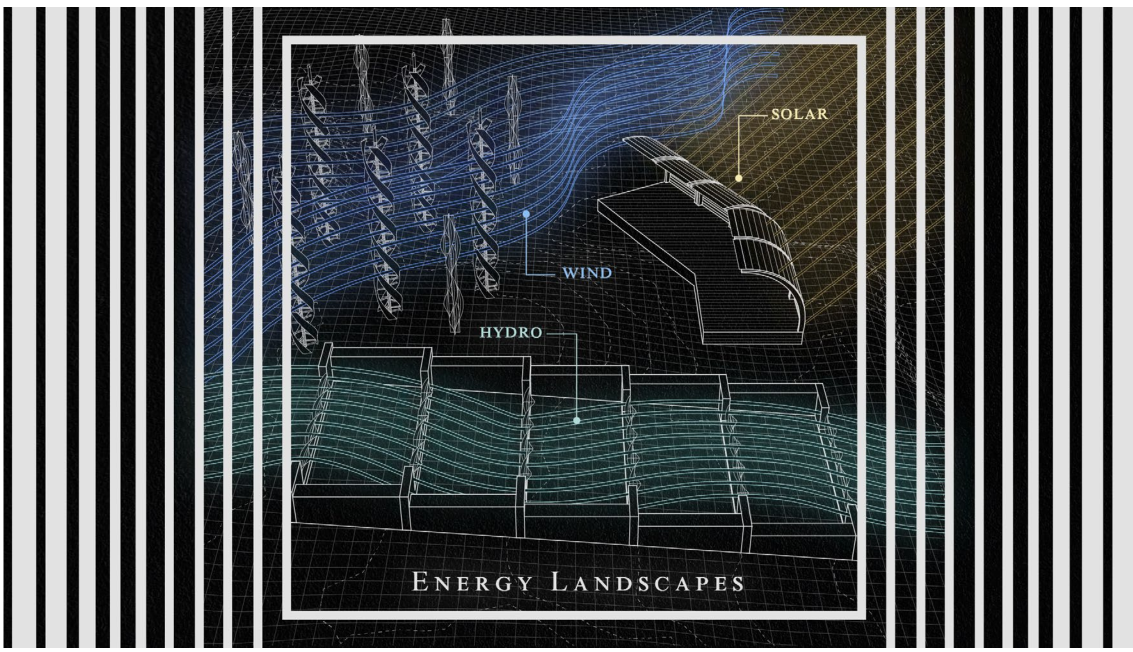
ENERGY LANDSCAPES
Small-Scale Solutions For Comprehensive Communities



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Abstract

With the escalating climate crisis, we are in desperate need of new technologies and solutions that will bring down greenhouse gas emissions in all aspects of our everyday lives. The energy sector is responsible for over 27% of the greenhouse gas emissions released annually and we are needing more energy than ever before to power our urban lives. We need to find solutions to keep up with demand when deploying renewable energy technologies, like solar panels on buildings, won't be enough. We need these renewable technologies everywhere and powering everything. In most cities, over 30% of land is city owned public space. This accounts for a lot of area that is currently under utilized for roads, sidewalks, parks, and auxiliary public spaces. How can small scale renewable energy solutions and technologies be integrated into our urban landscapes while reducing habitat and ecological impacts, increasing efficiencies and equitability in energy use, and above else enhancing a community's public realm and shared spaces? By analyzing current methods of energy production, evaluating the latest and best clean energy technologies, and thoughtfully selecting pilot sites and locations to deploy these new technologies, a comprehensive community can then be developed that mindfully and seamlessly integrates these energy solutions. This project aims to be a useful handbook for designing and discussing how small-scale technologies and innovations can be implemented into all scales of our everyday lives, from regions, to cities, to streets, to our very own yards, parks and streets.

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Acknowledgments

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To all the scientists, climate activists, and clean energy ambassadors, thank you for moving us towards a better future. To EM, thanks for dragging a reluctant world into the future and making sustainability and clean energy s3xy. This project probably wouldn't have come about 10 years ago without all the advancements we have made with renewable energy technologies. I look forward to what the next 10 years has in store and thank everyone who continues to strive to make our world a better place.

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A Brief Introductory Note

My goal for this thesis project is for the information and research shown to be approachable for everyone. I do not want to bury these ideas and technologies behind jargon and complex calculations. Of course, I could frame this thesis in a typical scientific manner, showing calculations for the 0.062 square meters of space required for the rate of energy transfer used for a 0.54 amp bulb operating at 110 volts…but I can see your eyes staring to glaze over already. Instead, I'll focus on breaking down such calculations and concepts into contextualized ideas and frameworks, making it easy to understand that a solar panel only the size of a single sheet of letter paper can illuminate a standard 60 watt incandescent light bulb. In comparison, a LED bulb could be powered by a playing card sized solar panel…but I'm not here to convince you to change your light bulbs. I believe that the research in this thesis needs to be distilled in a way that the information can be used and understood by anyone who is not familiar with the complexities and intricacies of energy production and distribution. While I'm not claiming to be a subject matter expert on the nuances of energy, my studies and education within the field of architecture and landscape architecture have allowed me to approach complex narratives and ideas, pull out the key underlying principals, and succinctly explain and visualize them in a way that is easy for all to understand…no technical expertise required!

If I've helped one person understand the challenges we face and the possibilities that we can create for renewable energy in public spaces, I've done a part in transitioning us towards a future with access to cleaner sources of energy. At the end of the day, I envision this project being a useful handbook for both myself and others to use when discussing and approaching the complex topics surrounding renewable energy production, in particular the small-scale technologies and innovations that can be implemented into all scales of our everyday lives, from regions, to cities, to streets, to our own backwards.

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An Essay on Energy

“Our opportunity, as designers, is to learn how to handle the complexity, rather than shy away from it, and to realize that the big art of design is to make complicated things simple.”

- Tim Parsey

Where We Are Now

The world is standing at a crossroads, where continuing forward on the path we've grown accustomed to will lead to its destruction, yet the alternative path may just be the most challenging problem humanity has ever faced. I'm talking about greenhouse gas (GHG) emissions and the escalating global warming climate crisis. We rapidly need new solutions to curb our emissions of greenhouse gases and bring our net carbon output down to zero. In 2021 it was estimated that the current amount of greenhouse gases released into the atmosphere is at all time high of 51 billion tonnes per year[1]. Fifty one billion. That's 51,000,000,000 tonnes (9 zeros!) worth gases that never used to exist in our environment. Now, it can be hard as a human to wrap our heads around how large this number really is. We can fairly easily visualize what a tonne of gases might be (picture a gaseous cube roughly 3 storeys tall and wide)…but 51 billion of these? Annually? That's as if everyone one currently on earth had 6 of these house sized cubes.

Of the GHG emissions released into the atmosphere, carbon dioxide (CO2) made up 32 billion of those tonnes released in 2021[2]. While other gases such as methane and nitrous oxide cause a higher short-term increase in climate warming when released into the atmosphere, carbon dioxide molecules last significantly longer in the air. So even though CO2 makes up only 63% of the GHG emissions, in 10,000 years there will still be over one fifth of those molecules left in the atmosphere (or about 6.4 billion of those gaseous house cubes left)[3]. For comparison, methane only has a 10 year atmospheric lifetime before being naturally absorbed. Now this project's focus is not to look at GHG and CO2 emissions, but these metrics play a critical role in why a proposal to help reduce our emissions is needed today.

[1] "Global Energy Review 2021," IEA (International Energy Agency, April 2021), www.iea.org/reports/global-energy-review-2021.
[2] IEA, " Global Energy Review 2021."
[3] EPA, "Understanding Global Warming Potentials," EPA (United States Environmental Protection Agency, 2021), www.epa.gov/ghgemissions/understanding-global-warming-potentials.

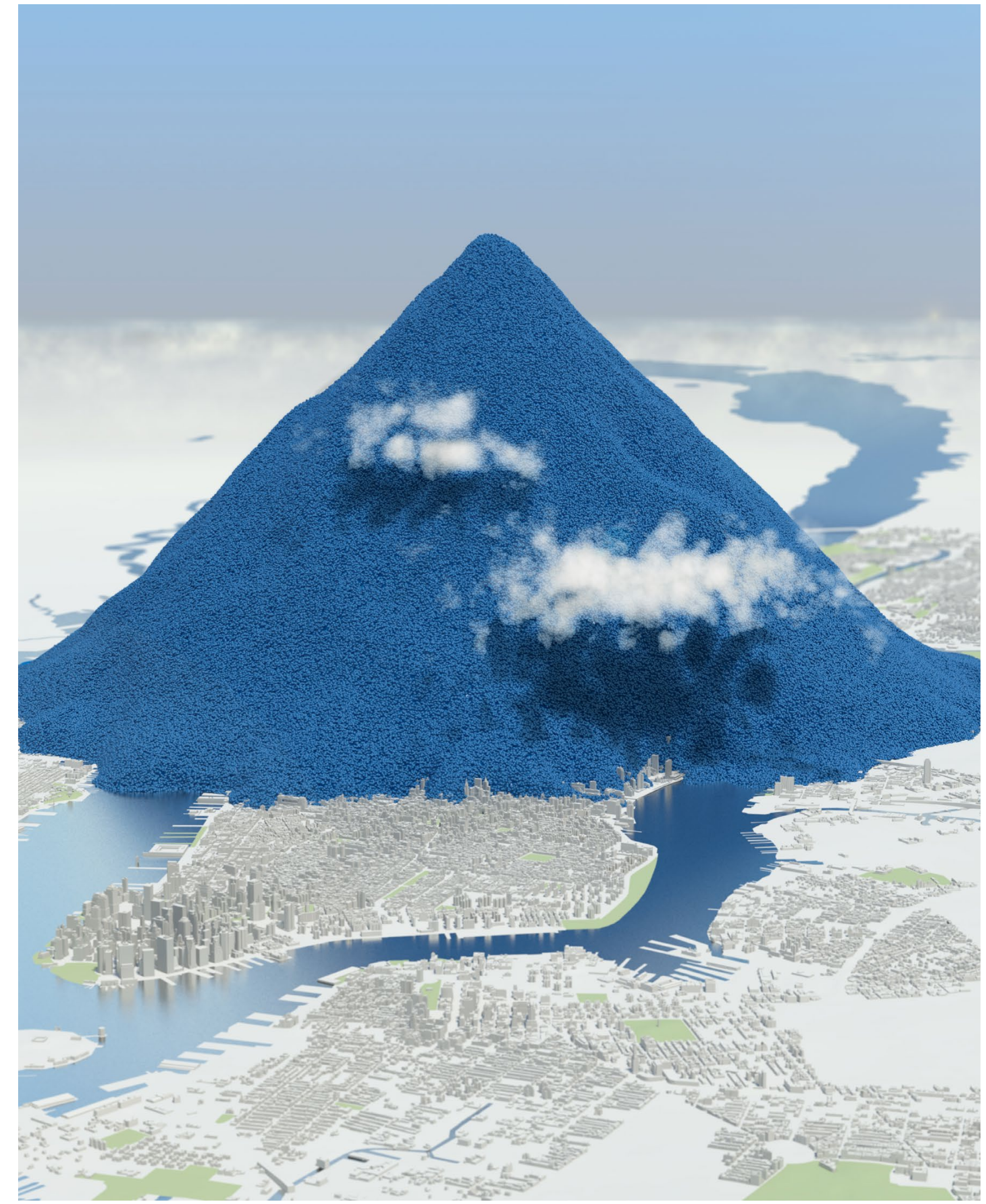

Figure 1. One Day's Carbon Dioxide Emissions from above - High Res Still from 'CCS: a 2 Degree Solution' (Film) © Carbon Visuals (https://www.flickr.com/photos/carbonquilt/15287664565/in/album-72157647370623779/). CC BY 2.0

Our Energy Addiction

One of the top polluting sectors that contributes to the growing GHG emissions is the energy sector (electricity specifically). It accounts for more than 27% of all emissions released annually[4]. What's especially terrifying about this number is that the energy sector is at an inflection point. The need for energy is not only at an all time high but is growing annually by 2.5% in North America[5]. As we race towards the future, energy demands have exploded. For example, just 30 years ago, the annual energy consumption of the US residential sector was 9.71 quadrillion British Thermal Units (BTUs)[6], which is roughly 2,845 Terawatt hours (TWh). In 2021, this number jumped to 3,379 TWh. Even with increased efficiencies, energy demands are expected to be 45% higher compared to today by the year 2040[7]. We are addicted to energy.

Look around you right now. Everything required some form of energy to be made. Even if you are somehow currently in the middle of a forest reading this paper, you theoretically needed to print out this paper, or have download it to a phone or tablet…all of which required energy in getting these words to you). Globally, over 36% of energy comes from coal, 23% from natural gas, 16% from hydro power, 10% from nuclear, and 11% from renewable energy sources[8]. There is a small silver lining in that renewable energy is the fastest growing energy division globally. Renewable energy sources include hydro power, wind power, and solar power. We'll dive deeper into these sources and their possible advantages and disadvantages in a later section. For the moment what is important to understand is that we need energy and we need it now. We also need this energy to be carbon zero (or as close to zero as we can possibly get), and we need it to be efficient!

[4] "Use of Energy Explained: Energy Use in Homes," EIA (U.S. Energy Information Administration, June 2021), www.eia.gov/energyexplained/use-of-energy/homes.php.
[5] IEA, Electricity in "Global Energy Review 2021."
[6] EIA, "Use of Energy Explained: Energy Use in Homes."
[7] "World Energy Needs," CAPP (Canada's Oil & Natural Gas Producers, October, 2021), www.capp.ca/energy/world-energy-needs.
[8] Bill Gates, How to Avoid a Climate Disaster: The Solutions We Have and The Breakthroughs We Need (New York: Random House, 2021), pp. 54-55.

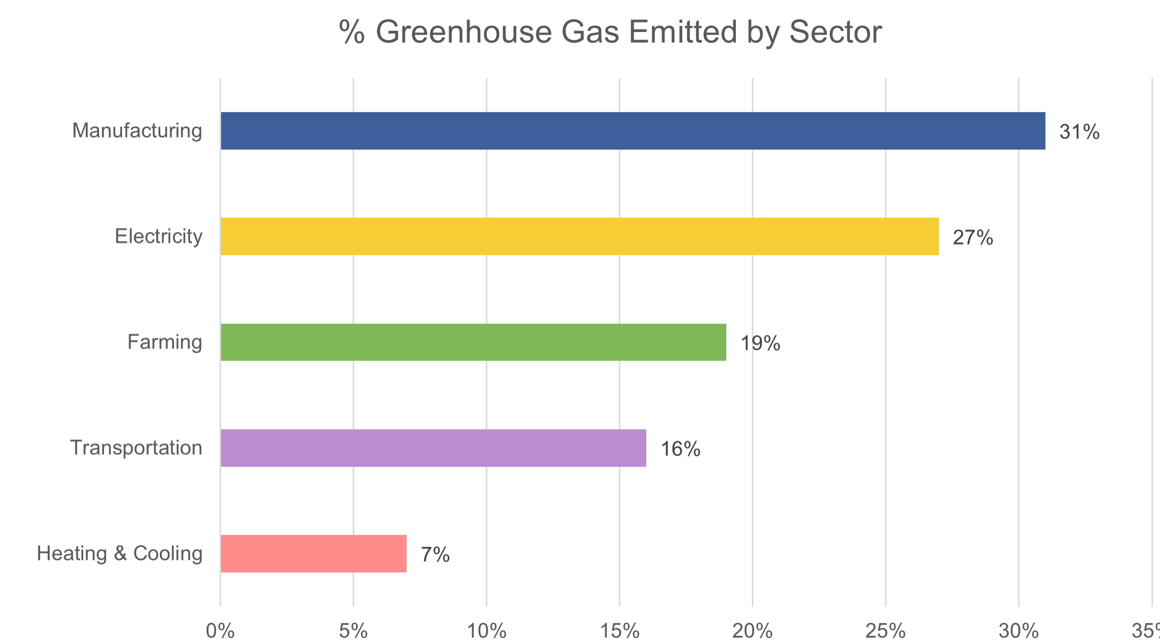

Figure 2. Percentage of Greenhouse gases that are emitted by sectors (2022, by author). Data retrieved from: Gates, How to Avoid a Climate Disaster: The Solutions We Have and The Breakthroughs We Need (New York: Random House, 2021), p. 55.

Terms & Conditions

Carbon: Neutral vs. Zero

I'll be using the term carbon zero in this project to discuss energy and design solutions that release no CO2 emissions. A common term you'll often hear in discussions around reducing carbon emissions is carbon neutral. You may be wondering "well, isn't that the same thing"? Carbon neutral does not equal carbon zero. Carbon neutral simply means that at the end of the day you've released a total net zero amount of carbon. The issue with this is that carbon neutral projects can still release carbon! They become carbon neutral through systems that allow them to offset or capture the carbon that they have released. It's like saying, for every 100 kilometers I drive of an internal combustion engine (ICE) car, I'll plant one fully mature tree to achieve peak carbon neutrally (if the average mature tree captures 25kg of carbon dioxide a year[9] and the average ICE car emits 0.25kg of CO_2 per km driven[10], you would need to plant 1 tree for every 100km driven to offset your emitted carbon). Simply put, carbon zero means no carbon was ever emitted, while carbon neutral means carbon was emitted but something was done to remove an equal amount of carbon from the atmosphere (think driving an electric car vs driving an ICE car and stopping to plant a large tree every so often).

Energy vs. Electricity

Now you may also be wondering what I mean by energy at this point. The simplest physics dictionary definition is "the capacity to do work", with work being "the force exerted over a distance". Perhaps a little confusing, right? Think of work as pushing or moving stuff around. Energy is then what makes it possible to push things around, or how much effort it will take to move that thing. Energy can be found all around us. Oil and gas have chemical energy that is converted to thermal energy when burned, water has motion energy when it flows down a river and gravitational energy when it becomes a waterfall, even sunlight has energy in the form of radiant energy[11]. Energy is typically measures in Joules, British Thermal Units (BTUs), Newton Meters, and Calories. However, the most common unit of energy we use in our everyday lives, is electrical energy and it is measured

[9] EcoTree, "How Much CO2 Does a Tree Absorb?," EcoTree, accessed May 1, 2022, https://ecotree.green/en/how-much-co2-does-a-tree-absorb.
[10] "U.S. Environmental Protection Agency (EPA), "Greenhouse Gas Emissions from a Typical Passenger Vehicle," EPA (Environmental Protection Agency, March 2018), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100U8YT.pdf.
[11] "What Is Energy? Forms of Energy," EIA, (U.S. Energy Information Administration, December 2021), www.eia.gov/energyexplained/what-is-energy/forms-of-energy.php.

in watt-hours (Wh), or kilo-, mega-, giga-, or tera-watt hours. So, while energy can be sourced and measured in many ways, I'm going to be converting most energy units to watt-hours as it will help contextualize our energy demands in relation to electrical energy equivalents. Electricity is the primary component of the two areas that make up total energy GHG and carbon emissions (that 27% I referenced earlier). The other is energy used for heating buildings from non-electrical sources (think natural gas, oil, or even wood burning fireplaces). As the energy sector needs to convert to renewable sources, the majority of these renewables will be generating electricity to replace their fossil fuel power generating ancestors. Electricity needs to become the core of the energy sector.

Electricity vs. Power

I'll also be using the terms electricity and power relatively interchangeably throughout this project as they are generally used as synonyms for each other. However, I think it is important to mention that they are not the same thing. While electricity is a type of energy, think of power as how fast something can consume or make energy. We measure power in watts. Sunlight has energy as we mentioned above, so to generate power from the sun, we need to convert that form of energy (radiant) into another form of easily usable energy (electric). How quickly a solar panel can convert this energy is its power output. When needed, I'll make the distinction between the two to clarify any calculations or design methodologies. Now that we know a bit more about the differences between energy, electricity, and power, let's jump back to how we can achieve a carbon zero energy sector.

Dam It?

In Canada, we are extremely fortunate that over 69% of our electricity is generated from renewable sources… 60% of which is produced from large-scale hydro-electric dams[12]. In fact, Canada has one of the highest amounts watt hours generated per capita. So much so that, we often export our excess energy to other countries like the USA. Unfortunately though, despite the relatively high amounts of renewable electricity in the country, there has still been a rise in electricity generated from gas over the last 35 years[13].

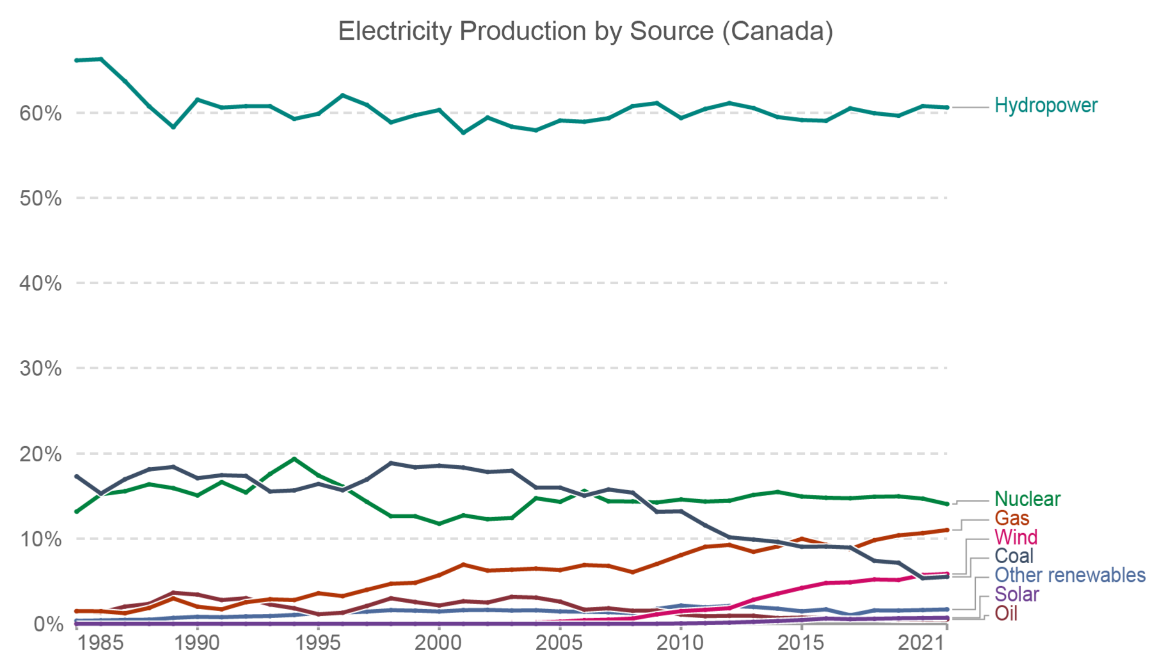

Figure 3. Electricity Production by Source in Canada. © Our World In Data (https://ourworldindata.org/grapher/primary-sub-energy-source). CC BY 4.0

In British Columbia, over 87% of the electricity we use is generated from hydro-electric dams located around the province[14]. In fact, we love our dams so much, that

[12] Hannah Ritchie, Max Roser, and Pablo Rosado, "Energy Mix," Our World in Data (Global Change Data Lab, November 28, 2021), https://ourworldindata.org/energy-mix#hydropower-what-share-of-energy-comes-from-hydropower.

[13] Ritchie, "Energy Mix", 2021

[14] Government of Canada, "Provincial and Territorial Energy Profiles," CER (Canada Energy Regulator, April 25, 2022), https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-british-columbia.html.

there are only 2 rivers in the entire province that have not been dammed and are still free flowing (the Laird and the Sitkine rivers)[15]. BC Hydro is the primary electricity producer in the province with 82 operating dams and over 75,000 kilometers of transmission and distribution lines[16]…or nearly enough power lines to wrap around the entire earth, not once, but twice! That's a huge network of infrastructure that traverses through our natural ecosystems and our communities, that not only had to be built but must now also be maintained.

While the energy produced from hydro is essentially renewable and often termed "clean", these large scale projects carry with them a host of issues. The damming of rivers

Figure 4 has been removed due to copyright restrictions. It was a photograph showing the environmental impact of construction at the location of the Site C Dam in British Columbia.

Figure 4. Site C Dam construction on the Peace River. © Garth Lenz for The Narwhal (https://thenarwhal.ca/wp-content/uploads/2018/10/%C2%A9Garth-Lenz-5443.jpg)

[15] Caroline Floyd, "Canada Home to Many of the World's Last Free-Flowing Rivers," The Weather Network (Pelmorex Weather Networks, May 19, 2019), https://www.theweathernetwork.com/ca/news/article/only-one-third-of-longest-rivers-on-earth-remain-free-flowing-mapping-hydropower-dams-development.

[16] BC Hydro, "Dam Safety & BC Hydro," BC Hydro - Power Smart (Government of British Columbia, 2022), https://www.bchydro.com/energy-in-bc/operations/dam-safety.html.

causes habitat fragmentation, impacts local and regional ecology and biodiversity, and the flooding of natural (and habitable) areas to create the reservoirs needed for the operation of these dams more often than not displaces communities and destroys culturally significant ancestral Indigenous land[17]. This doesn't even take into account the infrastructure needed to transmit this power from these remote locations to our urban communities and the effects that get strung along with the expanding network of these power lines.

Given our current pace for energy needs, we need to look for and find new ways to generate electricity through other even more sustainable forms of renewable energy. Large scale projects won't sustain our needs and often do not offer the resiliency we require. It is better to depend on 100 small sources of power rather than one large one.

So….

How can small scale renewable energy solutions be deployed and integrated into the public realm to create self-sufficient and resilient communities?

