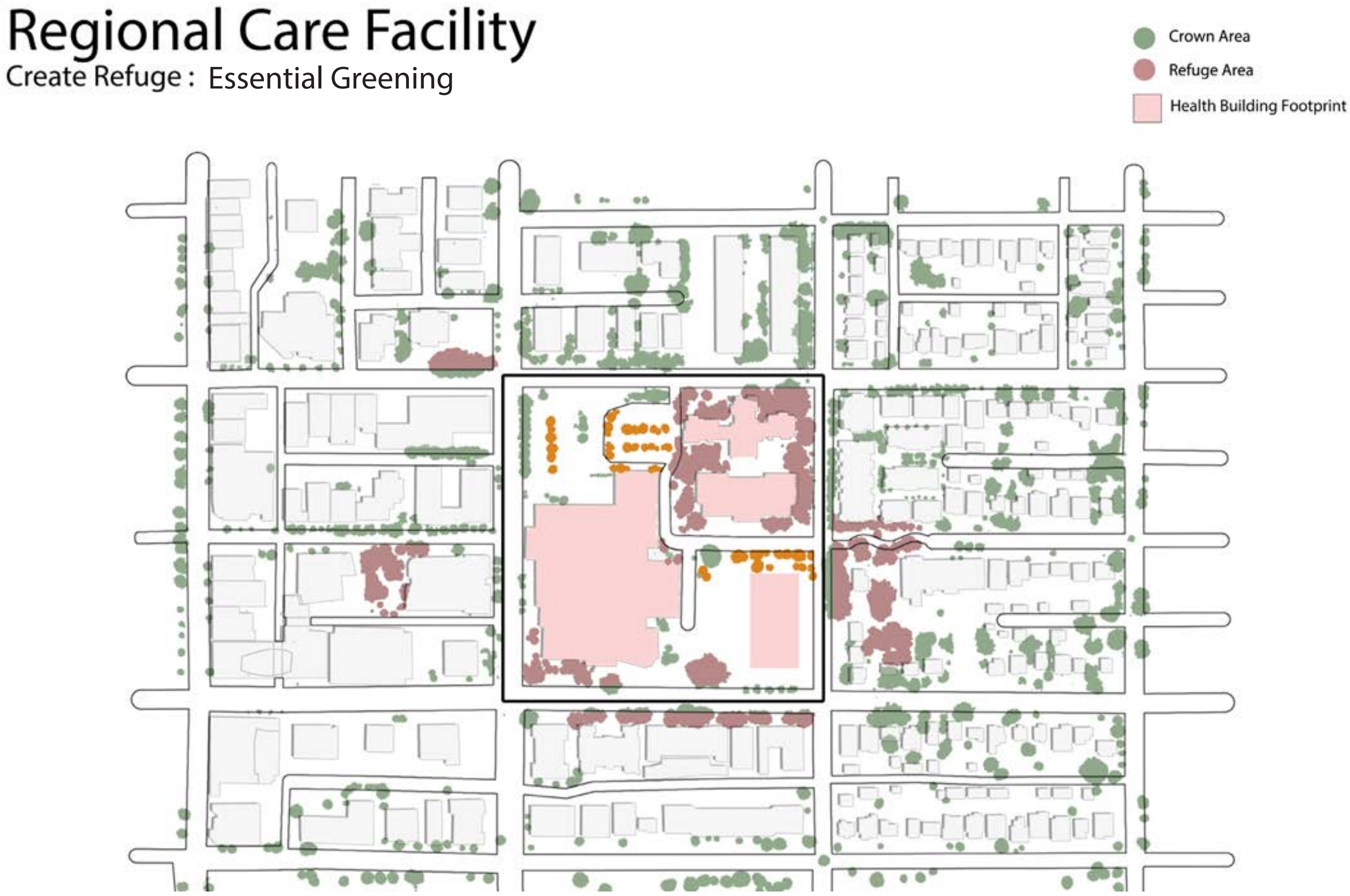


Figure Fifty Three: The additional refuge spaces created in the Essential greening scenario.