Integration of Today

Currently most urban renewable energy solutions are only deployed at the building scale. Naturally this makes the most sense. The easiest way to ensure your building is using clean energy is to integrate that clean energy generation into the building itself. Technologies such as solar panels, miniature wind turbines and geothermal can be designed into almost any new construction project, and even some renovations. With increased efficiencies in many of these technologies, it's even possible to supply 100%

[17] Anna Lieb, "The Undamming of America," PBS (Public Broadcasting Service, August 12, 2015), https://www.pbs.org/wgbh/nova/article/dam-removals/.

of a building's energy needs through its own interventions. However, many buildings will never be able to achieve these 100% targets whether by virtue of their design, their location, or even their micro-climates.

Let's take a quick look at powering a building on 100% solar. Firstly, your building we will need to have ideal siting conditions such as high sun, low shade, and even be in a climatic area with low daily cloud coverage[18]. If you can achieve this, the next thing you'll need is space for the solar panels. Buildings with large roof footprints with low energy demands will easily have capacity to transition to 100% solar. But what if you live in a high-density condo tower? Roof space for solar is limited, and all 150+ units will likely draw more power than the roof footprint allows…even if the building is highly energy efficient. If we ensured all future built buildings and homes achieved the highest standards

Figure 5. Solar panels mounted on building roof. © William F. Hertha (https://hertha.ca/blog/2015924installing-the-solar-panels). CC BY-NC-ND 4.0

[18] Alan Emanuel Ribeiro, Maurício Cardoso Arouca, and Daniel Moreira Coelho, "Electric Energy Generation from Small-Scale Solar and Wind Power in Brazil: The Influence of Location, Area and Shape," Renewable Energy 85 (January 2016): p. 554-563

of energy efficiency and were decked out in solar, there may still be buildings that will never be able to power themselves on 100% of their own renewable energy just due to their design or site location. If urban energy demands continue to rise, there needs to be alternative solutions that help transition everyone and everything to renewable energy sources.

Where Can It Go?

If not all buildings will be able to generate their own energy, and we can't fully rely on your grid energy to be 100% renewable, how will we be able to transition to a carbon zero energy reliance? We have the technologies. We have the building efficiency. But we are lacking some space to integrate these systems. Let's zoom in a little bit here and try to give ourselves some context to work a few things out. In the city of Vancouver, roughly 25% of the land area is made up of city owned and operated roadways[19]. This includes highways, main roads, smaller residential streets and laneways. If we threw in all the public parks and greenspaces too, the amount of city owned space could easily add up to 30% of all usable land. This is a huge portion of our urban environment that is dedicated solely as "city space". At the moment, this space is used mostly for transportation, of people, goods, and of resources such as water, sewage and energy, both above and below ground.

These city spaces not only have the capacity to offer more but the ability to connect and enhance our relationship to the urban environment. Roadways and transit corridors

[19] City of Vancouver, "Vancouver Open Data "(Vancouver, 2021).

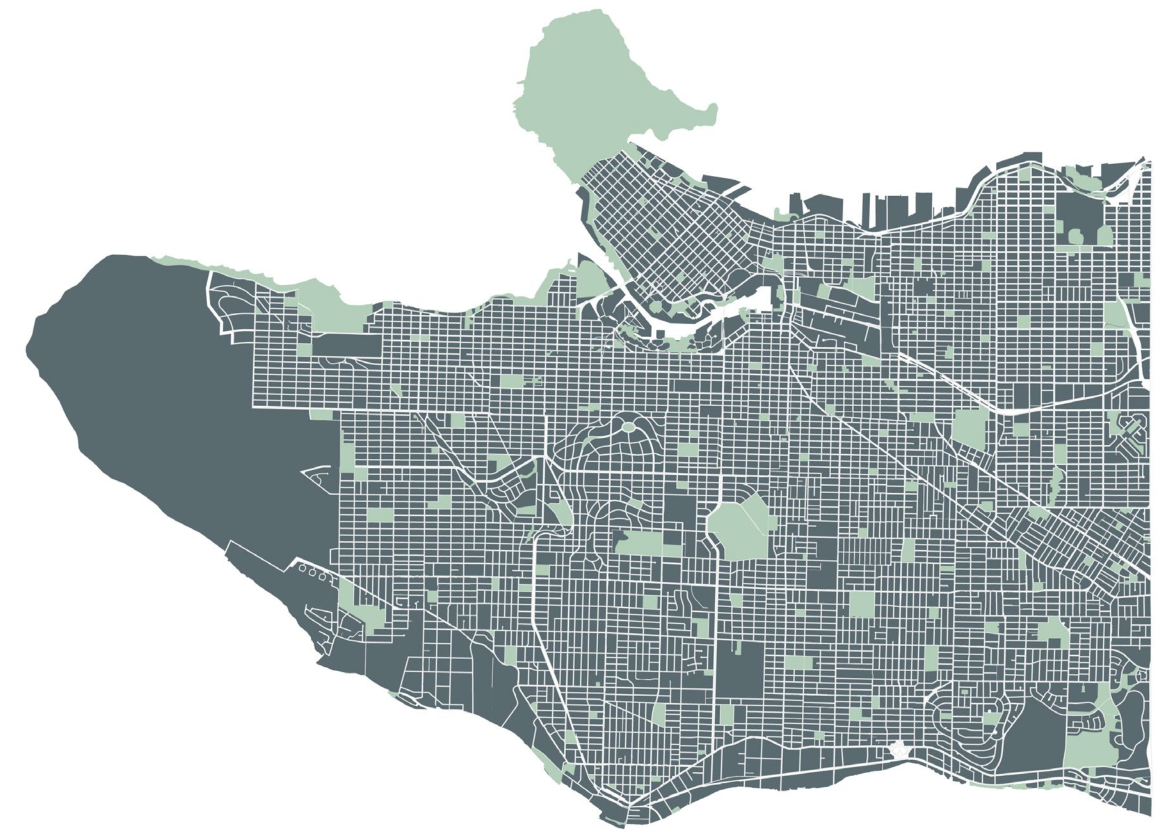

Figure 6. City of Vancouver Map (2022, by author). Data retrieved from: City of Vancouver Open Data Portal (https://opendata.vancouver.ca/explore/). Open Government License – Vancouver

are a matrix that run through almost all cities, and there is opportunity to maximize their usefulness while also building better public realms. Speaking of public realms, what if we took it a step further? What if we added in all the adjacent aspects of the public realm to this 30% total of "city space"? The City of Vancouver defines public realm as "the sum of parts" that make up the city, from building facades, to patios, to street furniture, to side walks and lighting[20]. These are the spaces that we generally interact with at eye level. Though portions of these spaces are privately owned (think of a plaza in front of an

[20] City of Vancouver, "Places for People," City of Vancouver, 2018, https://vancouver.ca/files/cov/places-for-people-information-boards.pdf.

office tower), they are still spaces within the public realm that could offer opportunities for renewable energy integration. Now that we know that there is space for renewable energy solutions within our urban cities, it is up to today's designers to stop dreaming of what could be and start flexing their design fingers to incorporate small scale renewable energy technologies everywhere.

Why Design(er)s Matter

Architects and landscape architects are in a unique position in that they design systems, buildings, spaces, and places literally from the ground up. Designers are able to distill complicated subjects and translate them into ideas and terms that are clearly represented. Sure, anyone can slap some solar panels on a roof and call it a day, but what designers bring to the table is a carefully throughout way in which to insert these systems into the world around us. On top of that, the role of a landscape architect or architect does not need to be based in complex technologies in order for us to use them in our designs. We can strive to understand the underlying principals and mechanics of complex system so that we can be intentional and considerate of how they function within the bigger picture. Great designs are comprised of a complexity of rules, conditions, systems and technologies; what makes the great ones stand out is how everything works together and complements each other[21].

Designers are also at a leading edge for climate change. We are in a position to design, recommend and integrate solutions into projects of the future today. While many

[21] David J. Kiss, "Principles: Scale and Proportion," in Designing Outside the Box: Landscape Seeing by Doing (Lulu.com, 2017), pp. 153-168.

energy solutions may need to be retrofits, designers, architects, and landscape architects should be leading the charge when it comes to building sustain and energy efficient buildings and spaces. After all, if we are the ones driving the bus, why not make the bus electric?

What's Up Next?

In further sections, I will dive into precedent cities that have (or are striving) to locally generate 100% renewable energy. These technologies and cities will also further highlight the importance of designs that work to serve a single purpose versus great designs that respond to a multitude of complexities. It's easy to design systems in isolation. Where an architect or landscape architect really shines is understanding enough of every single system and then deploying them in a way that works not only with human and nature, but across varying scales as well . With my precedents in hand, I will then begin to breakdown what it will take to start designing renewable energy solutions into an urban context. I'll begin by exploring and cataloging reoccurring typologies that can be found within most cities and urban contexts before jumping into the methodology behind implementing these solutions. I'll narrow my focus to "pilot" sites so that my designs are site based, while also delving into a variety of small-scale renewable energy solutions that could be deployed on these pilot sites. And then, finally, I'll present my final findings as small design propositions that could extrapolated to other site, cities, or even countries around the world.

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Precedent Studies

"Nothing in this world is more simple and more cheap than making cities that provide better for people."

- Jan Gehl

Copenhagen, Denmark

Scale: City

Area: 8,825 hectares (88.25 km^2)

Goal: First Carbon Neutral City

Target Year: 2025

Energy Infrastructure & Technologies: Off Shore Wind, Solar PV and Solar Thermal, Biomass and Waste to Energy, Energy Efficient Building Standards

Copenhagen plans to be the first major city in the world to be 100% carbon neutral by 2025. The plan includes the reduction of energy consumption through energy efficient buildings, increased renewable energy production to completely replace CO2 emitting fossil fuel energy, reduce carbon emissions from the transportation sector, and have zero emission construction and building sites[22] .

At the moment the greatest reduction of CO2 emissions has come from Copenhagen's increased development and use of renewable energy technologies, mainly in the form of wind farms and solar PV solutions on buildings. The Copenhagen International School features one of the world's largest solar facades built to date that is able to generate more than half of the buildings energy needs[23].

Advantages:

Multiple systems work together to reduce Copenhagen's GHG emissions. Renewable energy solutions and emerging technologies have put the city on pace to meet their 2025 target. Dual energy system are advantageous, as wind power yields can fluctuate

[22] City of Copenhagen, "The CPH 2025 Climate Plan," The CPH 2025 Climate Plan | Urban development (Technical and Environmental Administration, City of Copenhagen, December 2017), https://urbandevelopmentcph.kk.dk/node/5.

[23] Lorraine Chow, "World's Largest Solar Panel Facade," EcoWatch, February 2017, https://www.ecowatch.com/solar-facade-denmark-school-2263274993.html

Figure 7. Figure 07. Lillgrund Wind Farm off the coast of Copenhagen. © Mariusz Pazdziora (https://en.wikipedia.org/wiki/Lillgrund_Wind_Farm#/media/File:Sund_mpazdziora.JPG). CC BY-SA 3.0

Figure 8 has been removed due to copyright restrictions. It was a photograph of the Copenhagen International School facade in the evening emphasizing the solar glass.

Figure 8. Copenhagen International School. © Adam Mork for Moller Architects (https://www.cfmoller.com/imgintra/Copenhagen-International-School-Nordhavn-C-F-Moeller-img-60287-w1000-h430-tD.jpg)

throughout the year. Waste to Energy also doubles as a heat source at their combined heat and power that distributes the heat through a district heating network. Targeting other sectors to reduce emissions, such as through sustainable transit and implementing zero emission building standards and encouraging sustainable building materials (wood frame construction) will also bring down energy needs overall[24].

Disadvantages:

Copenhagen is looking mainly at large scale infrastructure projects to bring down it's carbon emissions and transition itself to renewable energy. Large scale projects can be expensive to implement and are often only feasible for larger communities and cities, such as Copenhagen. It can be challenging to retrofit an existing city to be carbon zero. There will need to be solutions to help older buildings become less energy intensive, and even reorganization of some city zoning so that communities are more comprehensive, thus allowing for more walking and biking type commutes.

Main Takeaways:

- More small scale energy solutions
- Look to new and innovative technologies that can generate energy (ie solar facades)
- Ensure community is comprehensive with necessities within a close walking or biking distance to reduce the need to travel
- Localize energy production (solar) can be supplemented with renewable energy produced outside of community (off shore wind) if needed

[24] Daniel Braff, "Copenhagen to Be Carbon Neutral by 2025," Green City Times, September 2020, www.greencitytimes.com/copenhagen/.

Figure 9. Wind turbines off the coast of Denmark. © CGP Grey at http://www.cgpgrey.com/ (https://www.flickr.com/photos/cgpgrey/4890240265/). CC BY 2.0

Vauban, Freiburg, Germany

Scale: Community

Area: 38 hectares (380,000 m^2)

Goal: Europe's First Eco-District

Year Completed: 2002

Energy Infrastructure & Technologies: Solar PV, District Heating, Passive House Buildings, Biofuel Heat and Energy Systems,

The small Vauban district of Freiburg, Germany is regarded as one of the first "eco-districts" and a leading example of what sustainable urban living can be. It's "Sun Ship" settlement (as seen in Figure 10) is known as Europe's solar city and the first community in the world to have buildings that produce more energy than they consume[25].

The both residential and commercial buildings in Vauban are built to Passive House standards and are equipped with solar panels on the roof and heat pump systems to keep them highly energy efficient. All the energy required to power Vauban is generated locally within the district through various renewable energy systems, such as biofuel waste to energy which runs the district heating system as well as generating additional power outside of the rooftop solar photo voltaic panels[26].

Advantages:

Vauban was a master planned community (Figure 11), and the planners integrated the most advanced energy technologies at the time into every phase of the project. Homes and buildings where carefully planned out and sited to achieve maximum solar energy

[25] David Thorpe, "The World's Most Successful Model for Sustainable Urban Development," Smart Cities Dive, 2017, www.smartcitiesdive.com/ex/sustainablecitiescollective/words-most-successful-model-sustainable-urban-development/

[26] Daniel Braff, "Most Sustainable Town in Europe," Green City Times, November 2020, www.greencitytimes.com/europe-s-most-sustainable-city/

Figure 10. "Sun Ship" settlement in Vauban. © Mangan02 (https://upload.wikimedia.org/wikipedia/commons/4/42/Solarschiff_Solarsiedlung_Freiburg_im_Breisgau_september_2014.jpg). CC BY-SA 4.0

Figure 11. Vauban Urban District Map. © District of Vauban - Stadtteil Vauban (https://stadtteil-vauban.de/en/quartier-vauban-2/). CC BY 2.0

capacity, and energy efficiency was the foundation of everything constructed.

Vauban also reduces it's carbon footprint through other interventions, such as having a car-free zone within the district, and encouraging residents to walk and bike to most places. As a result, Vauban emits over 2,100 tonnes less CO2 than a European community of similar size[27].

Disadvantages:

Vauban has not been without controversy though. Many view the community as not being inclusive enough. A majority of the homeowners in Vauban are sustainability specialist and are of middle income. While Vauban does have some low income rental homes, it can still be difficult to afford to live in the eco district[28]. While the streets are lined with trees and shrubs, many have also complained of the lack of visual interest in Vauban. Buildings take on the same characteristics with just a different colour of paint, and the community as a whole feels repetitive according to some residents[29].

Main Takeaways:

- Prioritize certain site locations for solar gains
- Incorporate more than 1 system for energy production
- Encourage GHG reductions in other sectors (ie.transportation)
- Inclusive housing and affordability for a wide range of demographics

[27] Thorpe, "The World's Most Successful Model for Sustainable Urban Development."
[28] Thorpe, "The World's Most Successful Model for Sustainable Urban Development."
[29] Andrew Purvis, "Freiburg, Germany: Greenest City in the World?," The Guardian (Guardian News & Media, March 2008), www.theguardian.com/environment/freiburg.germany.greenest.city.

Figure 12. Car-Free street in Vauban eco-district. © Lieven Soete (https://www.flickr.com/photos/lievensoete/7904535554/in/album-72157631248508562/). CC BY-NC-SA 2.0

Figure 13. Vauban public park and trail system. © Adeupa Brest (https://www.flickr.com/photos/adeupa/2402425583/in/album-72157604470478877/). CC BY-NC-SA 2.0

Solar Strand, University of Buffalo, USA

Scale: Site

Area: 8,825 hectares (88.25 km^2)

Goal: A Hybrid Energy Landscape Pilot Project Merging Energy, Ecology and Education

Year Completed: 2012

Designer: Hood Design Studio, California

Energy Infrastructure & Technologies: Solar Panel Arrays, Drought Tolerant Planting

Hood Design Studio was the winner of the 2012 University of Buffalo's Solar Park Competition. The solar Strand project is a small scale project (in comparison to the two previous city and community based precedents) that is capable of producing over 750 kW of energy through a 5,000 PV solar panel array[30]. The project provides enough renewable energy for over 700 on campus dormitories and reduces the campus' GHG emissions by 400 tonnes annually[31].

This project is unique in that incorporates community relationships and public space into it's agenda. Instead of hiding the energy production away, the Solar Strand project is situated at the gates of campus, welcoming students and faculty to take a stroll through the Solar PV field[32]. Pockets of public spaces were created through the orientation of the PV panels, providing shaded space in the summer and even event space for pop up markets and outdoor classrooms.

Advantages:

The one energy technology solution in this project is ideal as it allowed the design

[30] Hood Design Studio INC., "Solar Strand Project," HOOD DESIGN STUDIO, 2013, www.hooddesignstudio.com/solarstrand.

[31] John Della Contrada, "Walter Hood to Design Solar Array on UB Campus," University at Buffalo, April 2010, www.buffalo.edu/news/releases/2010/04/11249.html.

[32] "Solar Strand: Climate Change Exhibition," American Society of Landscape Architects, 2013, www.climate.asla.org/SolarStrand

Figure 14 has been removed due to copyright restrictions. It was a photograph of the solar PV installation "Solar Strand" at the University of Buffalo with tall grass at sun set.

Figure 14. Solar Strand with tall grass at sun set. © Douglas Levere Photography for Hood Design Studio (https://i0.wp.com/dirt.asla.org/wp-content/uploads/2022/04/solar-strand.jpg)

Figure 15 has been removed due to copyright restrictions. It was a photograph of the solar PV installation "Solar Strand" at the University of Buffalo set up as a community market.

Figure 15. Community market at Solar Strand. © Douglas Levere Photography for Hood Design Studio (https://images.squarespace-cdn.com/content/v1/57e2e36c893fc0b0fd1bc325/1488392962385-0HI30EV8BPFF7JQ6GSFJ/Earthday.3x5a9494_1.JPG)

team to focus specifically on the best ways to deploy the Solar PV panels. The design ends up not being overly complicated, yet still highly functionable to achieve the energy production goals. The single system was able to achieve additional goals outside of energy generation (such as public spaces). Having a narrowed focus also meant the designers could look for energy efficiencies within the landscape itself by introducing drought tolerant plants that required little to no care.

Disadvantages:

There is definitely opportunity on this site to further push energy integration and the community interaction proportions. While the use of one energy technology is justified for a competition project, it would be interesting to integrate other solutions into this scale of project. What might the project look like with micro-wind turbines that can operate during low solar generating days?

Main Takeaways:

- Potential to have a primary energy system that is very well integrated into all aspects of the project. How can one system be pushed to the extreme?
- Incorporate public space into and around the energy system(s)
- Educational opportunities on renewable energy generation
- Consider how energy can be conserved through even the smallest interventions (ie. drought tolerant planting schemes, low maintenance public spaces)

Figure 16 has been removed due to copyright restrictions. It was a photograph of the solar PV installation "Solar Strand" at the University of Buffalo showing an educational class taking place.

Figure 16. Educational class at Solar Strand. © Douglas Levere Photography for Hood Design Studio (https://images.squarespace-cdn.com/content/v1/57e2e36c893fc0b0fd1bc325/1488393046167-8M5N9MF85V1A3TXJBPNT/3X5A1174.jpg)

Figure 17 has been removed due to copyright restrictions. It was a photograph of the solar PV installation "Solar Strand" at the University of Buffalo showing the walking paths between the solar PV panels.

Figure 17. Solar Strand walking path. © Douglas Levere Photography for Hood Design Studio (https://images.squarespace-cdn.com/content/v1/57e2e36c893fc0b0fd1bc325/1488392929451-ZRFJAFL81M018Z0ZUUJ3/6+red+dress1.jpg)

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The Analysis

"The most dangerous phrase in the English language is
'we have always done it this way'."

- Dr. Grace Hopper

Space Typologies

After exploring and researching today's leading renewable energy cities, communities and sites, I began to breakdown what makes these projects what they are and what characteristics that could be found within them that may be replicable in other areas or communities. I was pleased to find that within most urban centers, such as in the precedent areas I analyzed and Vancouver, I was able to identify 3 common and recurring space typologies that could offer design opportunities for renewable energy integration.

The three typologies are:

Corridors

Greenspaces

Plazas/Open Spaces

Corridors

We know these types of spaces very well and they can be found pretty much everywhere. From our city roadways, to pedestrian and cycling paths, to little alleyways building buildings - these spaces exist to move and connect us from one place to another.

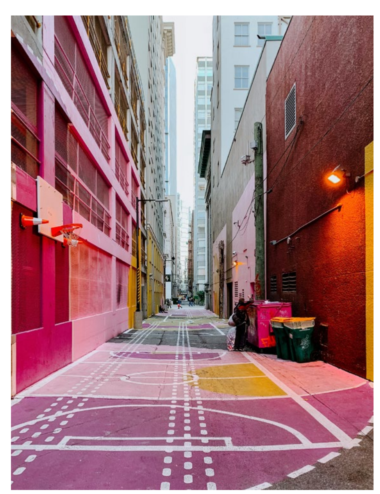


Figure 18 (left). Granville St, Vancouver. © AE Creations (https://www.flickr.com/photos/aecreations/5160248990/in/album-72157625191249152/). CC BY-NC-ND 2.0
Figure 19 (center). Hornby St bike lane, Vancouver. © Paul Kreuger (https://www.flickr.com/photos/pwkrueger/5973057250/in/album-72157625160007617/). CC BY 2.0
Figure 20 (right). Alley-Oop (The Pink Alley), Vancouver. © Aditya Chinchure (https://unsplash.com/photos/5-ZnHMSBRTM). CC0 1.0

Greenspaces

Who doesn't love a bit of nature in the city? These spaces include parks, green networks and waterfronts, but also extends to community gardens, planted medians and those curbside grass and tree strips.

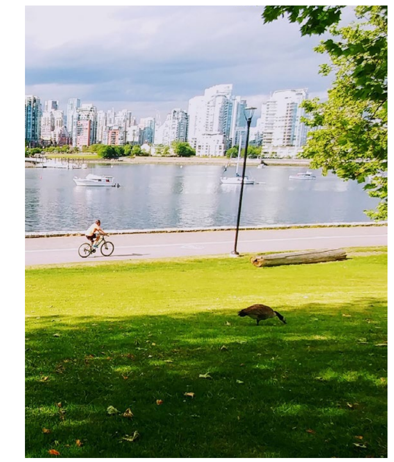
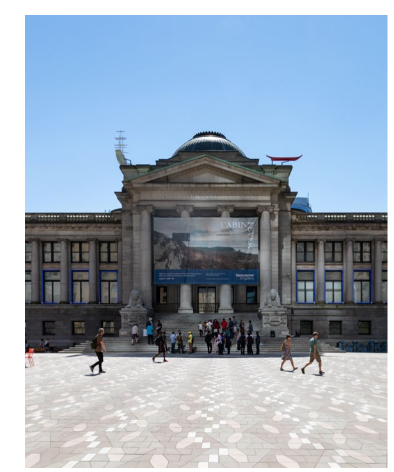


Figure 21 (left). Stanley Park, Vancouver. © Ethan Mabunay (https://unsplash.com/photos/LvMUk9Gq5uA). CC0 1.0
Figure 22 (center). School Green, Vancouver. © Larry Nalzaro (https://unsplash.com/photos/BZGdwD9EEAU) . CC0 1.0
Figure 23 (right). Street Tree, Richards St, Vancouver. © City of Vancouver (https://thethunderbird.ca/wp-content/uploads/2022/02/trees1-e1644971500979-1024x970.jpg). CC BY 2.0

Plazas/Open Spaces

These spaces are generally large and more often than not, of a hardscape in nature. The amount of people present on them can be few - think people enjoying their lunch in their office's front plaza, or quite full in a concert or activist setting.

Figure 24 has been removed due to copyright restrictions. It was a photograph of the Olympic Village Plaza in Vancouver BC.



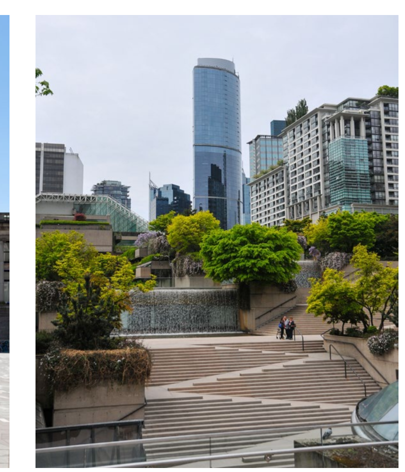


Figure 24 (left). Olympic Village Plaza, Vancouver. © Stephanie Braconnier (https://futurelandscapes.ca/olympic-village-waterfront)
Figure 25 (center). Vancouver Art Gallery Plaza. © Dronepicr (https://upload.wikimedia.org/wikipedia/commons/c/ca/Vancouver_Art_Gallery_%2829787380987%29.jpg). CC BY 2.0
Figure 26 (right). Robson Street. © Alexander Serzhantov (https://unsplash.com/photos/xN0zxqQSdCk). CC0 1.0

Pilot Project Methodology

Now the breadth of locations in which these site typologies occur is vast. In order to focus this project's research, I've adopted a pilot project methodology that will explore a few different renewable energy solutions in the context of one of these typologies. Selecting pilot sites to implement these solutions allowed the exploration of design and ideas at site specific scales while still being able to later extrapolate these ideas to other areas.

UBC Selection

The UBC campus proved to be the ideal testing ground to start exploring small scale renewables due it's diversity of community and public based pilot site locations. Additionally, many of these solutions could further inform the campus' 2030 Climate Action Plan. Key takeaways from the plan include the goal of having Net Zero Carbon emissions by 2035, eliminating fossil fuels from campus operations, diversifying energy infrastructure to provide resiliency, opportunities to research multiple scopes of emerging solutions, as well as to enhance education and understanding of renewable energy operations and initiatives on campus[33].

[33] University of British Columbia, "Climate Action Plan 2030," Climate Action Plan 2030 | UBC Campus & Community Planning (University of British Columbia, December 2021), https://planning.ubc.ca/cap2030.

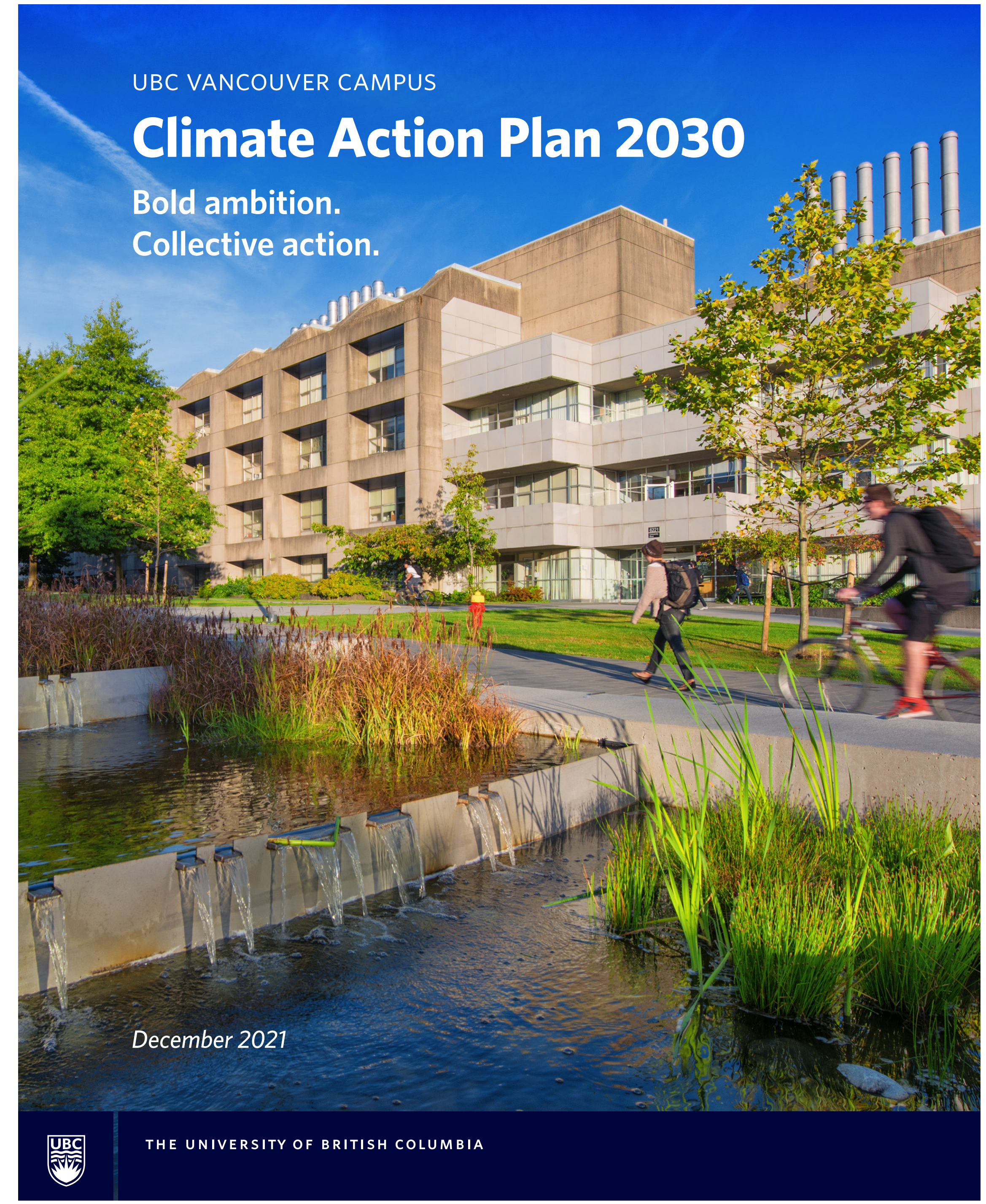


Figure 27. UBC Vancouver Campus Climate Action Plan 2030 report cover. © University of British Columbia. "Climate Action Plan 2030." Climate Action Plan 2030 | UBC Campus & Community Planning. University of British Columbia, December 2021. (https://planning.ubc.ca/cap2030), p. 1.

Technologies We Need

It was also important to understand the current capacities of today's system, as well as the advantages and disadvantages of these solutions in certain settings. I'll be exploring and designing with the most cutting edge technologies that are in development regarding renewable energy generation with the understanding that we can only improve upon the solutions we have at our disposal today. The technologies explored will mainly cover the well-known and reliable renewable energy solutions of today, but at a micro-scale.

Micro-Hydro

At the moment, micro hydro electric power is more like mid-size hydro-electric power. Traditional dam and turbine structures are extremely efficient at larger scales. However, there is one way that hydro can still be a big time player in a small scale way. And that is by using water as an energy store…or rather using water's potential kinetic energy to generate power.

Figure 28 has been removed due to copyright restrictions. It was a photograph of the small-scale hydroelectric turbine river system by the company Idénergie Inc.

Figure 28. Idénergie™ small-scale hydroelectric turbine. © Idénergie Inc. (https://idenergie.ca/wp-content/uploads/2014/10/thumbnail-dissassemble-turbine.jpg)

How this works is fairly simple. For example, we are able to generate electricity by allowing water to flow downstream through turbines. When this water reaches the lowest point, the water is transported back up to its higher starting point and allowed to flow down through the turbines again[34]. But how does this in any way act as a battery? Enter solar PV. On a lovely sunny day, we capture solar energy and use some of this energy to pump the water back up the hill. Then in the evening, when there is no solar, or on overcast days with lower solar generation, we release the water to flow back down hill and generate power with the turbines. The next day when the sun comes back, the water goes back upslope.

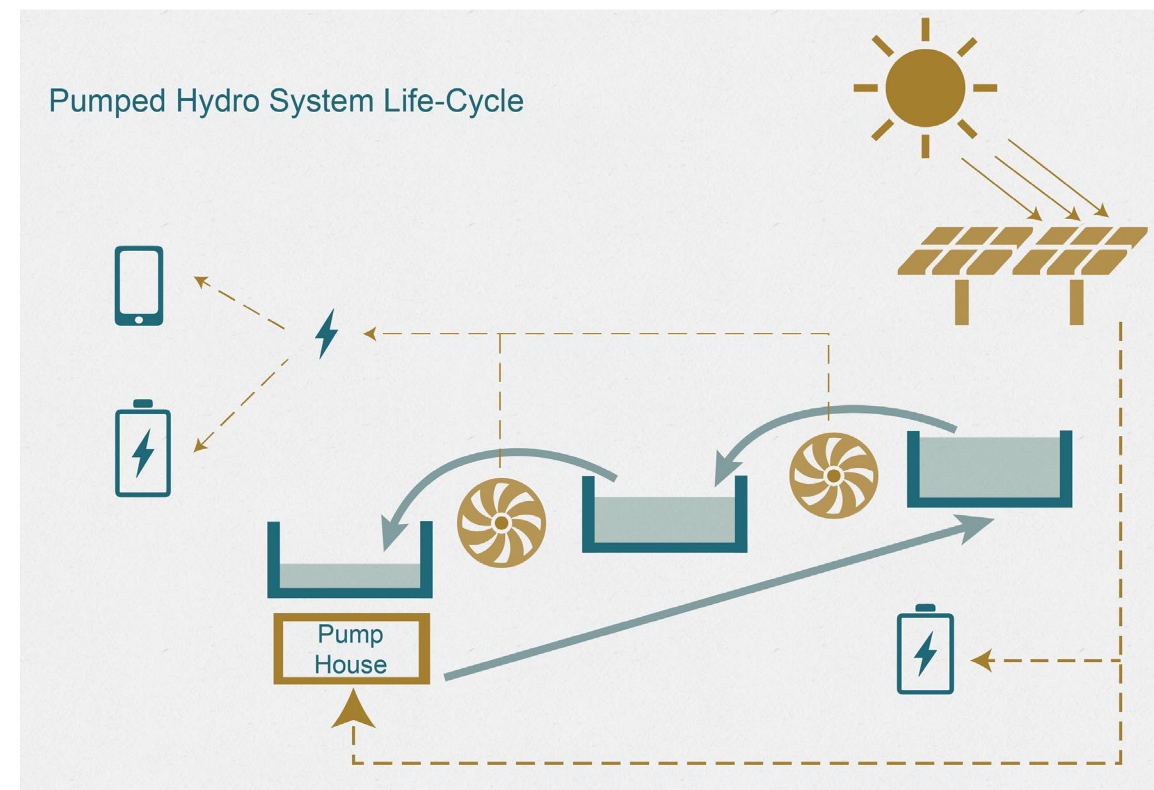


Figure 29. Pumped Hydro System Diagram. 2022, by author.

[34] Gates, "How to Avoid a Climate Disaster." 2021, p. 92-93.

Micro-Wind

While wind turbines are nothing new, micro-wind turbines being deployed in small urban scales, are bursting onto the scene. Their well-known bigger versions have provided lots of key metrics in designing miniaturized versions of these wind catchers, that are equally as reliable and efficient.

Micro vertical wind turbines need a minimum breeze level air speed to work, and are most efficient with continuous air flow or average annual winds of 10 to15 km per hr[35]. They are relatively cheap to install and are excellent at occupying a small footprint for the amount of wattage produced. Combine this solution with a battery pack and you'll be able to use wind power at a later time, when there's not a rolling tumbleweed in sight.

Figure 30 has been removed due to copyright restrictions. It was a photograph of the small-scale vertical wind turbine system by the company Helix Wind Corp.

Figure 30. Helix Wind vertical wind turbine. © Helix Wind Corp (https://inhabitat.com/files/helix05.jpg)

[35] Kennedy Maize, "Outside-the-Box Renewable Energy Microturbines," POWER Magazine, October 1, 2015, https://www.powermag.com/outside-the-box-renewable-energy-microturbines/.

Micro-Solar PV

The humble solar panel. Since its invention in 1883, the solar photovoltaic panel has come a long way from its first 1-2% efficiency[36]. Today's standard commercially available panels are efficient at capturing about 20% of the energy emitted from the sun, while some prototypes are seeing 35% efficiency[37]. In today's world we also are no longer bound to rigidity and shape as we have been in the past. New panels can be built in virtually any size you want.

Not only that, but some are flexible, can be made ultra thin, and there are even translucent panels that can be substituted in for glass. Solar is also getting incredibly cheaper year over year to install as the industry continues to develop and grow. Solar panels are best used in places with…sun. Despite many misconceptions, solar PVs can still produce energy in overcast conditions and diffused shade, so don't count these areas out! Add in some battery storage and you too can have light even in the dark.

Figure 31 has been removed due to copyright restrictions. It was a photograph of flexible solar panel sheets.

Figure 32 has been removed due to copyright restrictions. It was a photograph of the clear solar PV roof at Radboud University in the Netherlands.

Figure 31 (left). Flexible Solar PV sheets. © Chris Tokloper (https://christokloper.tumblr.com/post/53349078308)
Figure 32 (right). Clear Solar Roof at Radboud University, Netherlands. © Jannes Linders (https://images.adsttc.com/media/images/53fd/63ff/c07a/8009/6200/0909/slideshow/667_Grotiusgebouw_N13_Jannes_Linders.jpg?1409115106)

[36] Elizabeth Chu and Lawrence Tarazano, "A Brief History of Solar Panels," Smithsonian Magazine (Smithsonian Institution, 2022), https://www.smithsonianmag.com/sponsored/brief-history-solar-panels-180972006/.

[37] SunPower, "How Many Solar Panels Do You Need: Panel Size and Output Factors," SunPower.com, September 9, 2021, https://us.sunpower.com/how-many-solar-panels-do-you-need-panel-size-and-output-factors.

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The Project

"As an architect you design for the present, with an awareness of the past, for a future which is essentially unknown."

- Normon Foster

After determining suitable typologies and analyzing the pros and cons of each micro-wind-solar-&-hydro solution in hand, I embarked on a self guided campus tour exploring various routes, areas and common "hot spots" around UBC that would be amenable to some renewable energy integration. From an initial starting list of 12 sites, further assessments where done to narrow the focus to 9 sites...then more whittling to get to 6… and then finally, the final 3 sites that proved to offer a diversity of programs, a sizable list of needs, some ideally average and common site conditions, as well as some endearing quirks and character.

These Sites are:

Stores Road

Orchard Alley

AMS Nest Plaza

Figure 33. Preliminary site assessment matrix - A. 2022, by author.

Figure 34. Preliminary site assessment matrix - B. 2022, by author.

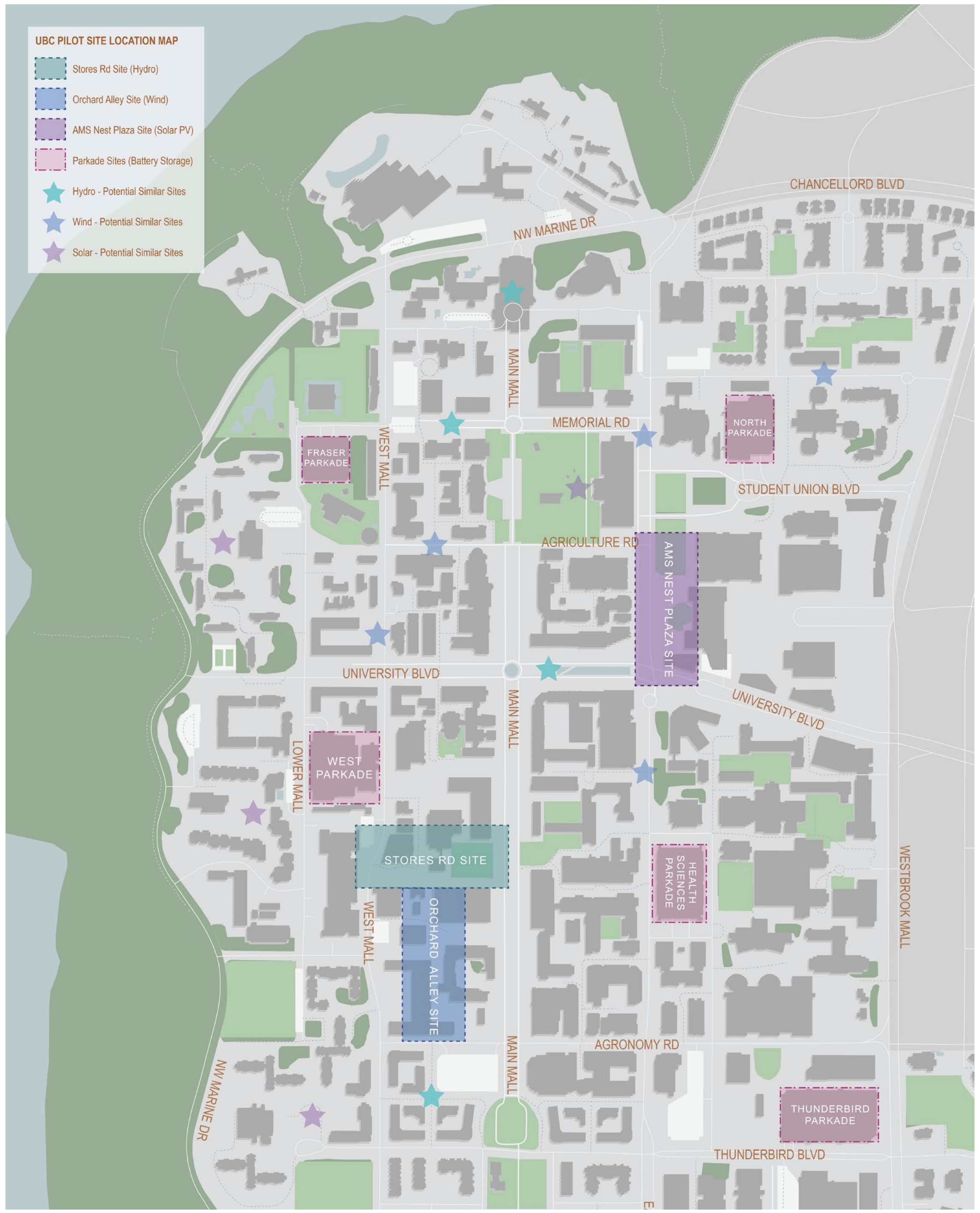


Figure 35. Pilot Site Location Map. 2022, by author. *(not to scale on a 8.5x11 sheet)*

Stores Road

Site Investigations

Stores Road is located on the south west side of UBC's academic campus. It serves as both a vehicle and pedestrian corridor connecting key arterials such as Main Mall and West Mall.

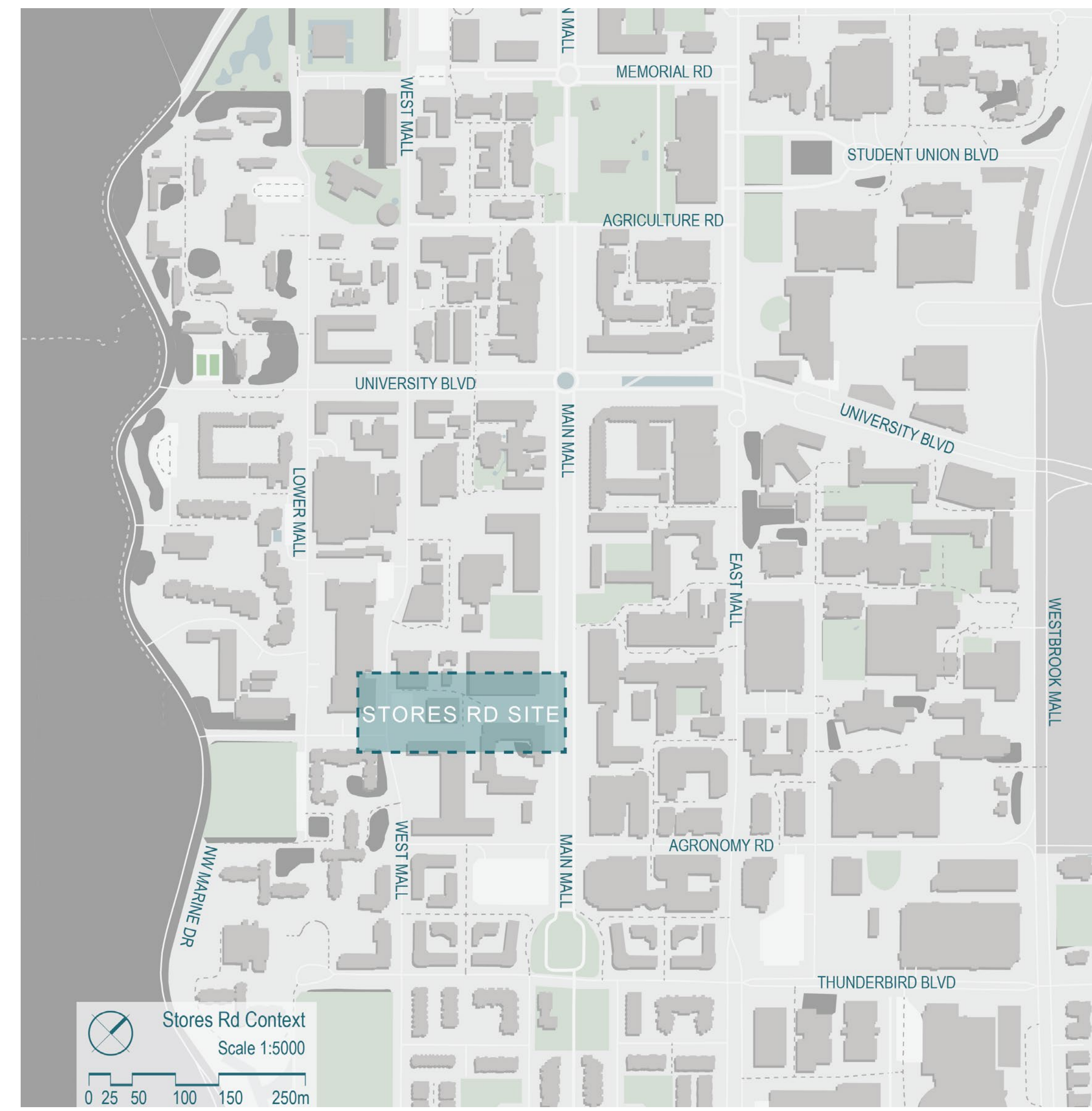


Figure 36. Stores Rd Location Map. 2022, by author. *(not to scale on a 8.5x11 sheet)*

Key characteristics of this site is that it is highly topographic with an elevation change of over 10 meters from end to end. It serves as a greenspace and green network between many buildings such as the Center for Integrated Research and Sustainability, the Earth and Ocean Sciences Building and what will be the new Faculty of Applied Science building - Applied One. The site contains many mature coniferous and deciduous trees and was designed as a rainwater infiltration network. Unfortunately with UBCs current zoning policies, water infiltration is not allowed on site to prevent the erosion of nearby cliffs. The site receives relatively good amounts of sunlight throughout the year.

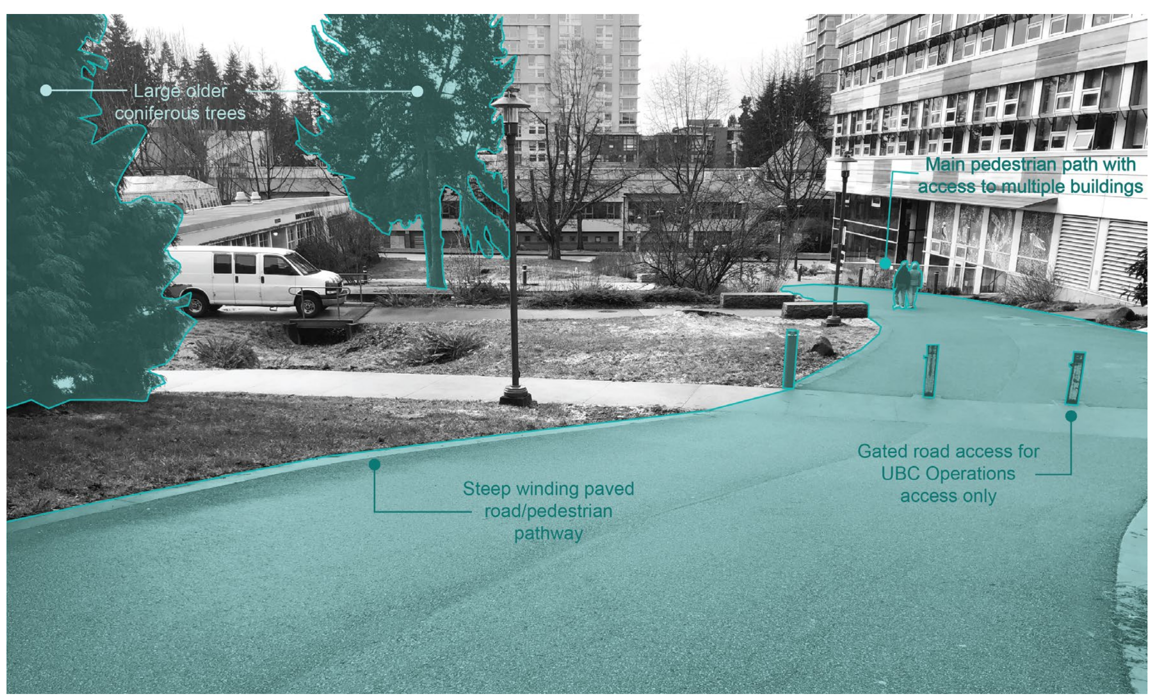


Figure 37. Stores Rd site analysis photo essay - A. 2022, by author.

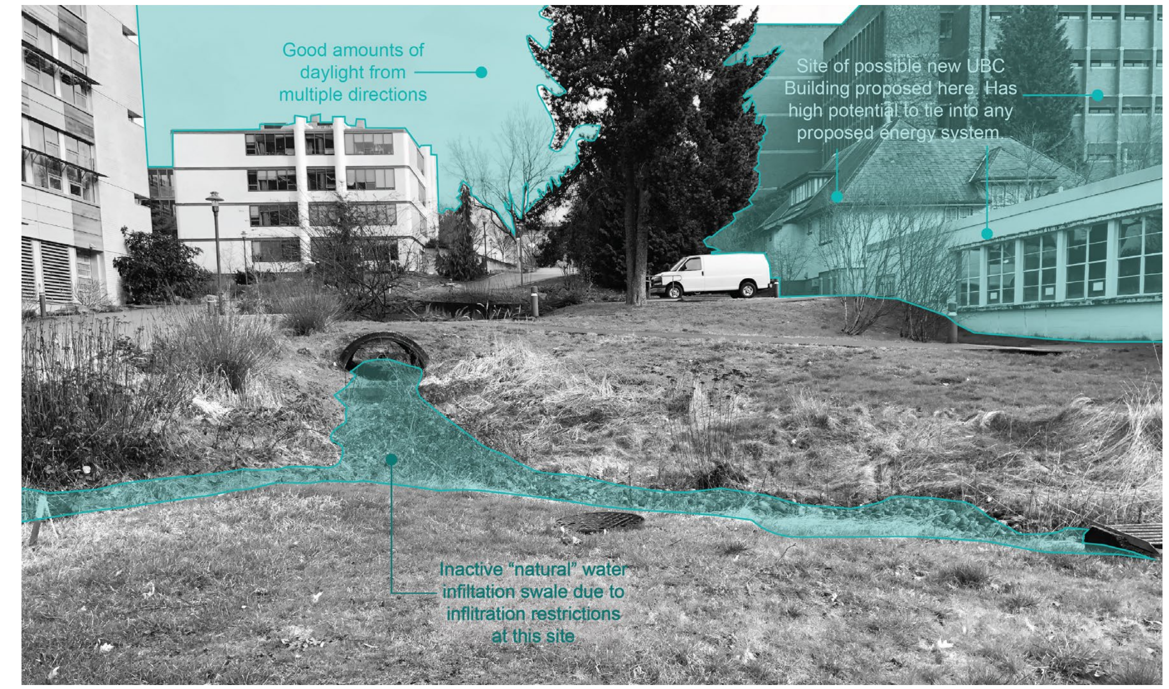


Figure 38. Stores Rd site analysis photo essay - B. 2022, by author.