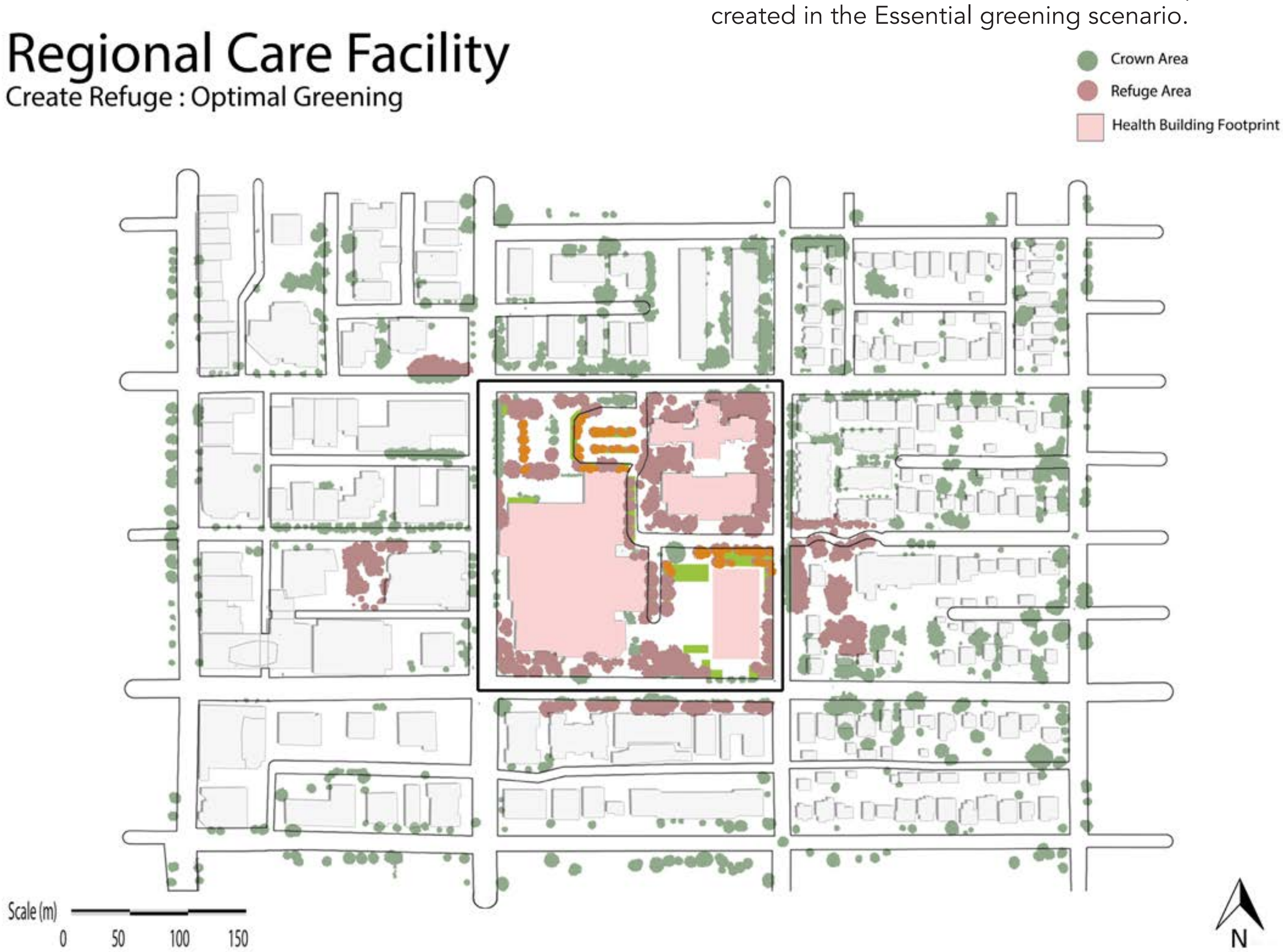


Image Credit: CALP, Xinke Yu

Figure Fifty Four: The additional refuge spaces created in the Optimal greening scenario.

STRATEGY SEVEN: Connect Experiences

Around seventy-two percent of the right of ways in and around the health campus are connected with continuous canopy or eye level greenery. However, all the connected green corridors are on the perimeter of the campus. There are no connected green pathways within the campus connecting all of the buildings on the campus. The essential and optimal greening scenarios add green all the movement corridors within and immediately bordering the health campus.

	Base Case	Essential Greening	Optimal Greening	Green roofs and facade
% connected pathways	72	75	77	75

Table Seventeen: The percentage of pathways with connected green corridors for each scenario in the Regional Care Facility experiential neighbourhood

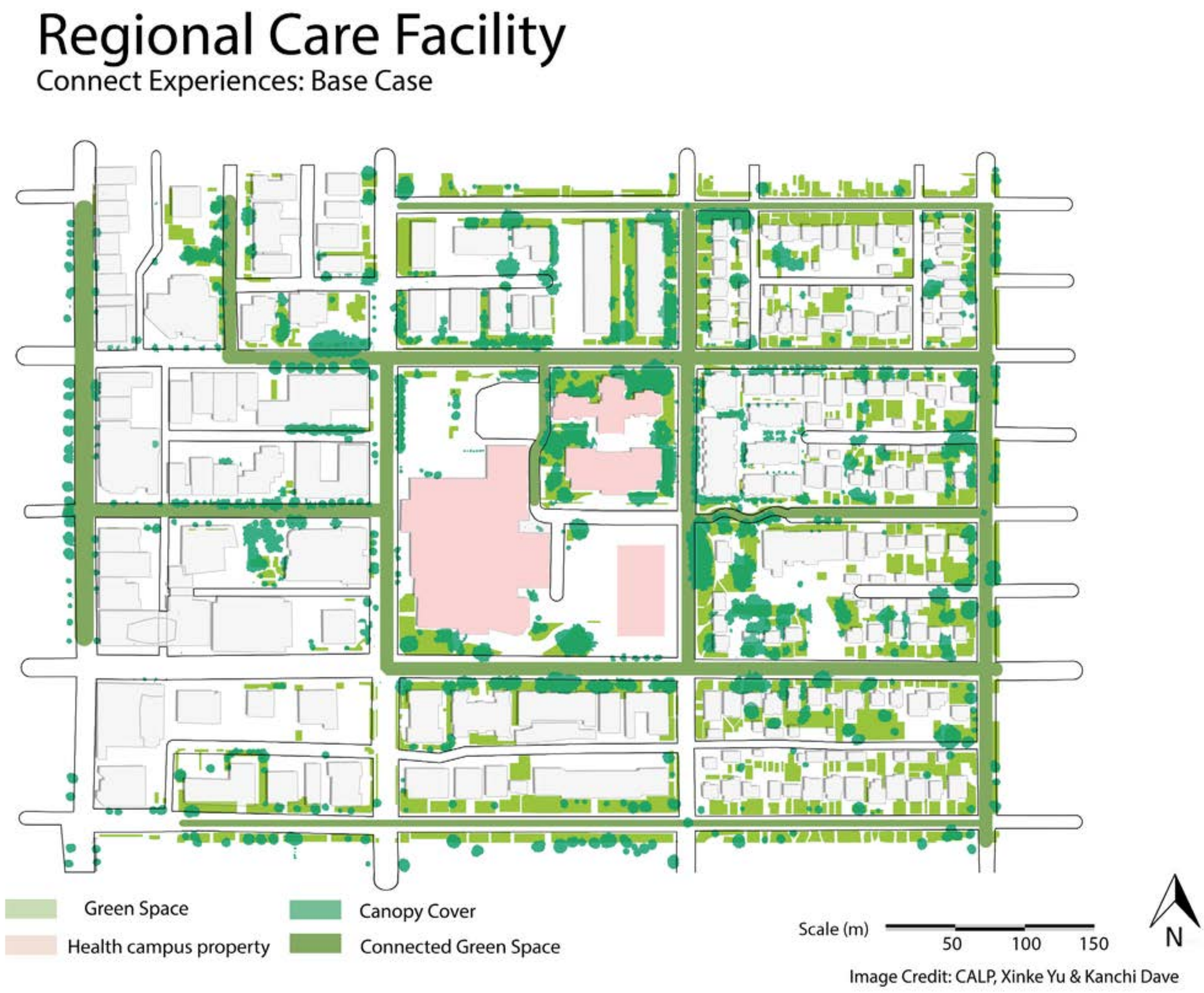


Figure Fifty Five: Existing connected green corridors in the neighbourhood.

STRATEGY SEVEN: Connect Experiences

Connect Experiences: Essential Greening

Figure Fifty Six: New connections in the Essential greening scenario.

Connect Experiences: Optimal Greening

Figure Fifty Seven: New connections in the Optimal greening scenario.

STRATEGY EIGHT: Optimize Green Infrastructure

The overall canopy cover of the experiential neighbourhood is currently twelve percent. In this scenario, all new trees are added only to the campus meaning that the overall canopy cover of the experiential neighbourhood cannot increase significantly.

	Base Case	Essential Greening	Optimal Greening	Green roofs and facades
% canopy cover	12	12	14	12
% pervious ground	17	17	17	19

Table Eighteen: The percentage of canopy cover and pervious ground changing through the four scenarios. Optimal greening has the highest canopy cover while adding green roofs would increase the pervious ground cover. All the scenarios still do fall short of the 40% canopy cover goal.