Given these site conditions an ideal renewable technology for the site would a pumped hydro solution that would network with the surrounding buildings for its pump energy supply.

The key program considerations for the site are its connection to nature via free spaces, it's vehicular and pedestrian accessibility and it's servicing of both the adjacent buildings and public realm users.

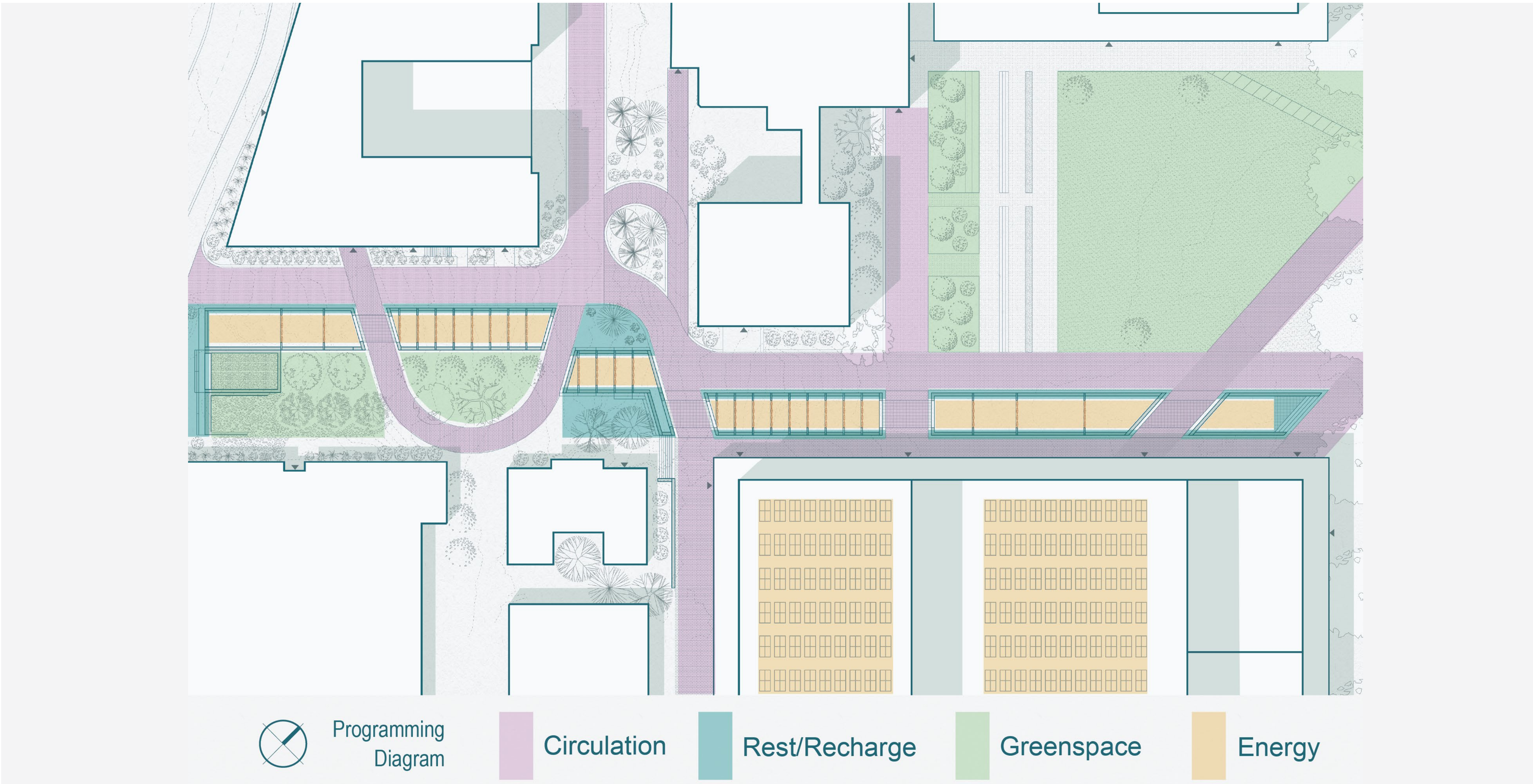


Figure 39. Stores Programming Diagram. 2022, by author. (not to scale on a 8.5x11 sheet)

Design Proposal

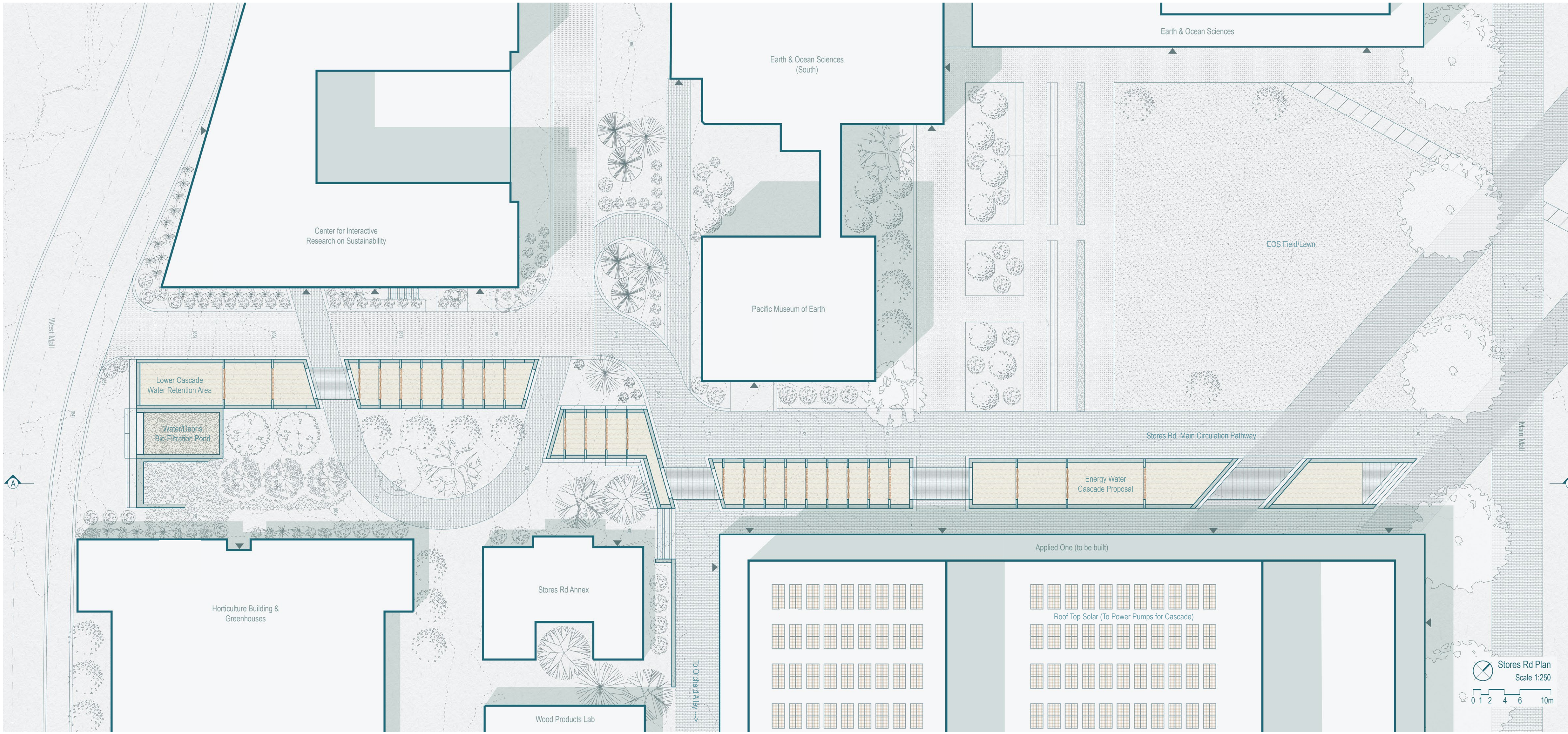


Figure 40. Stores Plan. 2022, by author. (not to scale on a 8.5x11 sheet)

Located centrally down the axis of the site is a cascading water feature with integrated micro hydro turbines. This feature shares a design language with other on campus water features, namely the planted water feature outside of the campus bookstore (figure 41).

Figure 41 has been removed due to copyright restrictions. It was photographs of the UBC University Blvd cascading water feature designed by PFS Studios.

Figure 41. UBC University Blvd water feature (compilation). © PFS Studio (https://pfsstudio.com/project/university-of-british-columbia-university-boulevard/)

The nature of this site as a corridor and green space poses some limitations. Firstly, a vehicle egress must be maintained from top to bottom. This also means that any surface treatments must be driveable but still offer a pleasant experience for pedestrians. Using the campus brickwork pattern throughout the site ties everything together and makes the site seem like a continuous extension off of Main Mall (figure 42).

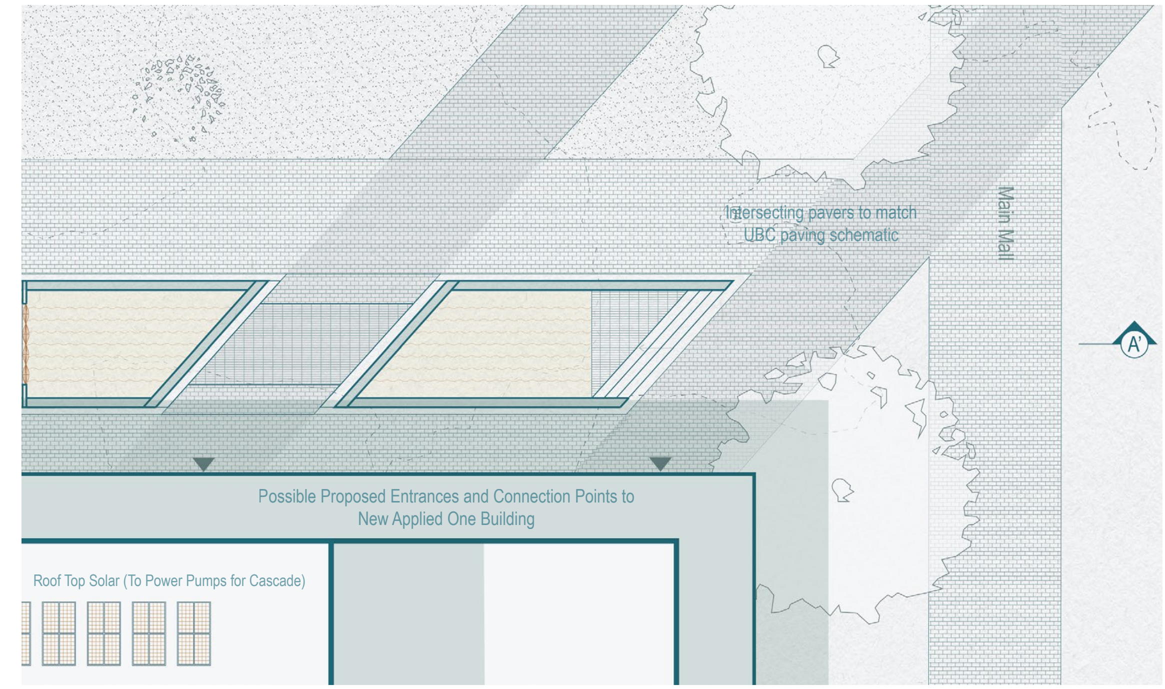


Figure 42. Stores path detail - Plan. 2022, by author. (not to scale on a 8.5x11 sheet)

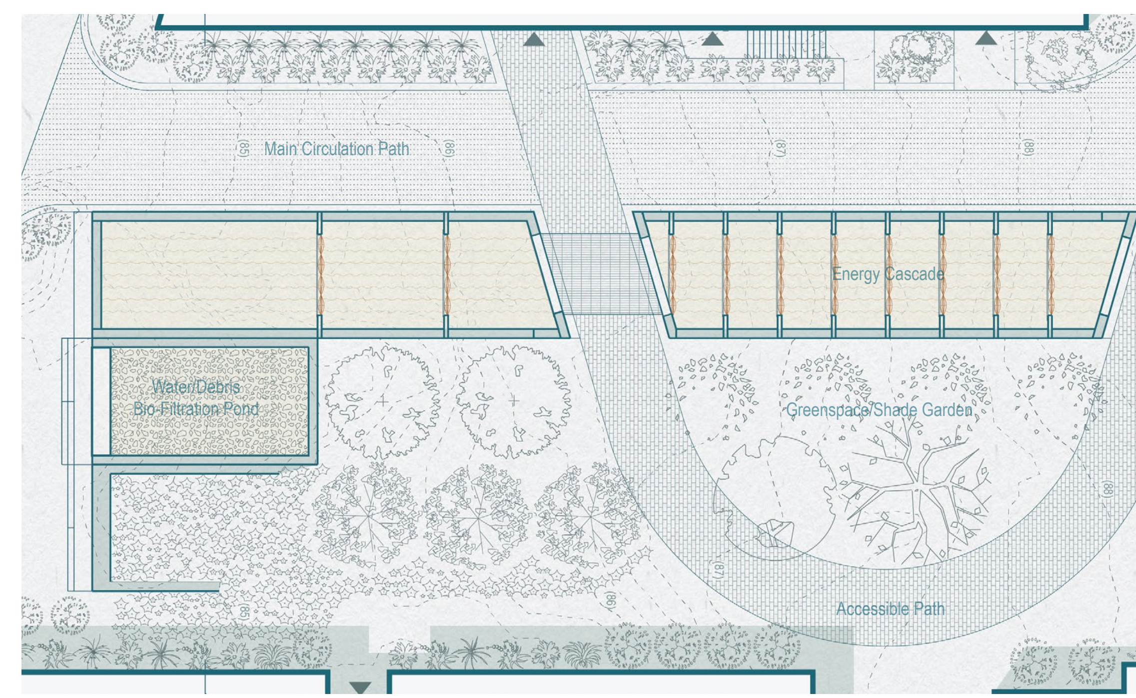


Figure 43.Stores lower greenspace detail - Plan. 2022, by author. (not to scale on a 8.5x11 sheet)

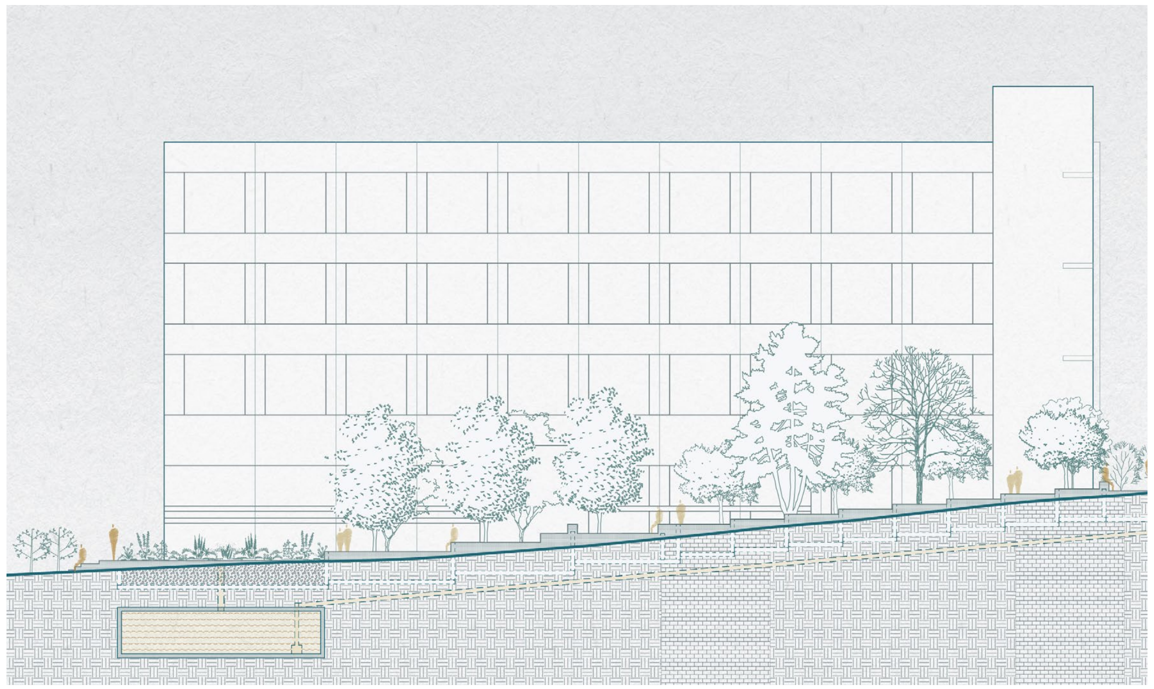


Figure 44.Stores lower greenspace detail - Section. 2022, by author. (not to scale on a 8.5x11 sheet)

Retaining the many large mature trees on site is also important as well as enhancing and maintaining the biodiversity of the planted areas. On the lower end of the site (figure 43) more trees and plants contribute to the free space while also providing shaded areas in the summer months.

Now, just because rainwater infiltration is not allowed on the site, does not mean it can't collect rainwater for energy use. After the water moves down slope and before being pumped back up hill, gravel and planted filtration beds will clean the water and filter out debris. In very rainy seasons, excess water that cannot fit into the system can contribute to the below grade water retention cisterns for use in dryer months (figure 44).

Connections to all facing building is a must, as many facades could be considered priority second entrances such as for applied one. These connections also serve as extensions of the buildings and provide spaces to rest, study, gather, or recharge. Making sure that these spaces are in proximity to or integrated into the energy solution will further enforce a users understanding on the energy being created and encourage education and stewardship of renewable energy technologies (figure 45).

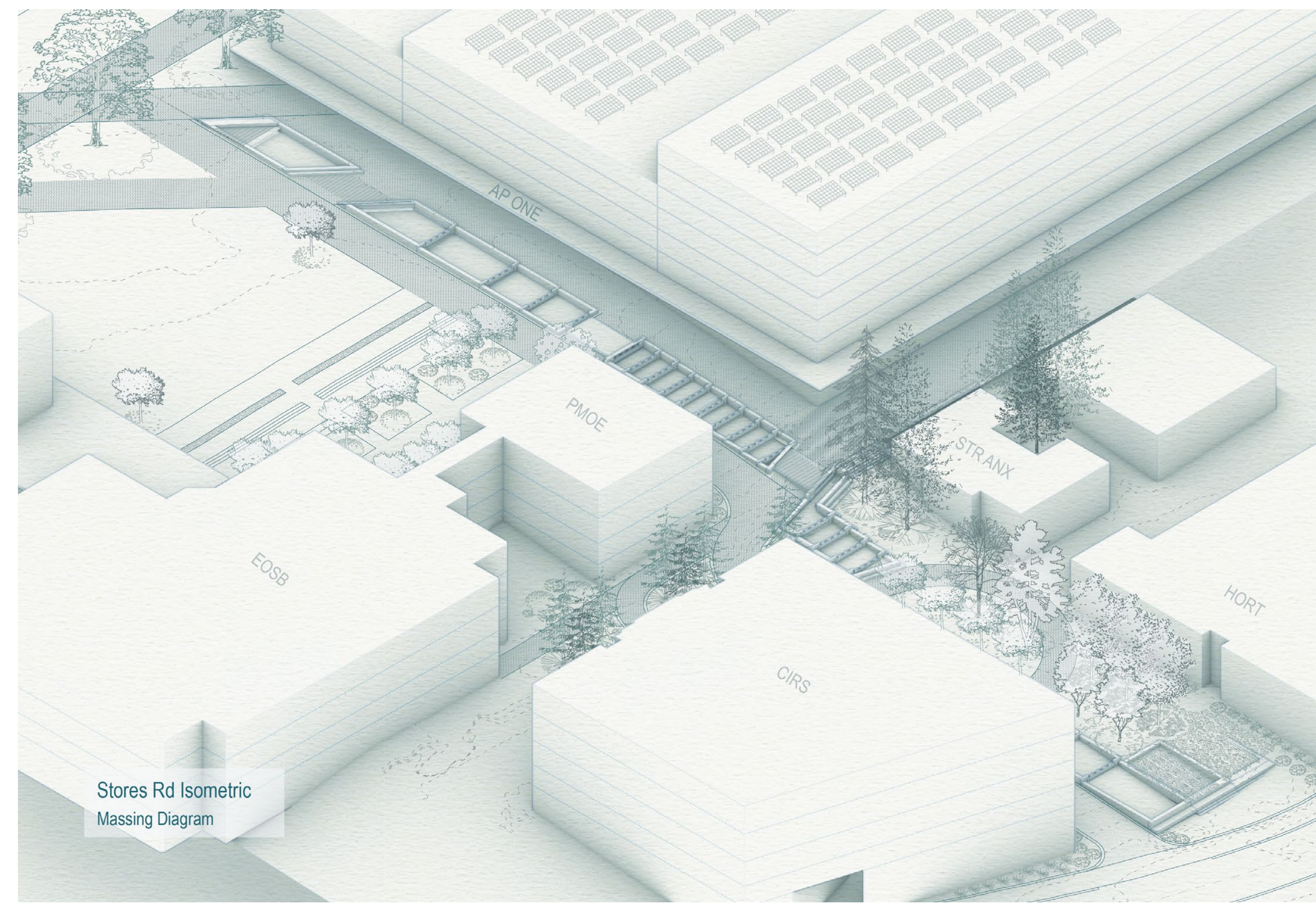
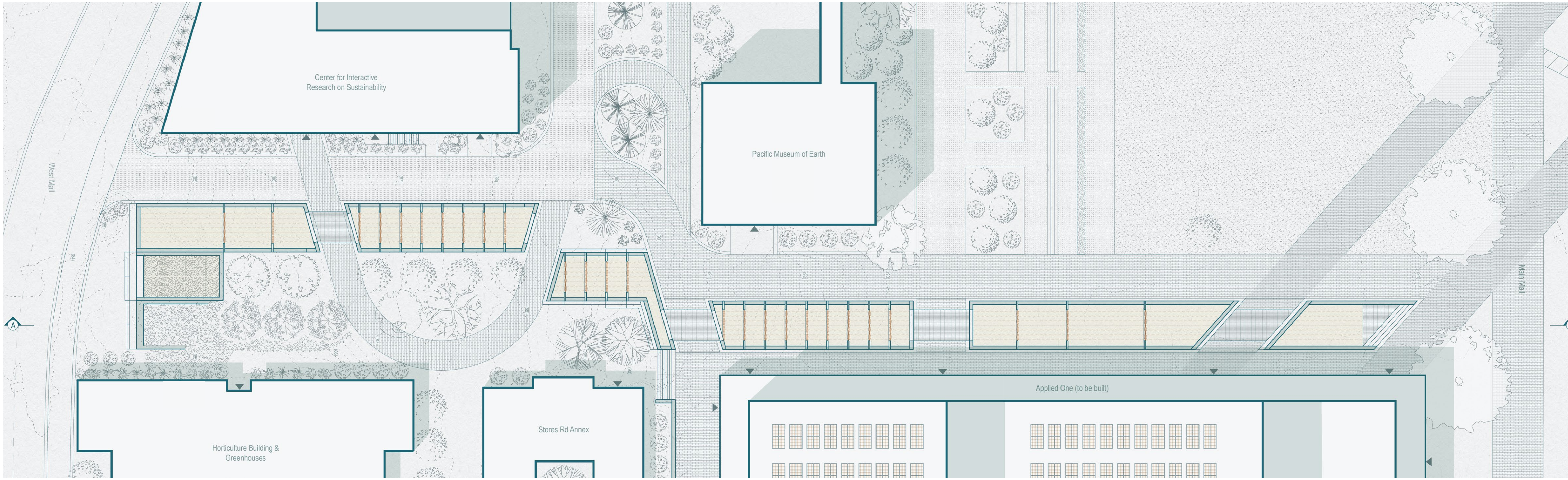


Figure 45. Stores isometric massing diagram. 2022, by author



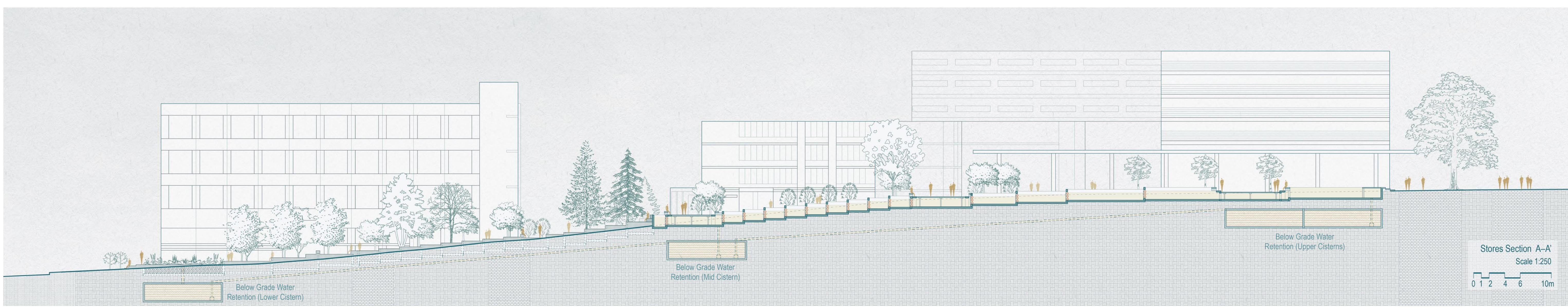


Figure 46 (above). Stores Plan. 2022, by author. (not to scale on a 8.5x11 sheet)
Figure 47 (below). Stores Section. 2022, by author. (not to scale on a 8.5x11 sheet)

The cascading pools consist of a series of networked turbines (figures 46 & 47). Depending on the energy needs, water is allowed to flow through this cascade to create power. The amount of water released through the system is controlled through a series of weirs that can incrementally be raised and lowered to generate different flow rates. The energy created from the turbines can directly power recharging areas or be stored in batteries for later use.

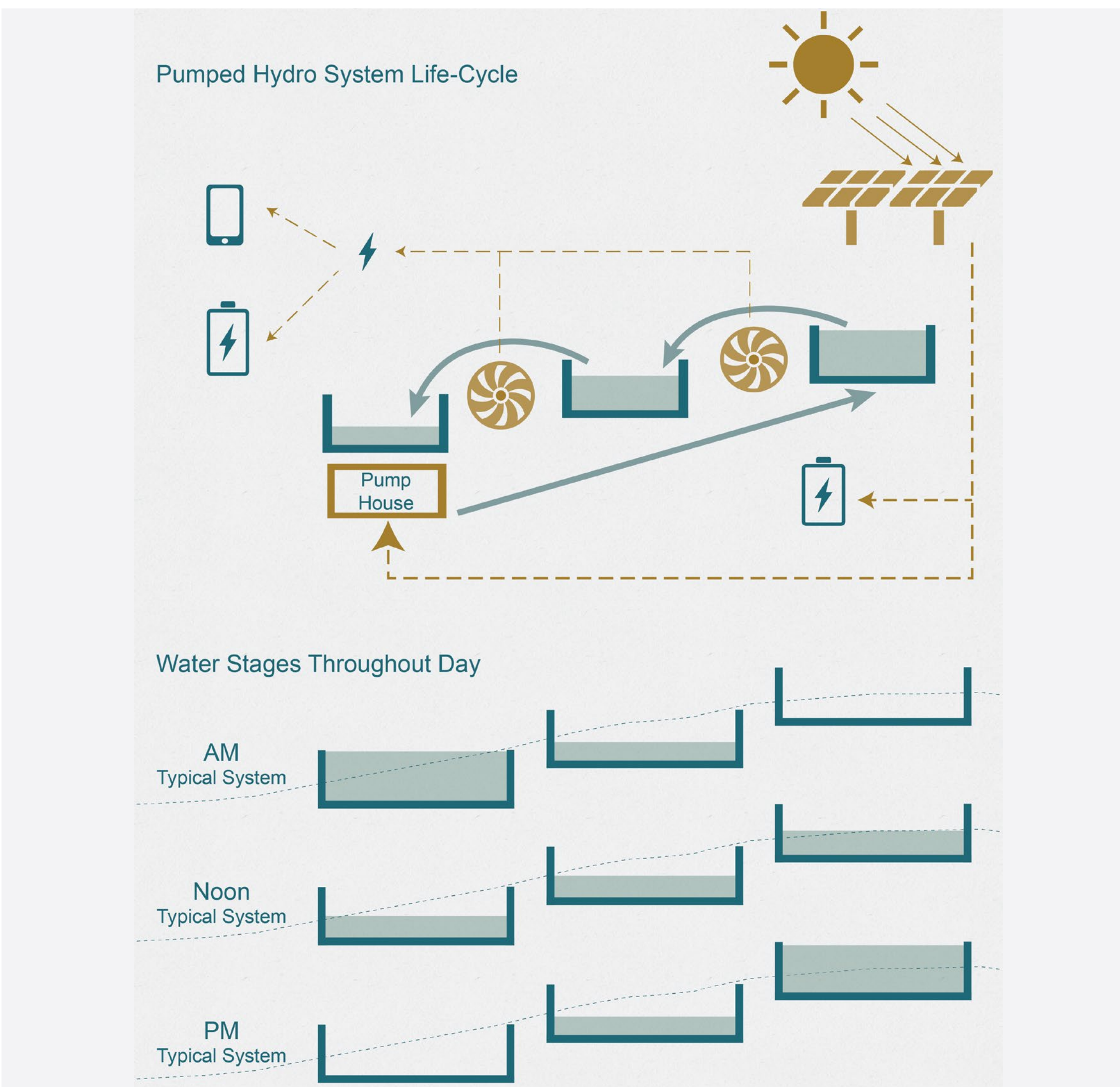


Figure 48. Pumped Hydro and Water Levels diagram. 2022, by author.

Energy Analysis

The water volume of this system is approximately twelve hundred (1200) cubic meters (the size of half an Olympic pool). Each set of turbines is capable of generating 1kW of energy with a water flow rate of 150 L/sec[38]. Don't worry I've done the math for you and this overall system is capable of generating 30 kW or enough power to recharge 600 laptops for 1hr*.

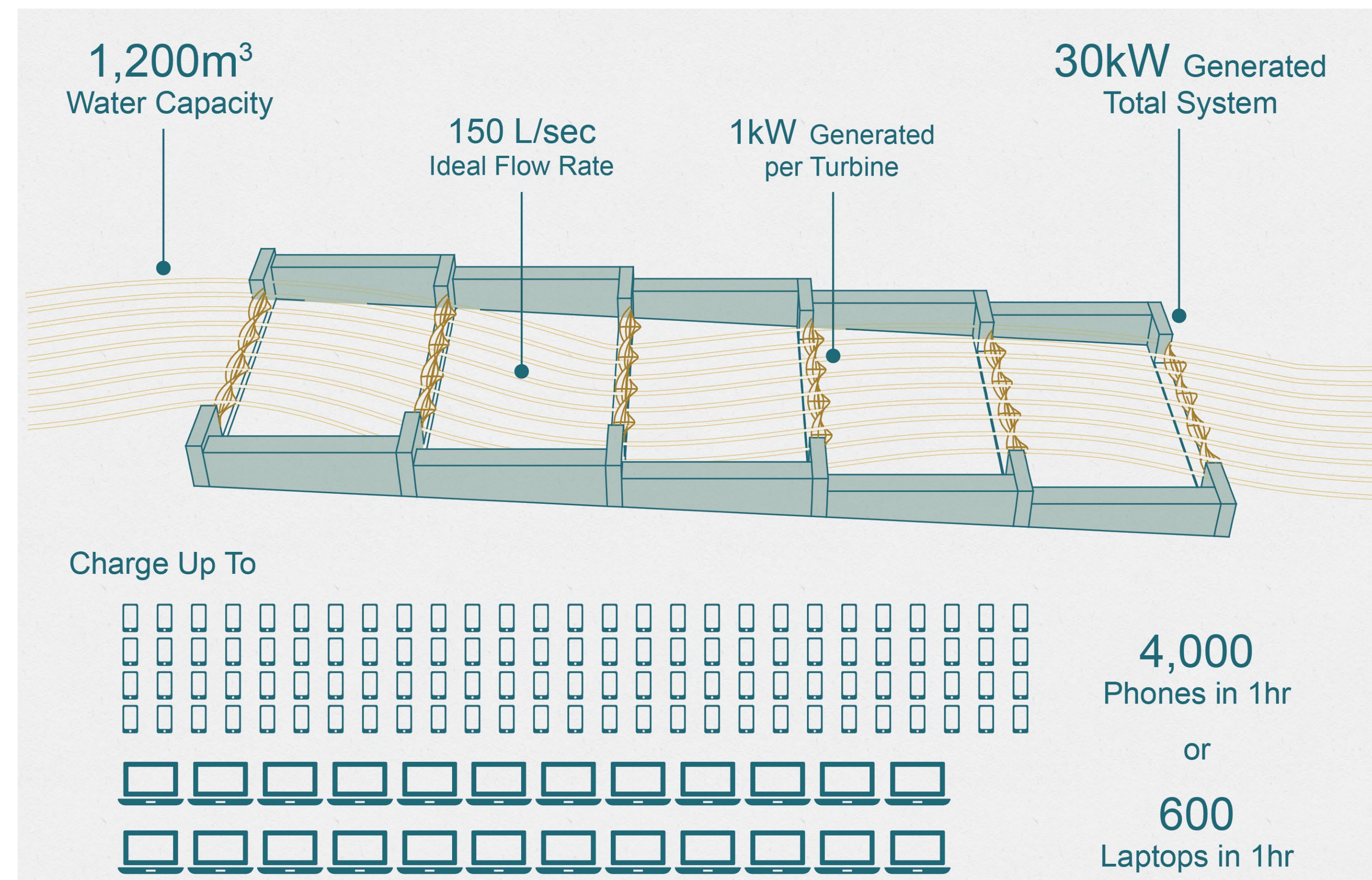


Figure 49. Stores road energy calculation graphic. 2022, by author

[38] Idénergie, "Energy Production - River Turbine," Idénergie (Idénergie Inc., November 26, 2018), https://idenergie.ca/en/power-production/.

*Assuming average phone used between 5-7.5 watts to charge, while laptops are 50 watts. With 31 turbine sets in this design generating roughly 30kW total.

Orchard Alley

Site Investigations

This site is located on the south west end of the UBC academic campus. It is nestled between multiple buildings, with the main ones being MacMillan and Orchard Commons which is a tall student residence building. The new faculty of applied science building - applied one - is planned to be adjacent to MacMillan and will be another primary building facing this site.

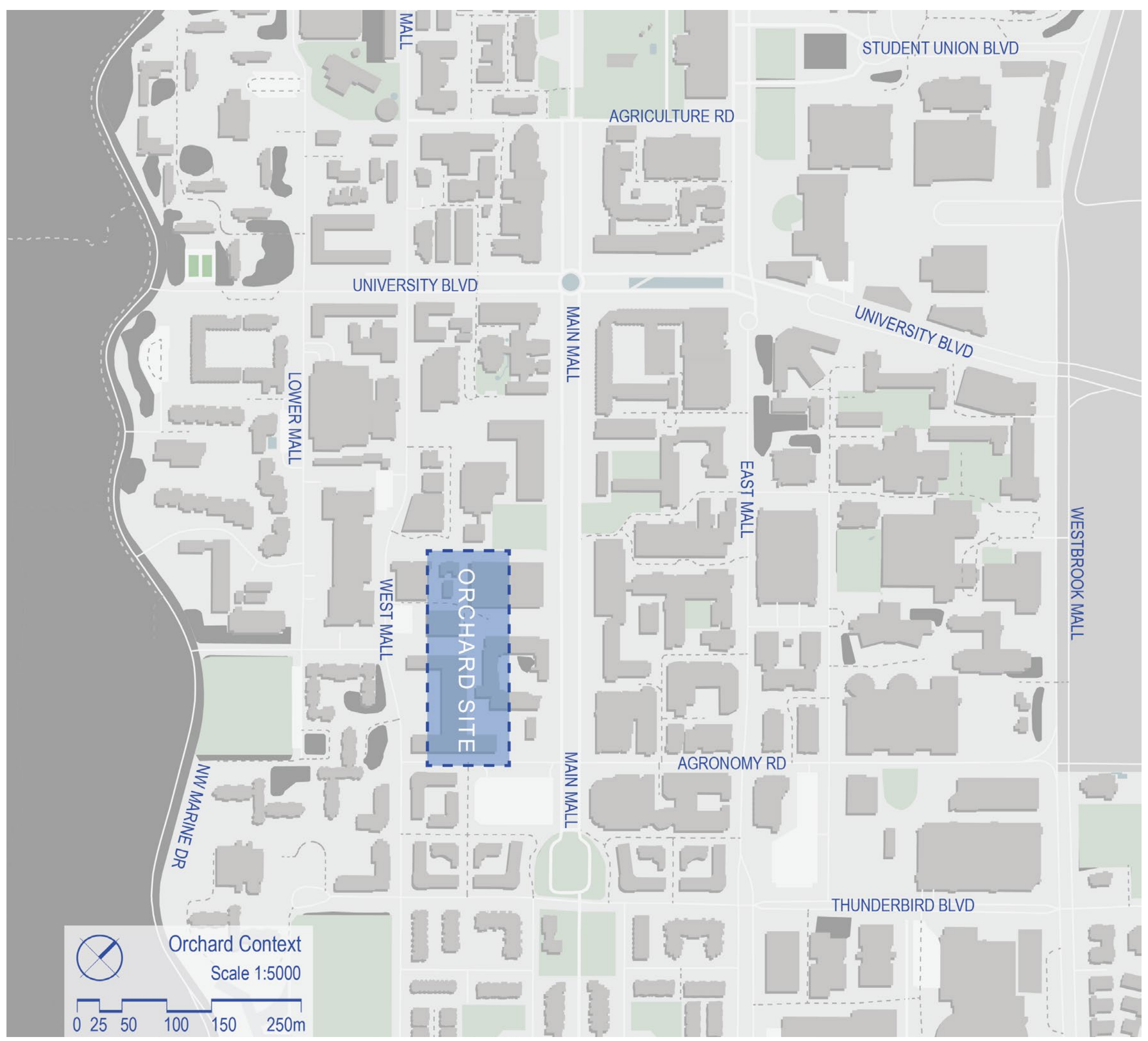


Figure 50. Orchard Alley Location Map. 2022, by author. *(not to scale on a 8.5x11 sheet)*

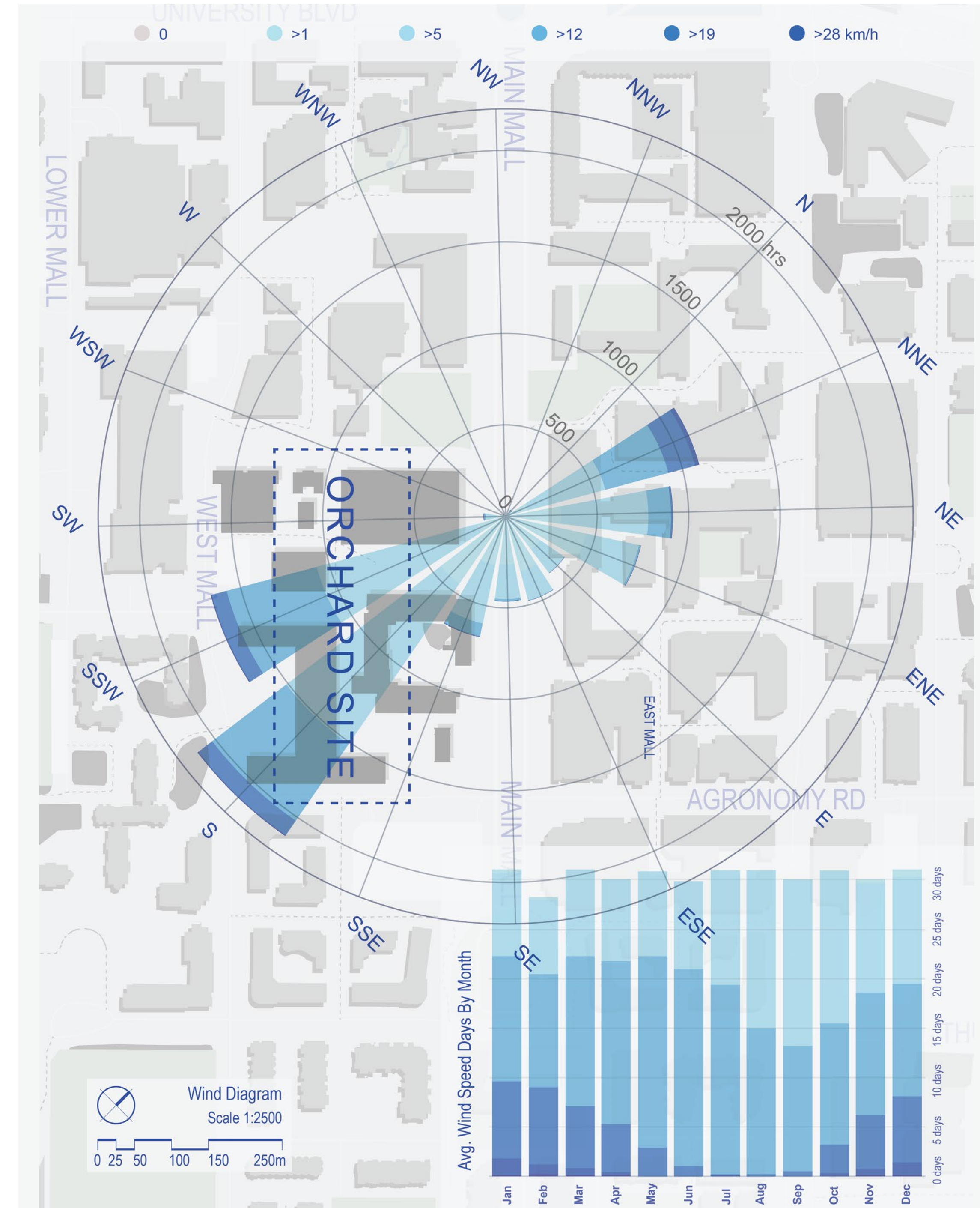


Figure 51. Orchard Wind Rose and Wind Data. 2022, by author. *(not to scale on a 8.5x11 sheet)*

The key defining characteristic of the orchard corridor site is its narrowness. The buildings that line either side of it are quite tall, the student housing building being 18 stores in height. This alleyway-like corridor serves as a main connection point between stores rd and agronomy road and runs parallel to Main Mall. While mainly a pedestrian and cycling corridor, there is egress space for emergency vehicles to access the buildings.

The tall buildings amount to a substantially shaded corridor that receives little sunlight year round. Though the patio space of the student run cafe - the Agora - in MacMillan is well situated to take advantage of the few sunny spots along this route. Unfortunately there are very few amenities and things to activate this patio space as a desirable outdoor extension of the cafe.

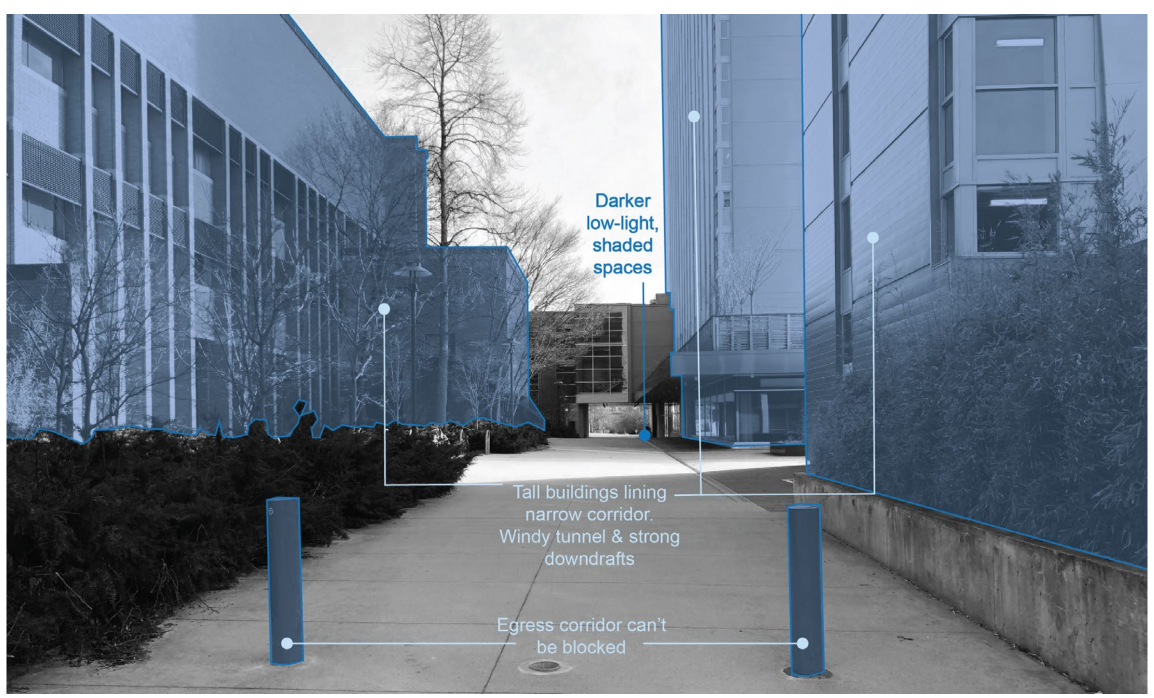


Figure 52. Orchard site analysis photo essay - A. 2022, by author.

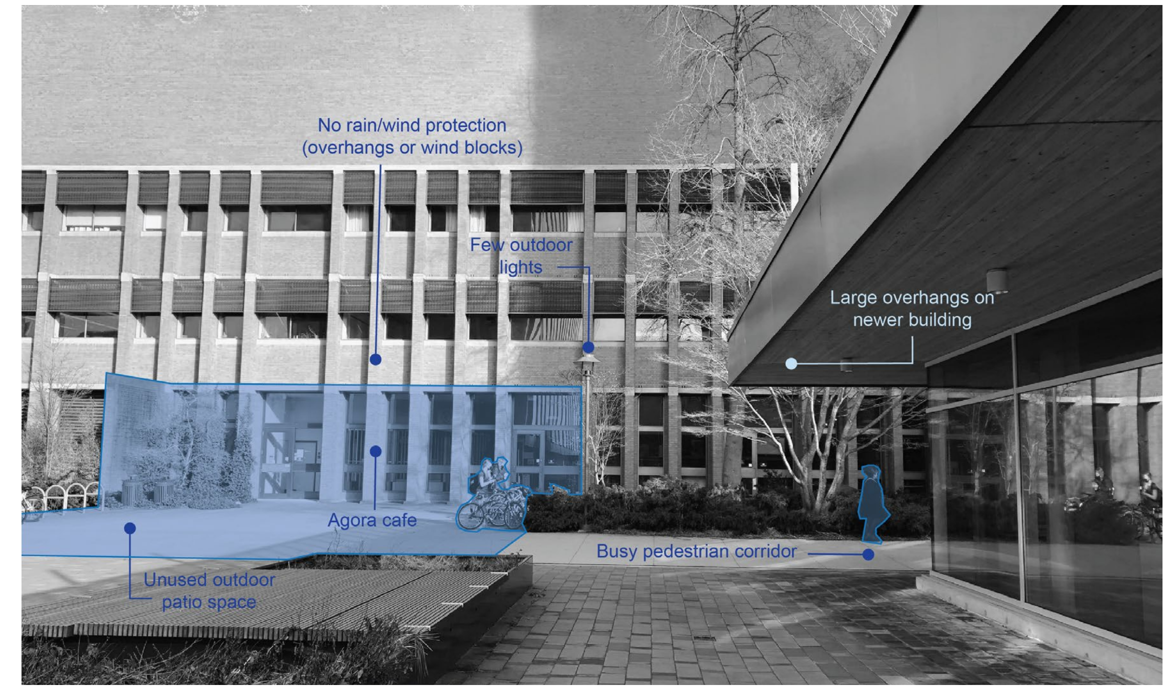


Figure 53. Orchard site analysis photo essay - B. 2022, by author.

The tall buildings and the narrowness of this North-South axis corridor, combined with a decent year round Southerly wind direction creates a trifecta when it comes to creating ideal wind tunnels and strong downdrafts (figure 51 previous). Given these site conditions an ideal renewable technology for this site would be a micro wind turbine solution. With the limited width of the site, vertical helix turbines offer an efficient way to capture the breeze through here while not sacrificing space.

The key program considerations for the site are its need to act primarily as a corridor, while offering spaces to rest, eat at the cafe, gather or study…..Facade to site connections are also an important factor given the condensed space.