Figure Fifty Eight: Existing canopy cover and pervious surfaces in the Regional care facility.

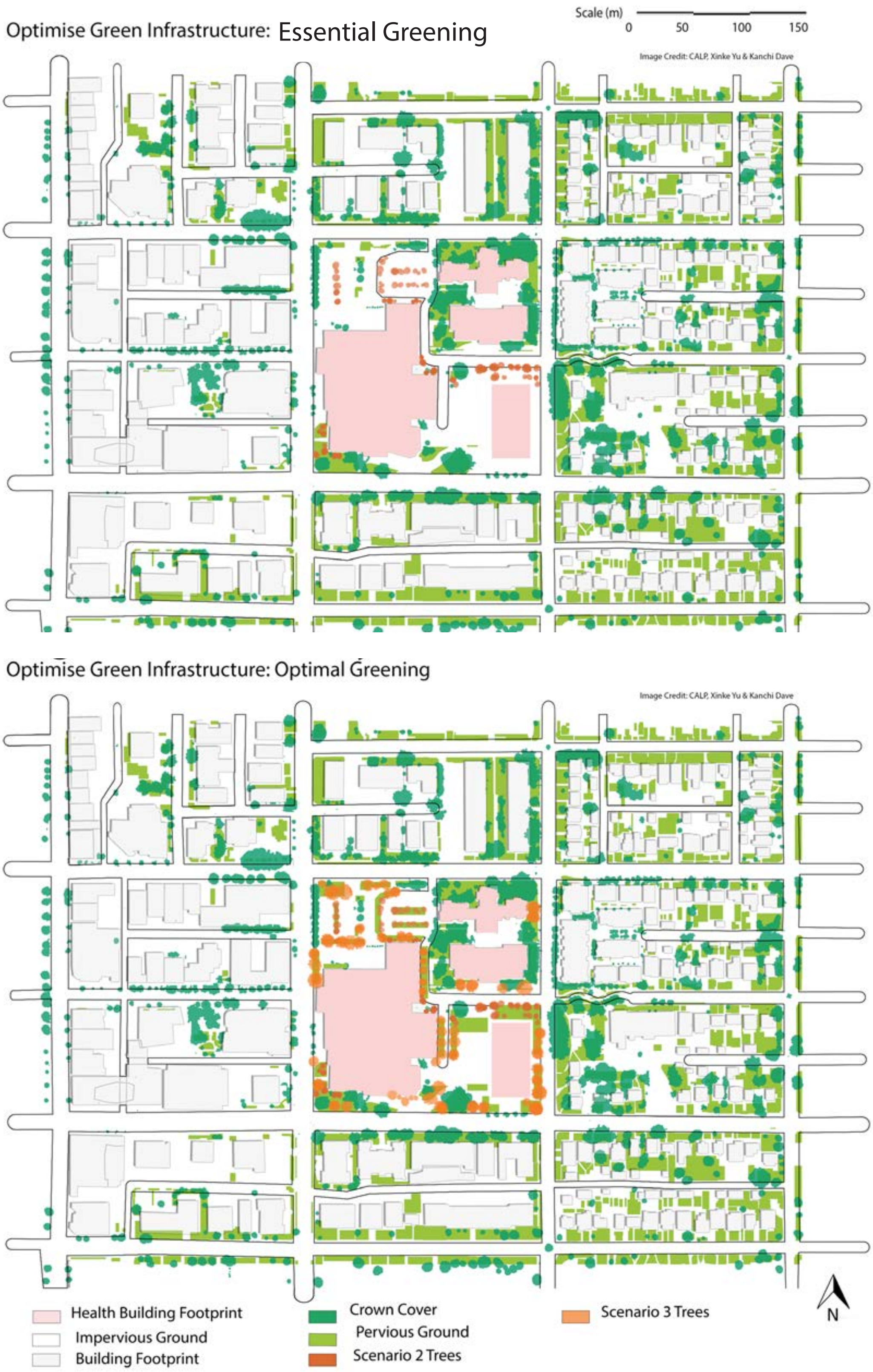


Figure Fifty Nine & Sixty: Plan view of the scenarios. Optimal greening closes a street to create quality nearby green space within the campus.

CONCLUSION

The preceeding pages show how applying the design strategies through their sequential pathways each contribute to the human wellbeing and climate-readiness of the facility. By measuring the base case, adding essential greenspaces to meet goals, and visualizing optimal greening strategies both on the ground and on roofs and facades, the scenarios provide guidance to help decison-making about new green spaces within and around the facility.