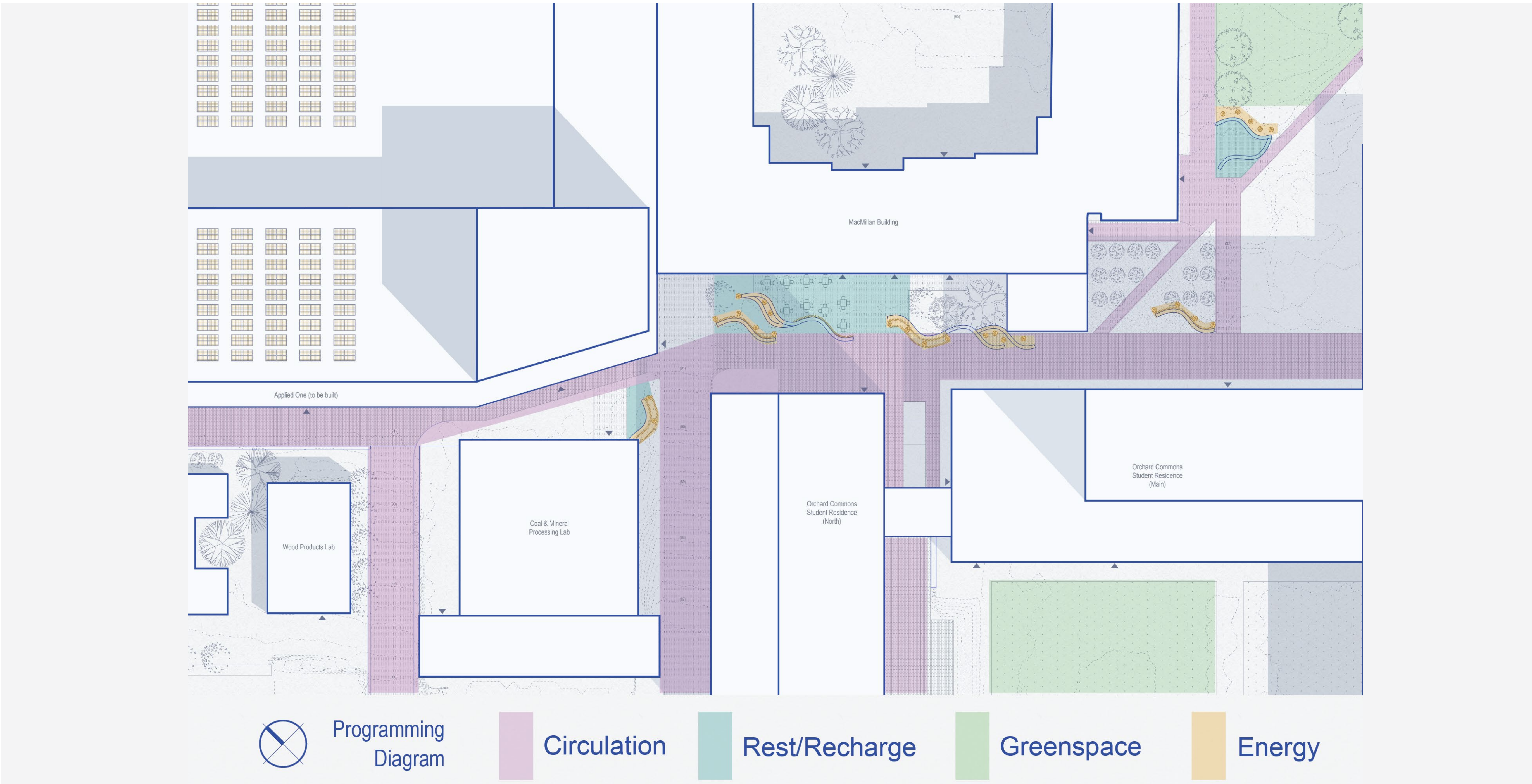


Figure 54. Orchard Programming Diagram. 2022, by author. (not to scale on a 8.5x11 sheet)

Design Proposal

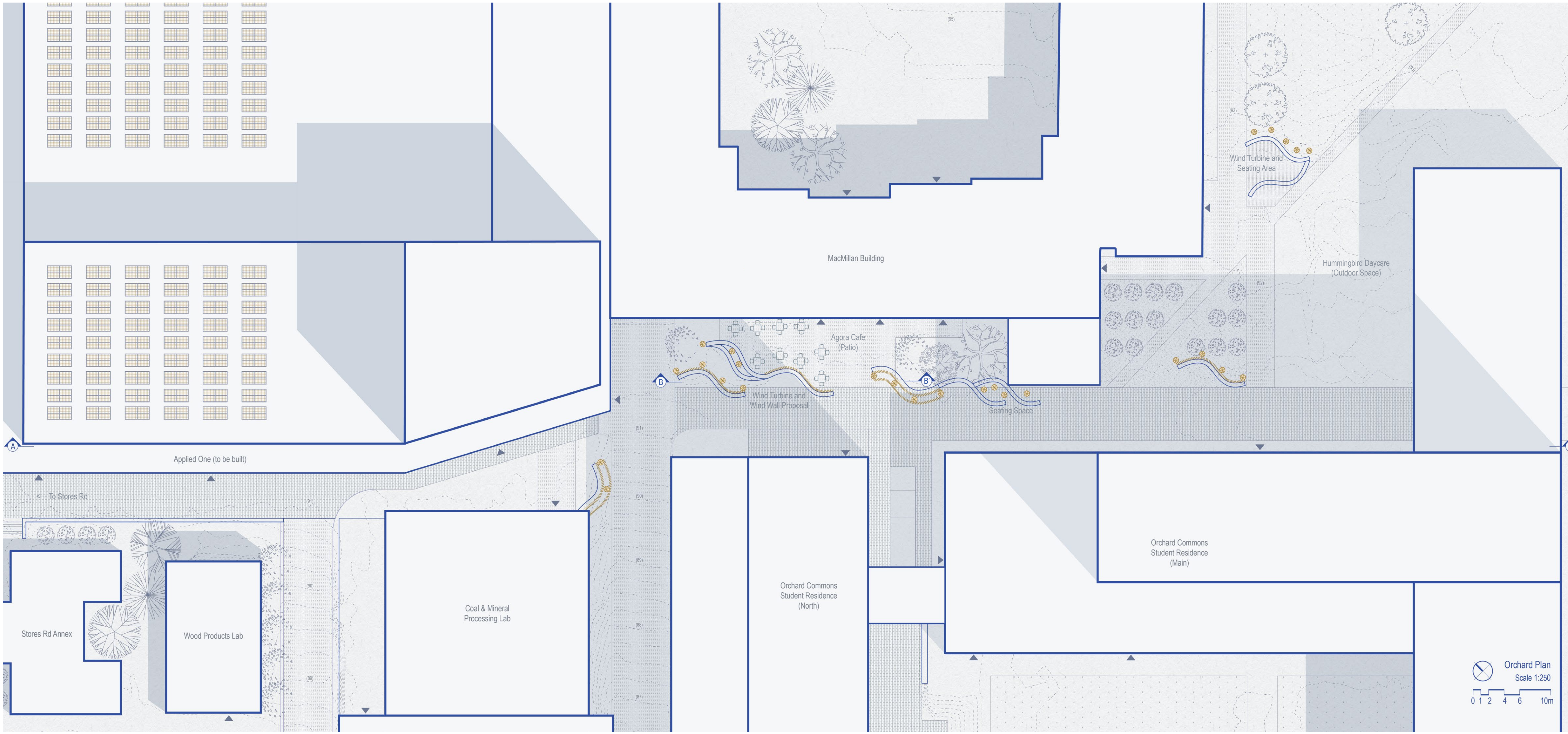


Figure 55. Orchard Alley Plan. 2022, by author. *(not to scale on a 8.5x11 sheet)*

The orchard site has to navigate a fine balancing act between both energy production from prevailing winds, while also protecting users from this same wind. A series of wall and wind structures can be deployed across the span of the site to offer solutions to both.

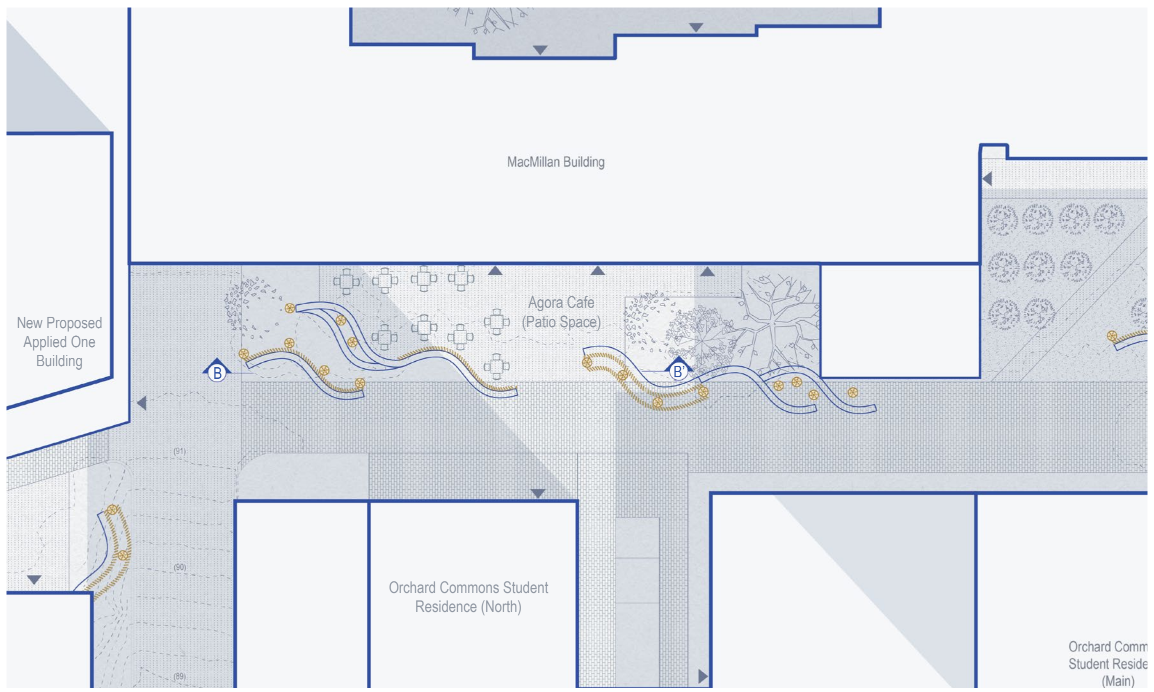


Figure 56. Orchard detail walls and turbines. 2022, by author. *(not to scale on a 8.5x11 sheet)*

These wind walls also further act as elements that contribute to the extension of the Agora patio space, creating protected pockets of space where it is much more enjoyable to stop and enjoy a bit to eat, or take a break between classes and charge up (figure 56).

Built in seating is also designed into many of the walls, offering more opportunities for activation of orchard outdoor spaces along this site. The wind screens are also designed to offer porosity of views with slatted members that are angled against the wind but open when viewed perpendicular to the wind direction of travel (figure 57).

The wind screens not only help to block site users from the wind, but also can act to direct wind currents into wind turbines, further maximizing energy yields while still serving the site occupants (figure 58).

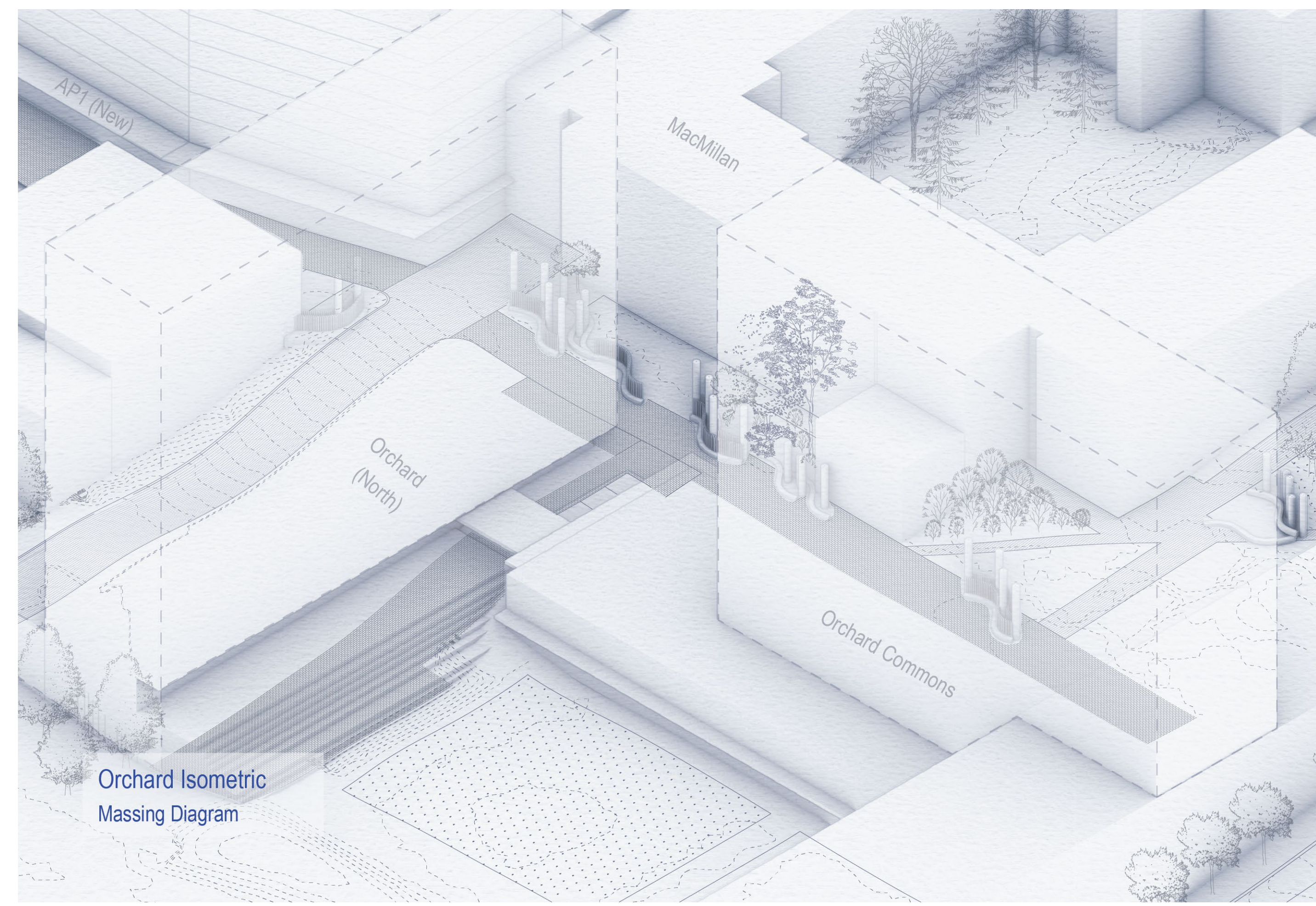


Figure 57. Orchard isometric massing diagram. 2022, by author.

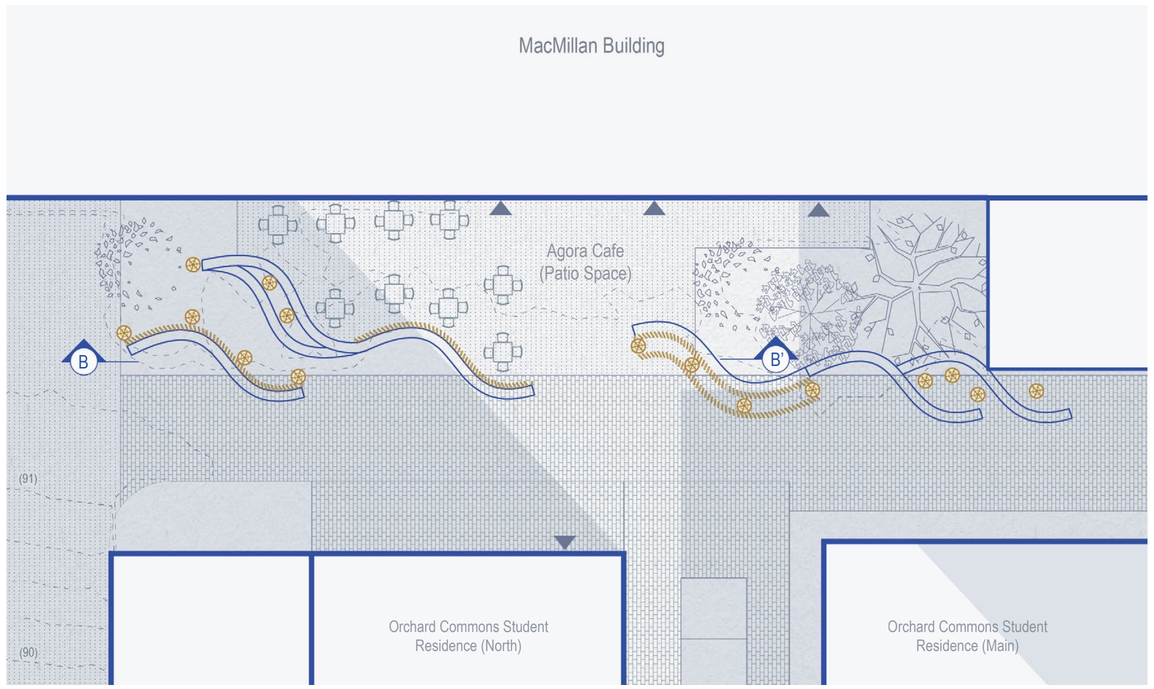


Figure 58. Orchard wall and turbines detail - Plan. 2022, by author. *(not to scale on a 8.5x11 sheet)*

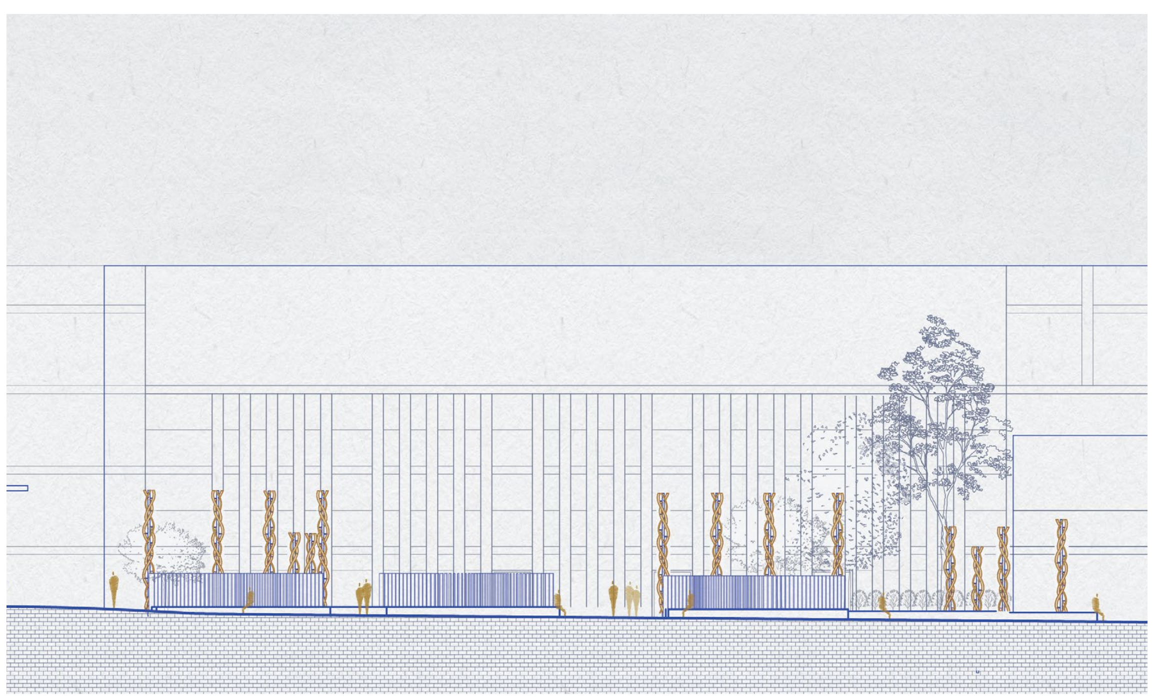


Figure 59. Orchard wall & turbines detail - Section B-B'. 2022, by author. *(not to scale on a 8.5x11 sheet)*

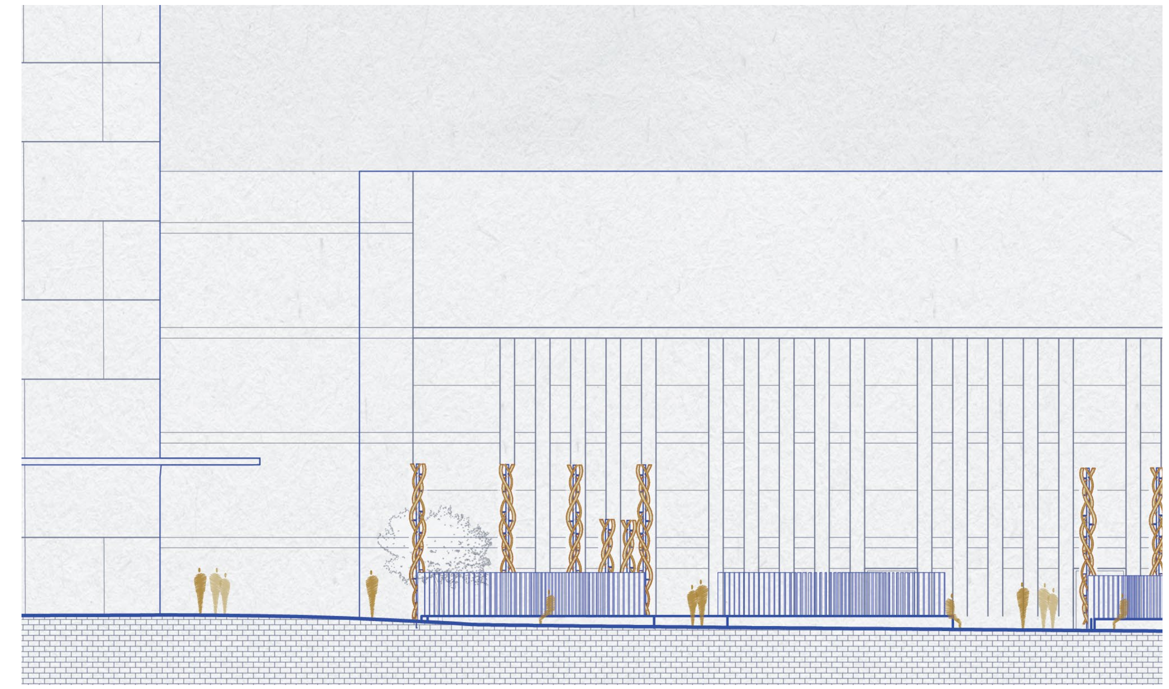
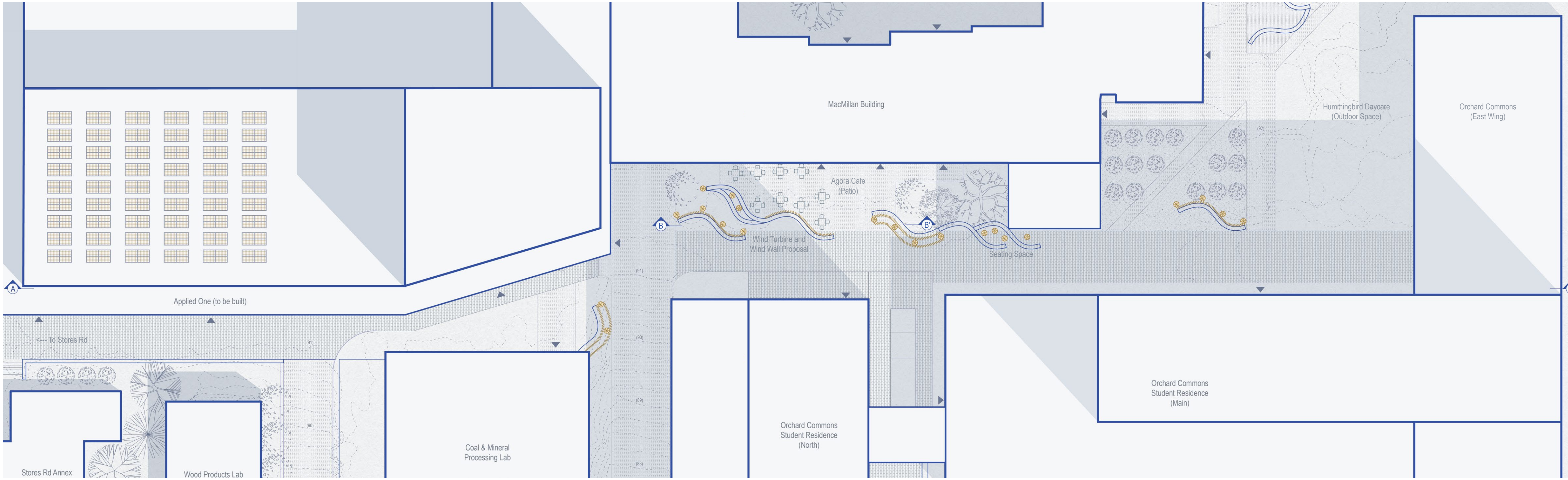


Figure 60. Building to turbine relationship - Section. 2022, by author. *(not to scale on a 8.5x11 sheet)*

With the majority of turbines lifted up, the structures become highly visible from both the ground plane as well as from the adjacent buildings. One is able to visually interact with the production of wind energy from multiple perspectives.

The height and visibility of the structures can act as a way finding mechanism across campus. When deployed to other areas of UBC, a network of wind energy systems could be created.



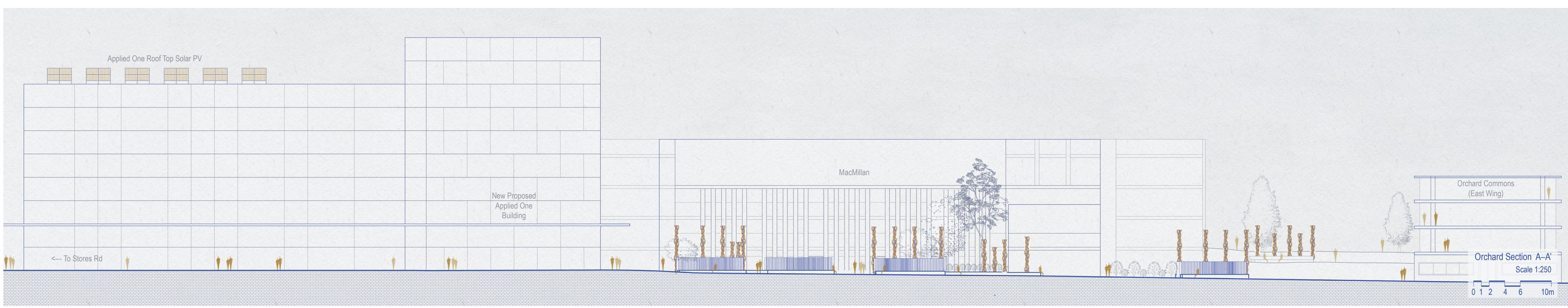


Figure 61 (above). Orchard Plan. 2022, by author. (not to scale on a 8.5x11 sheet)
Figure 62 (below). Orchard Section A-A'. 2022, by author. (not to scale on a 8.5x11 sheet)

Energy Analysis

With each turbine capable of generating 500 watts of energy when there is wind over 10 km/hr, the production capacity of the site is at 12 kWh[39]. This is enough energy for over 1600 users to charge their phone over a 1 hr lunch break, or enough to power 240 laptops over a 1hr period*.