The concluding figure (below) shows how each strategy is improved through the scenarios. While the green cover surrounding the campus exists, there is limited green infrastructure within the campus. Emphasis on nearby green and entrance green for this Case Study explain the improvements in these two strategies.

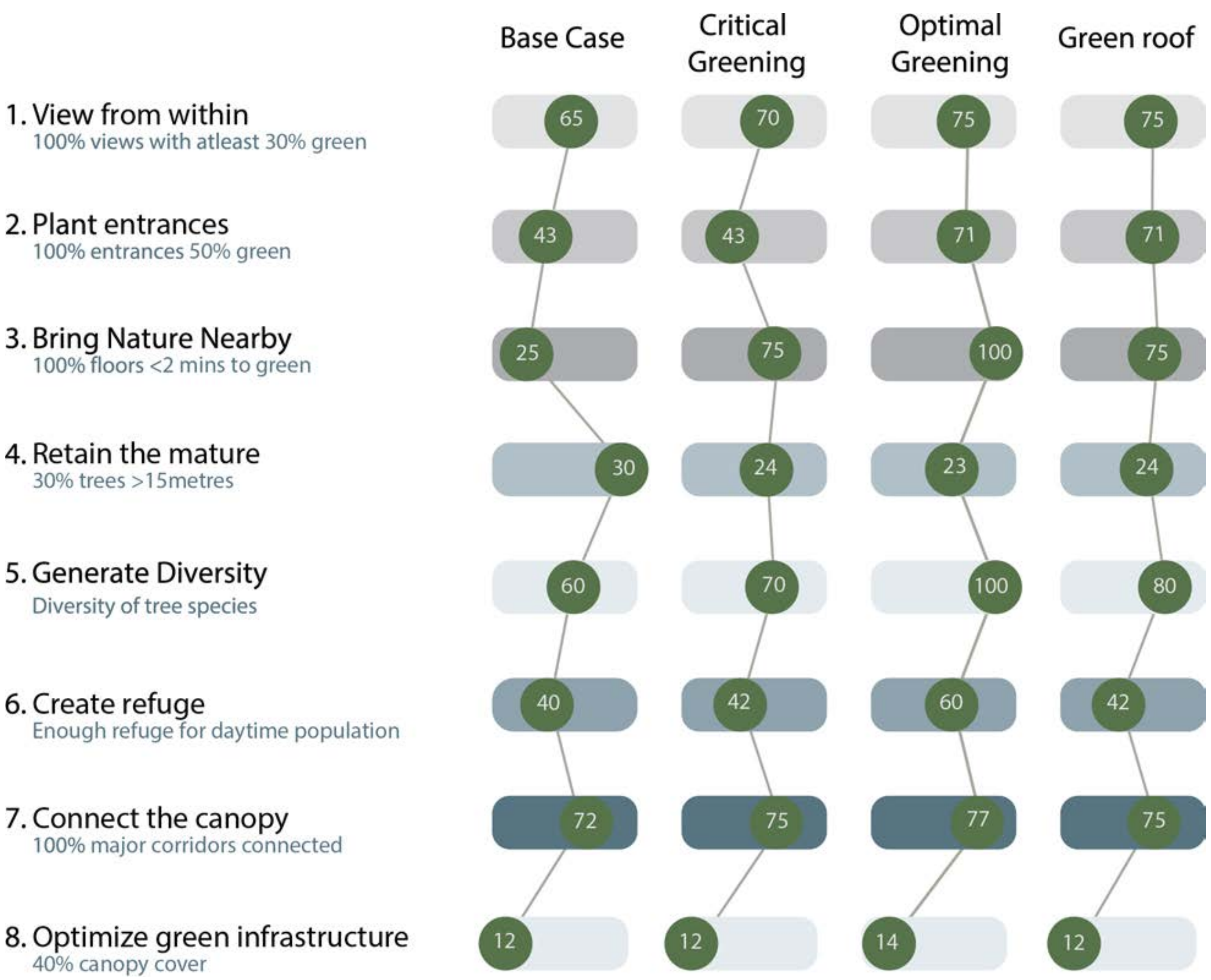


Figure Sixty One: Image showing the summary results of all the scenarios for all the eight design results. The goals are written in blue below the design stategies. Optimal greening has the best results of all the scenarios for the eight deign strategies. The mature trees strategy is temporatily low while new trees grow to maturity.

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