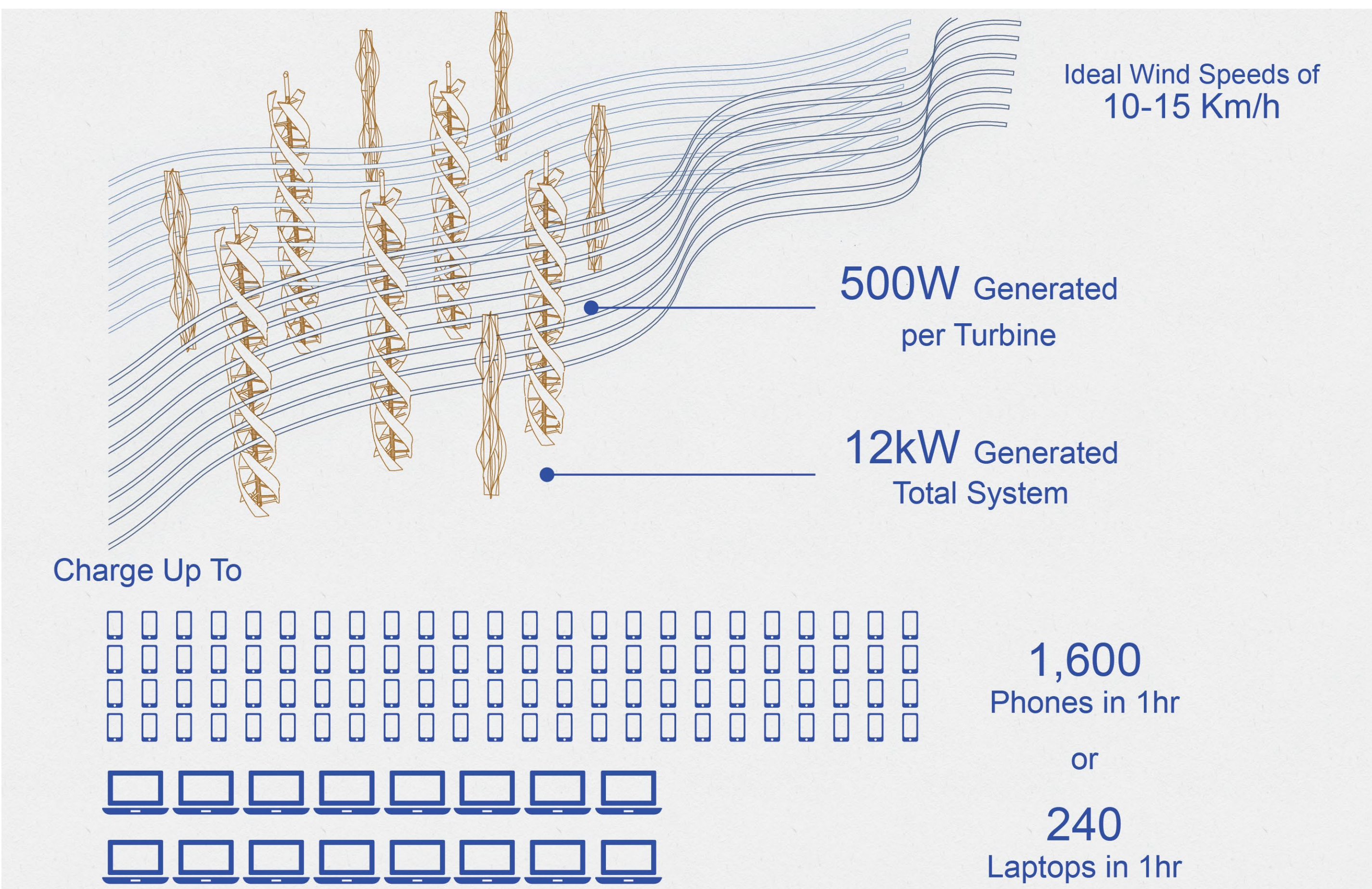


Figure 63. Orchard Alley energy calculation graphic. 2022, by author.

[39] Kennedy Maize, "Outside-the-Box Renewable Energy Microturbines," 2015
*Assuming average phone used between 5-7.5 watts to charge, while laptops are 50 watts, with 24 turbine sets in this design generating roughly 12kW total.

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AMS Nest Plaza

Site Investigations

The AMS (or Alma Mater Society)'s Plaza is located outside of the AMS Student Nest building on the north east side of the academic campus. It serves as a key connection point and gathering space at the core of UBC's community.

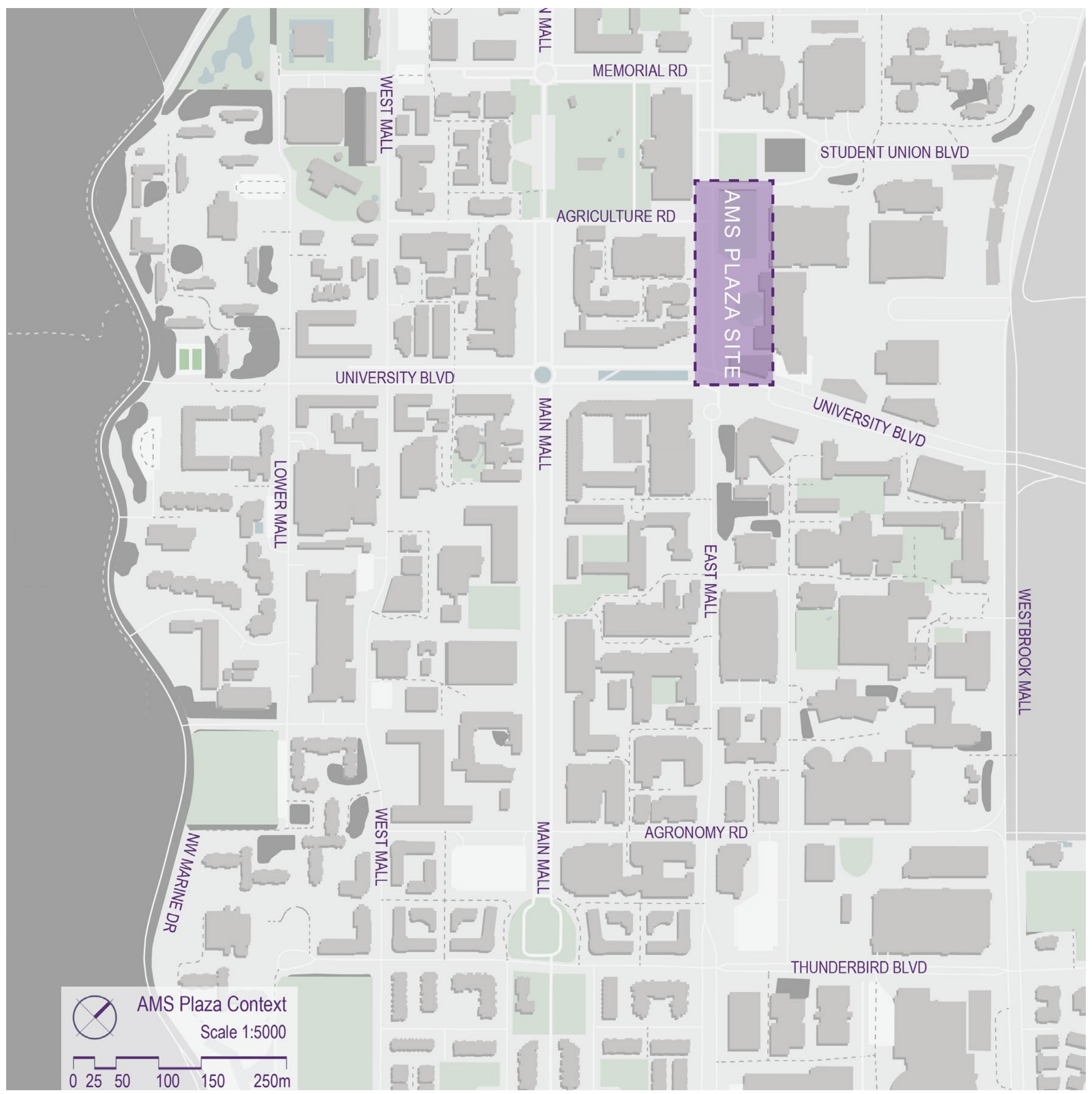


Figure 64. AMS Plaza Location Map. 2022, by author. *(not to scale on a 8.5x11 sheet)*

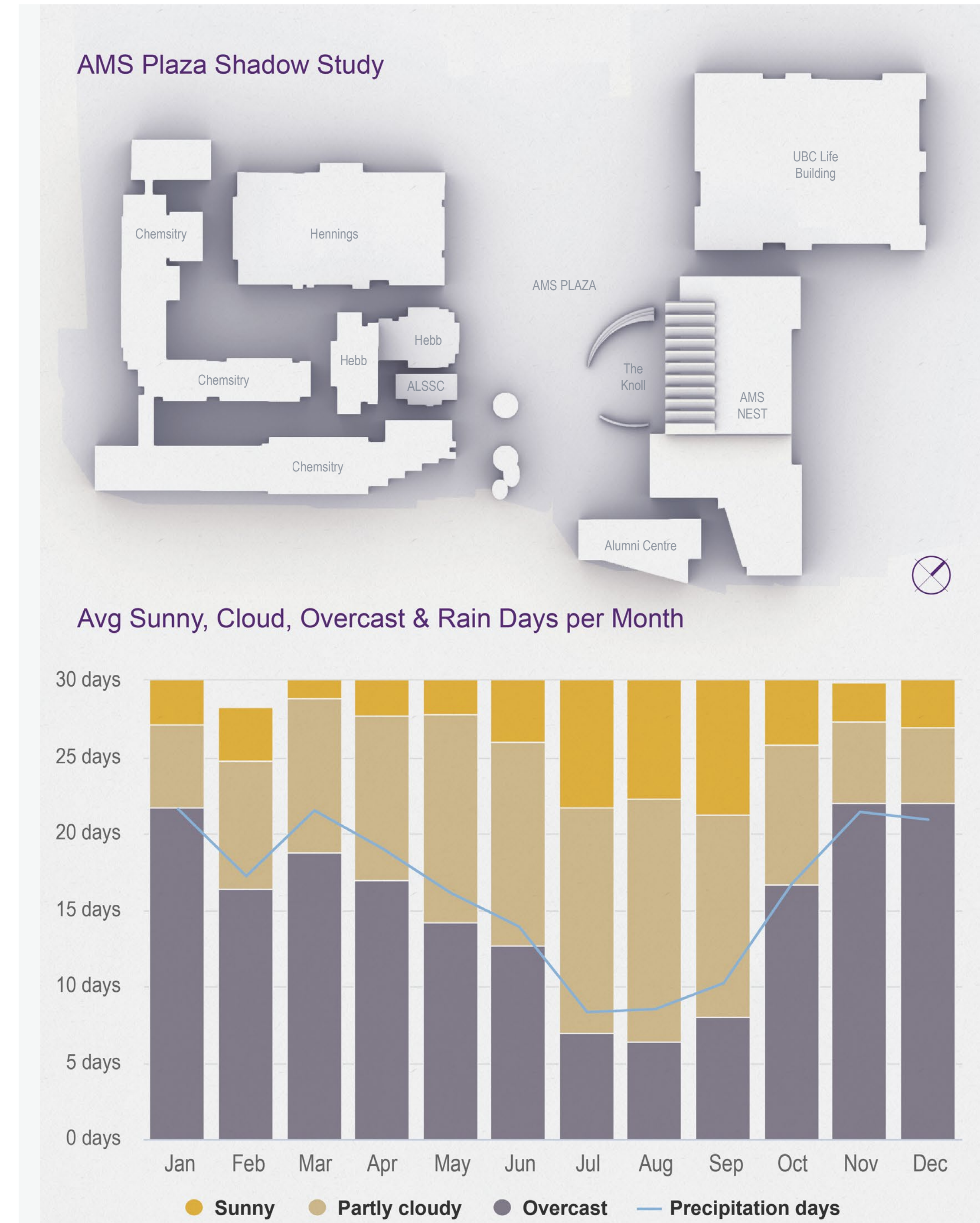


Figure 65. AMS Plaza shadow study and weather data. 2022, by author.

This large hardscape plaza is the primary event and large function gathering space on the UBC campus. However, during most of the year, the space is left as an open hardscape plaza. The large open aspect of the site means that there are very few structures that interrupt the space. As a result, shade can be pretty limited in the warmer months, as well as rain protection during days of inclement weather.

Many primary corridors across campus intersect with the AMS plaza space, making it a go to area for many students to stop for lunch or to run by and grab a coffee before classes from inside. Some peripheral seating spaces are located around the site, and there are oftentimes temporary tables and chairs set up closer to the main entrance so people can enjoy a bit to eat outdoors.

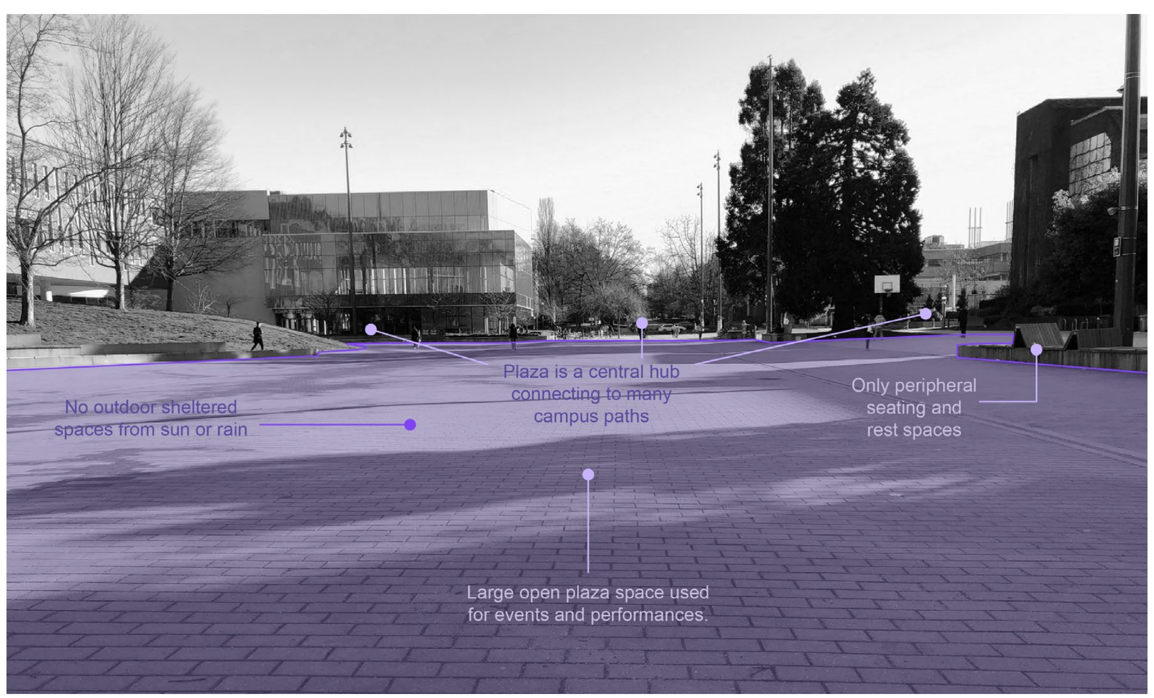


Figure 66. AMS Plaza site analysis photo essay - A. 2022, by author.

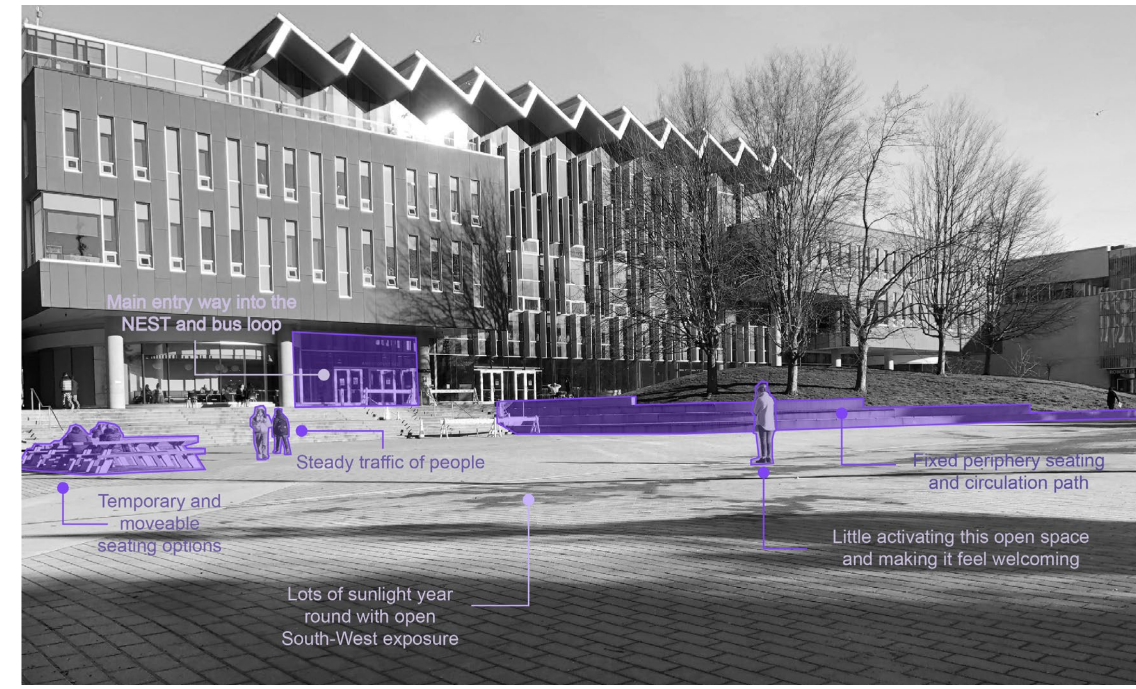


Figure 67. AMS Plaza site analysis photo essay - B. 2022, by author.

With these conditions in mind, a smaller scale Solar PV solution would be the ideal technology of choice to deploy here. High solar yields can be expected year round with the lower level east side buildings that are set a ways back from the main paved plaza area.

The key program considerations for the site are its connection to many campus locations, its necessity to be converted into open flexible space, as well as more opportunities for site activation and solar protection.

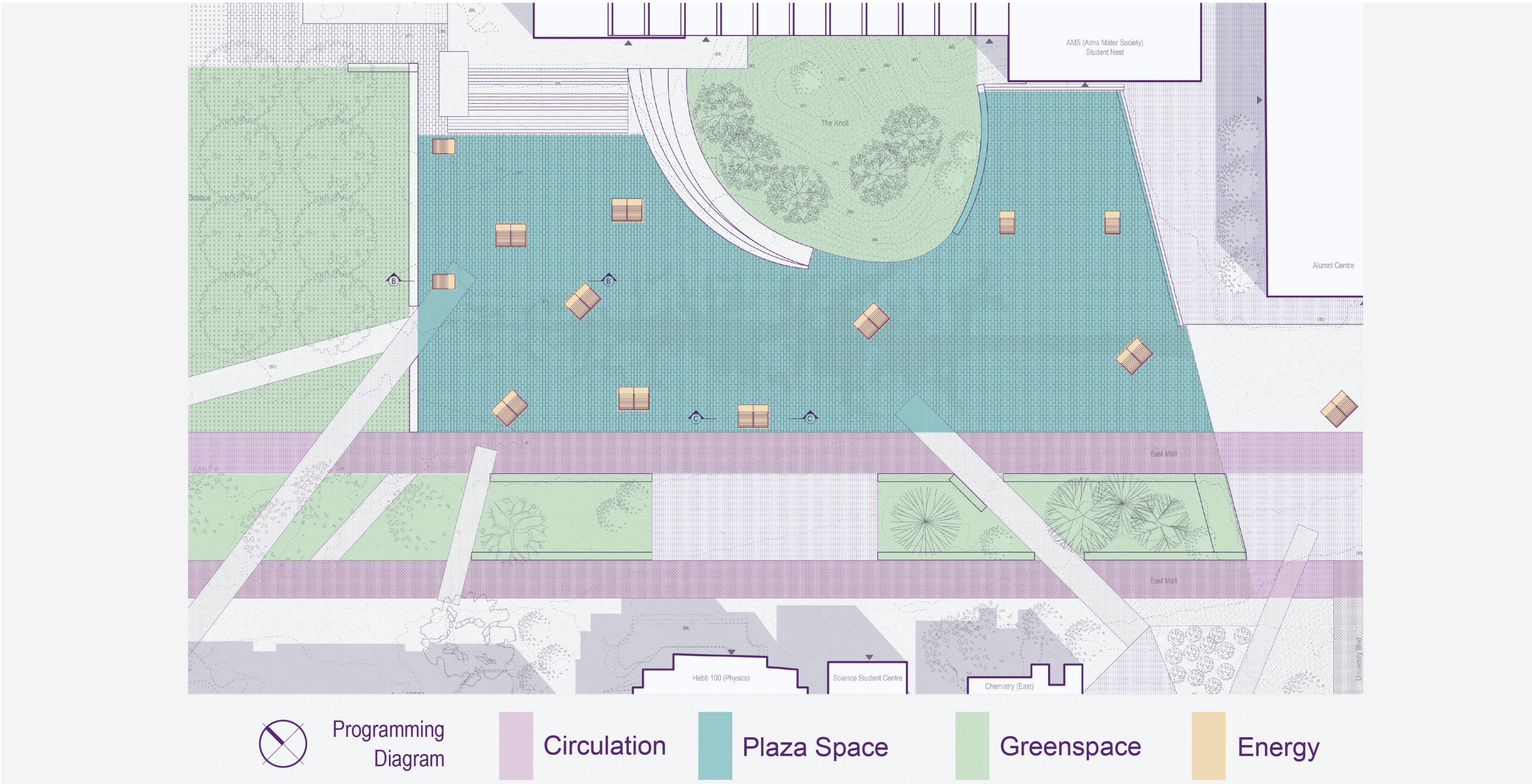


Figure 68. AMS Plaza Programming Diagram. 2022, by author. *(not to scale on a 8.5x11 sheet)*

Design Proposal

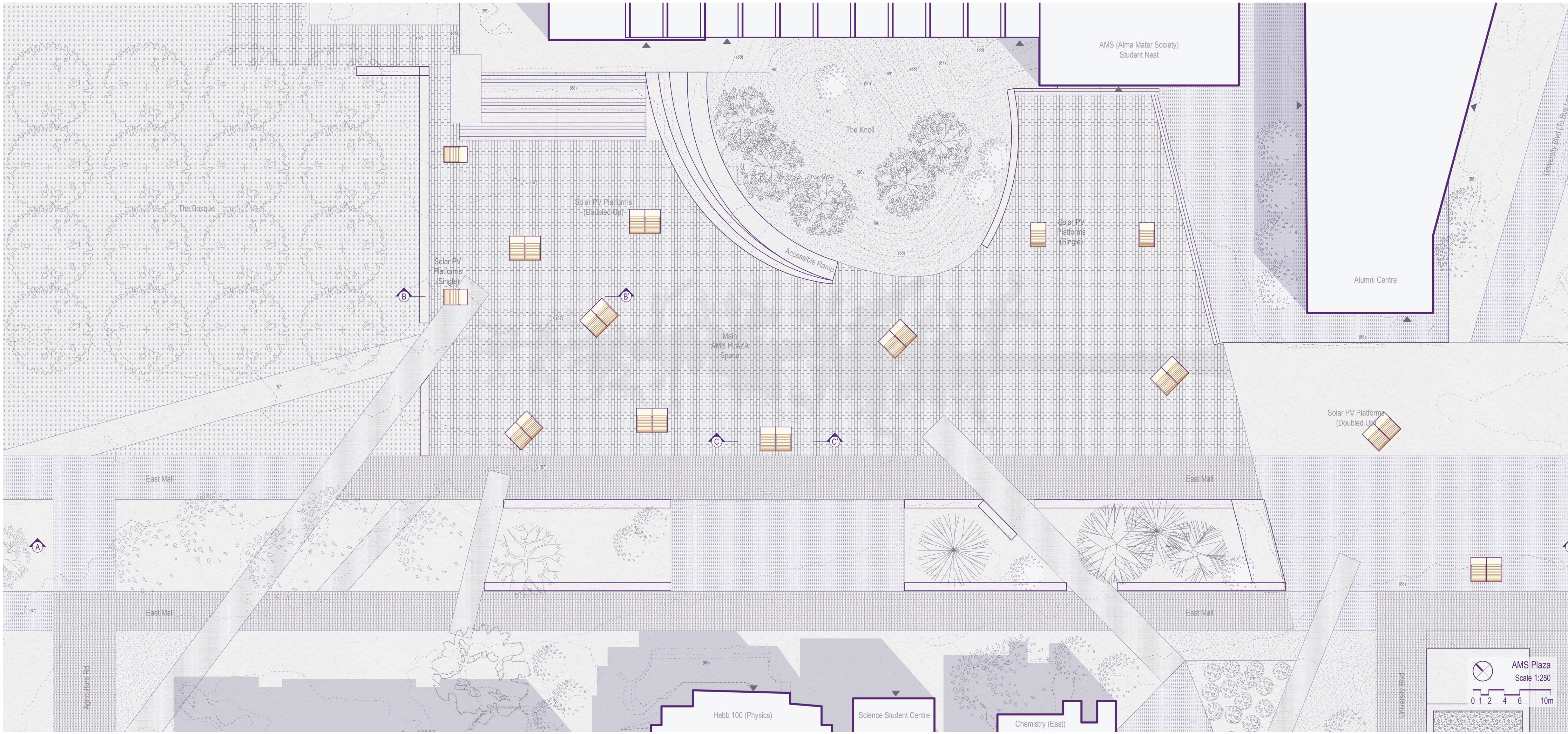


Figure 69. AMS Plaza Plan - Solar PV Platforms in dispursed formation. 2022, by author. *(not to scale on a 8.5x11 sheet)*

Throughout the day a decent portion of the UBC population passes through the AMS nest plaza site. As the hub between many vital campus buildings and locations such as the bus loops and pathways across campus, the site experiences an ebb and flow of people either moving through it or hanging around for a bit to break for lunch, coffee or socialize. This site is therefore in a prime location to be an interactive and educational nexus for renewable energy integration.

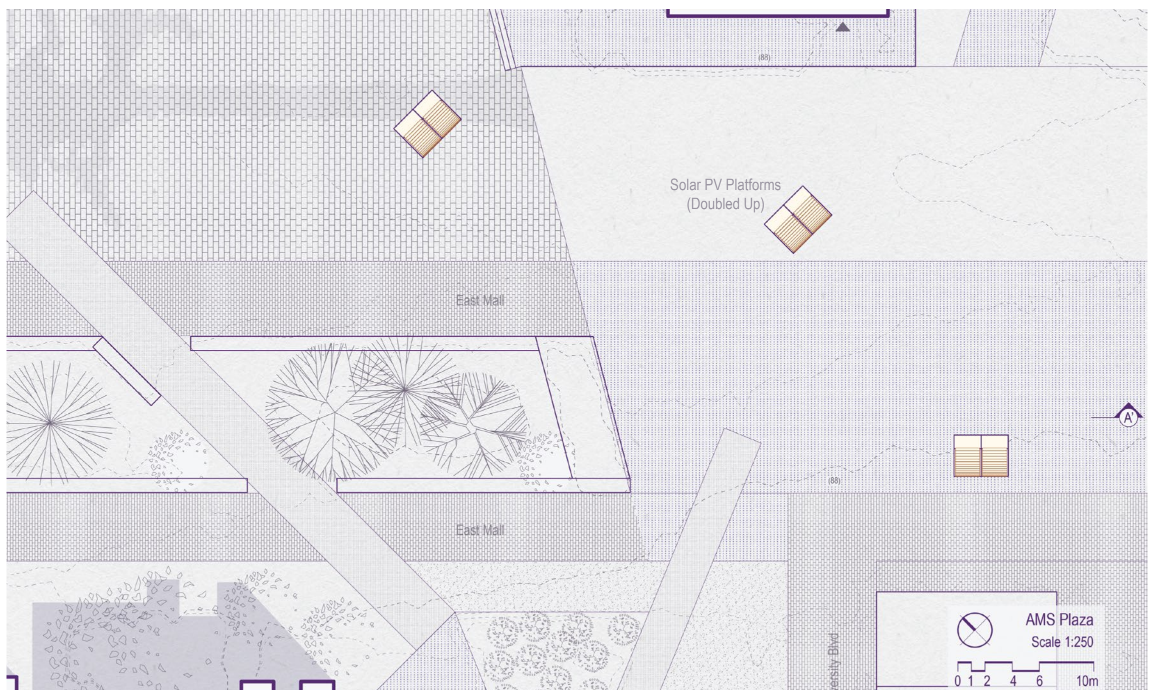


Figure 70. AMS Plaza pathway network detail - Plan. 2022, by author. *(not to scale on a 8.5x11 sheet)*

Because the space needs to remain flexible to accommodate the diversity of programs deployed here, nothing can remain too permanent. With these factors in mind, modularity of structures deployed will mean that they can more easily be moved about as needed, are easy to reconfigure depending on need, and can be used in a multitude of ways across many different areas.

Oftentimes the best way to learn about something is by doing. The solar structures deployed across the AMS plaza site offer just that; a way to interact directly with renewable energy production and learn how best to capture and utilize solar energy (figure 72).

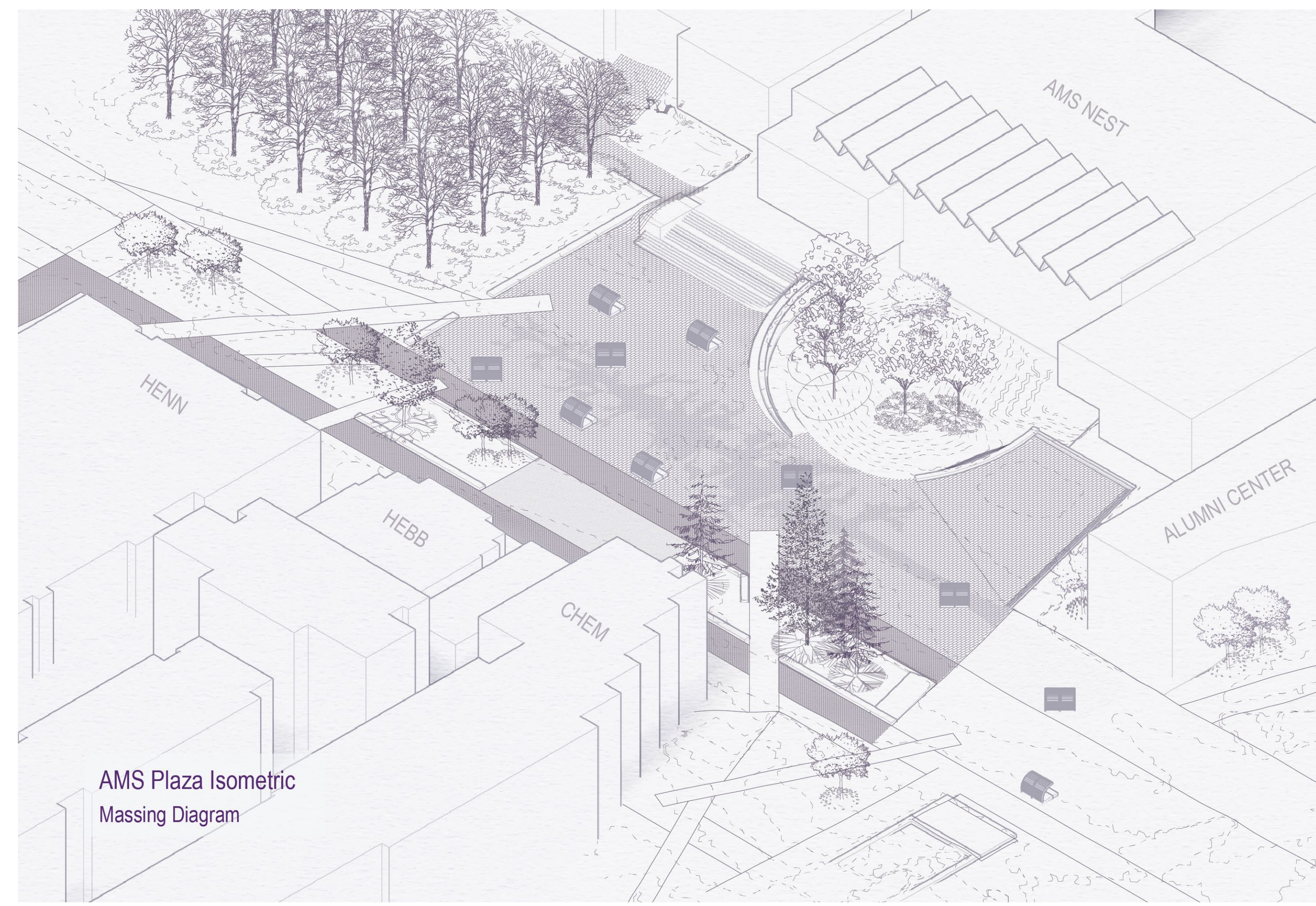


Figure 71. AMS Plaza isometric massing diagram. 2022, by author.

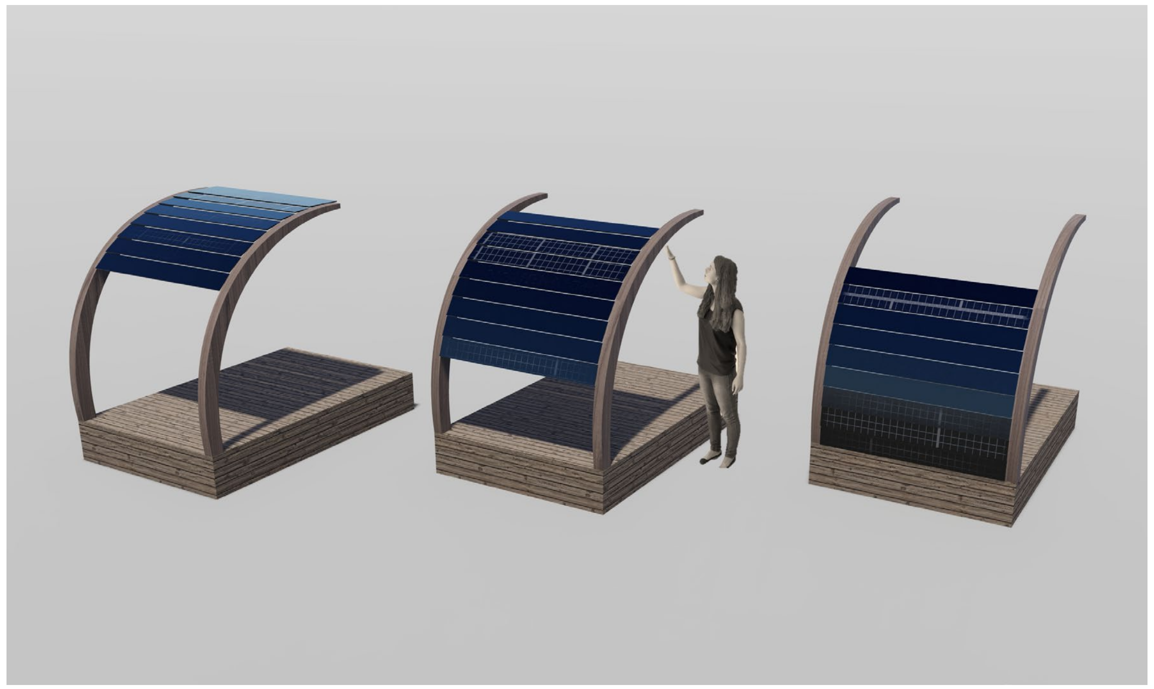


Figure 72. AMS Plaza solar platform - operation and interactive render. 2022, by author.

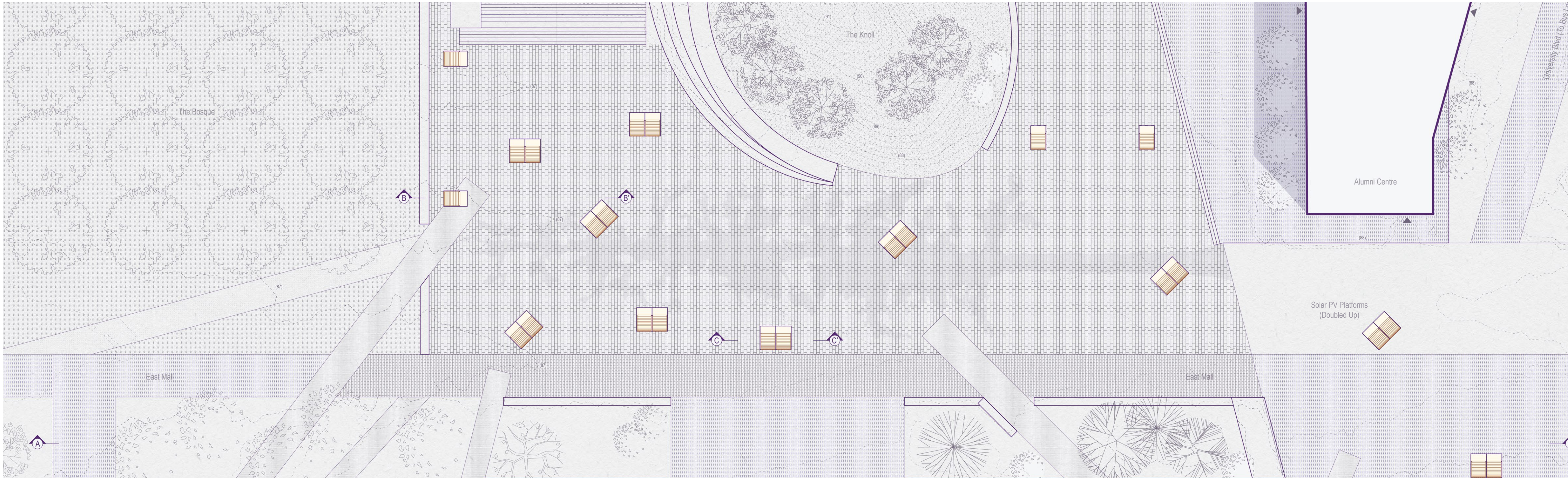
The modular structures can be moved and manipulated by students to maximize the most energy from the sun. Depending on the location of the sun throughout the day, students are able to rotate the solar platforms as well as raise and lower the solar blinds to capture the best solar angle in which to generate the most power. The power captured by these structures can then be used directly to recharge devices in real-time, allowing users to recognize and understand ideal solar siting conditions that yield the best charging experience.

The energy harvested can then be used directly by the occupiers of the platforms to do everything from recharge phones, power laptops or even provide some extra reading light when using energy from the battery storage.

Figure 73. AMS Plaza detail Section B-B'. 2022, by author. (not to scale on a 8.5x11 sheet)

With 24 platform modules deployed across the area, there is also the opportunity to double platforms to create little pods or islands for gatherings or group study spaces… perhaps they could even be used by student run clubs as meeting spaces. You could also go solo and have an energy hub all to yourself! The options are endless.

But what if it's the end of the year and the AMS is hosting their annual block party? Luckily, they can be easily rearranged and linked up to create event spaces such as raised stages. The same can also be done for other events held in the plaza that require an open space. The platforms can be gathered up and moved to other locations or even temporarily moved to other nearby sites like the UBC Bookstore plaza space (figure 76-77).



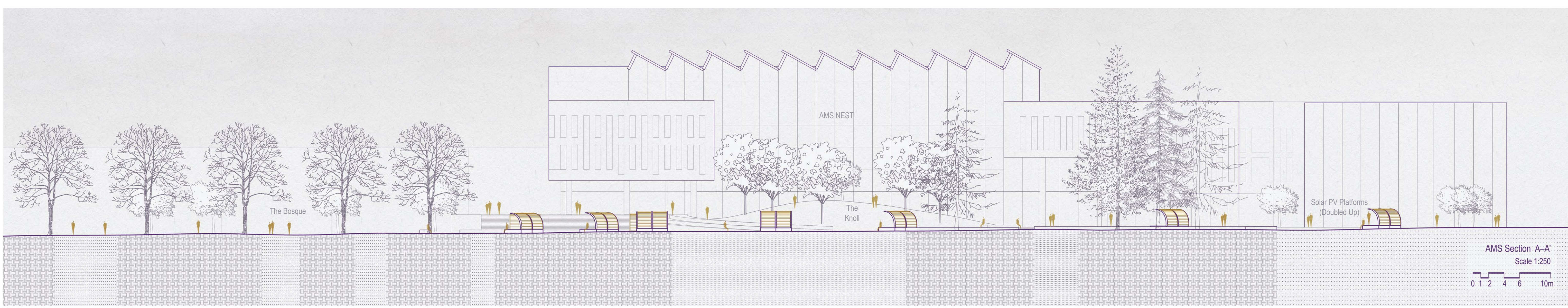


Figure 74 (above). AMS Plaza Plan. 2022, by author. *(not to scale on a 8.5x11 sheet)*
Figure 75 (below). AMS Plaza Section A-A'. 2022, by author. *(not to scale on a 8.5x11 sheet)*

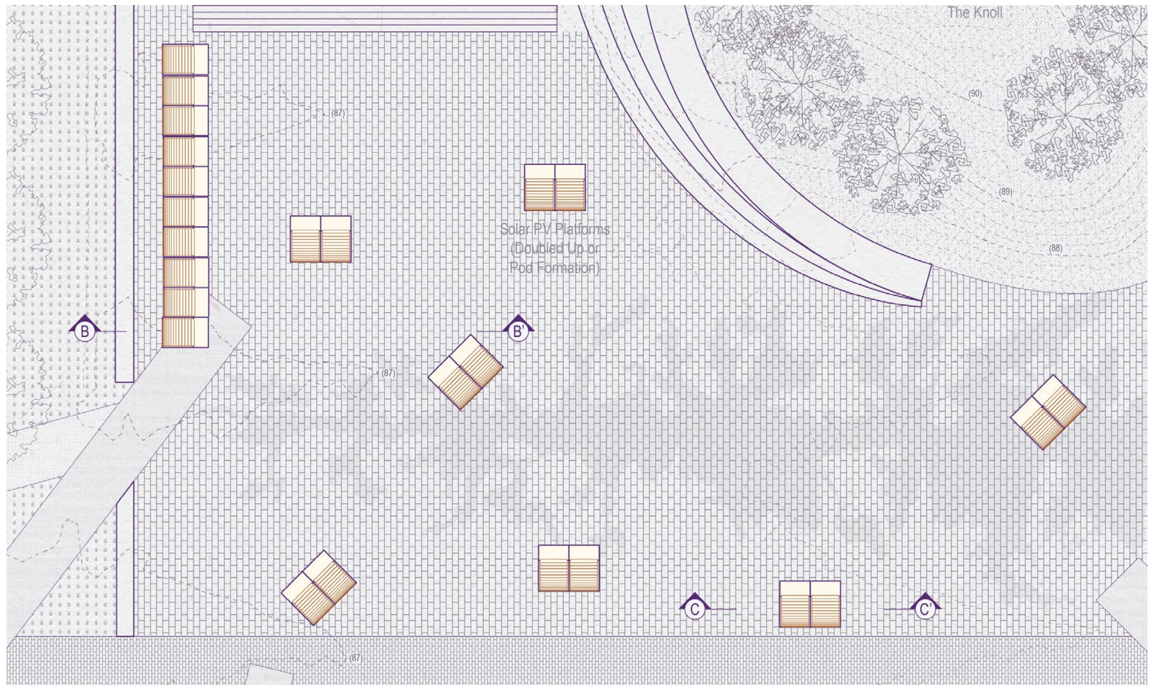


Figure 76. AMS Plaza platforms in pod configuration. 2022, by author. (not to scale on a 8.5x11 sheet)

Figure 77. AMS Plaza platforms in gathered configuration. 2022, by author. (not to scale on a 8.5x11 sheet)

Energy Analysis

The total solar area of one canopy is capable of capturing 416 watts, which, with favorable conditions could charge up 56, phones or 8 laptops[40]. Multiply this by the 24 platforms deployable across the space and there is over a total of 10 kilowatts hours available for use. And some below deck batteries and the platforms can provide up to 1kWh of energy at night or in raining conditions*.

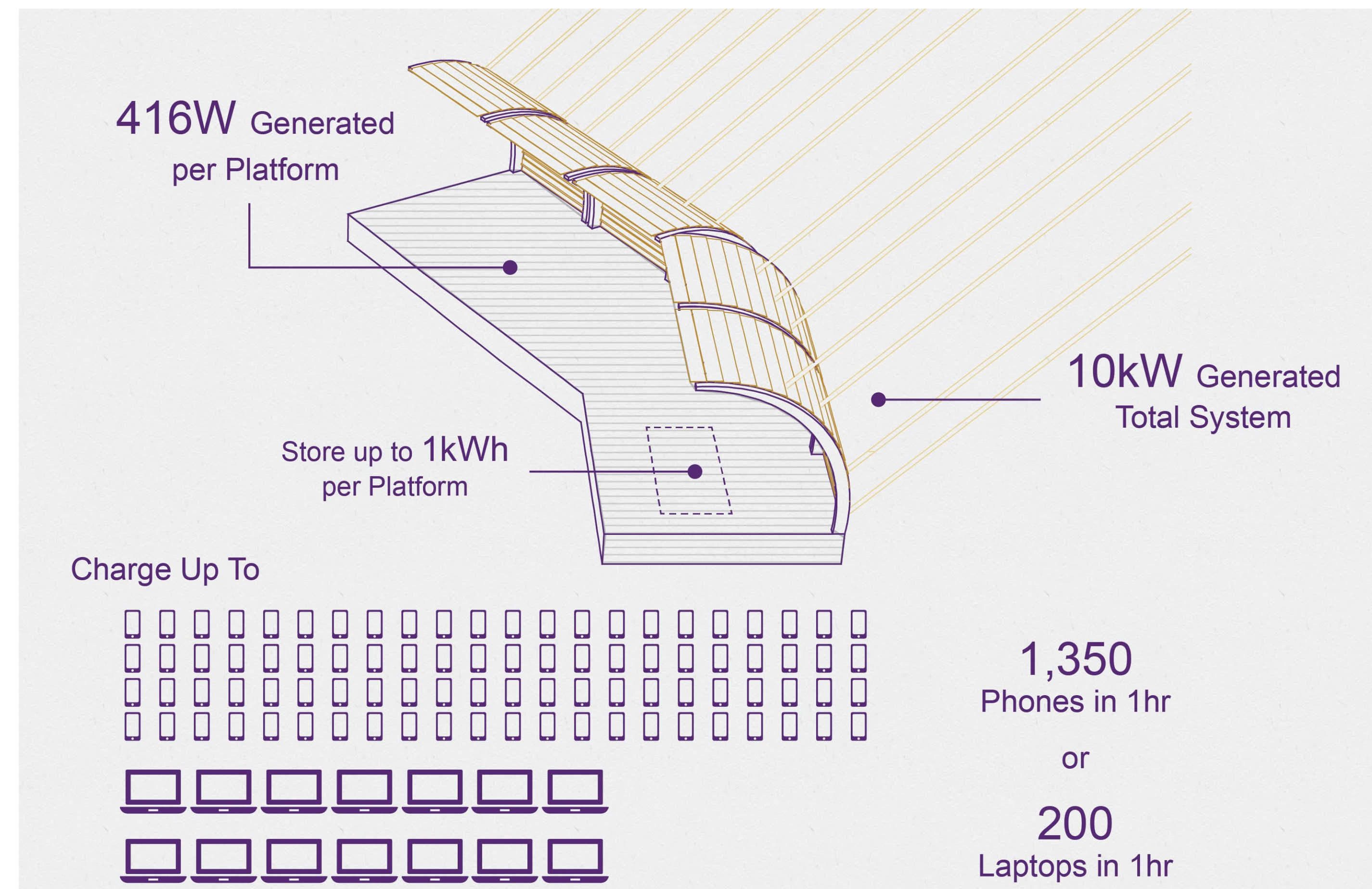


Figure 78. AMS Plaza energy calculation graphic. 2022, by author.

[40] SunPower, "How Many Solar Panels Do You Need: Panel Size and Output Factors," 2021
*Assuming average phone used between 5-7.5 watts to charge, while laptops are 50 watts, with 24 platform sets in this design generating roughly 10kW total.

Parkades

Storage & Networks

While this concludes the exploration of my pilot site projects, I feel like it is also important to briefly explore the energy network and storage that could go into supporting this matrix of sites and renewable energy technologies.

While many of the solutions I've explored offer the possibility of on site battery storage, there is also opportunity to direct portions of the energy generated on campus into larger battery storage facilities. These networked battery locations would serve as an added layer of resiliency to the UBC campus energy sources and demands. To achieve this, these storage devices would ideally be located throughout campus to minimize the transmission loss of energy from the site of generation. Luckily, the UBC campus offers an

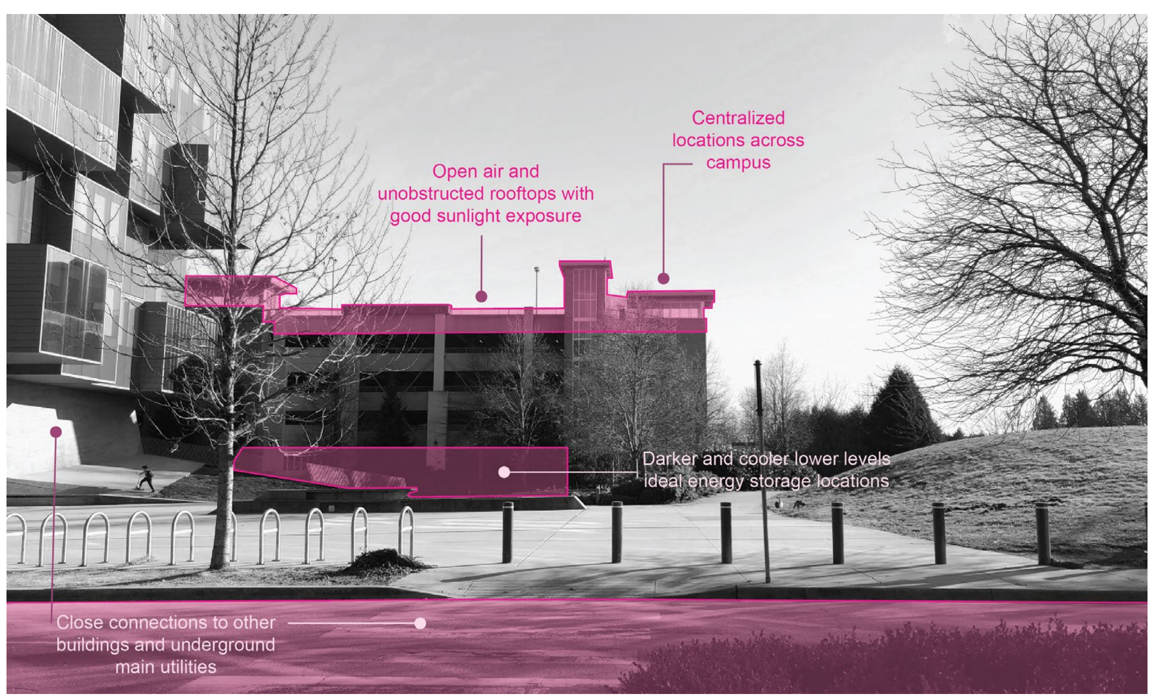


Figure 79. Parkade (Thunderbird) site analysis photo essay - A. 2022, by author.

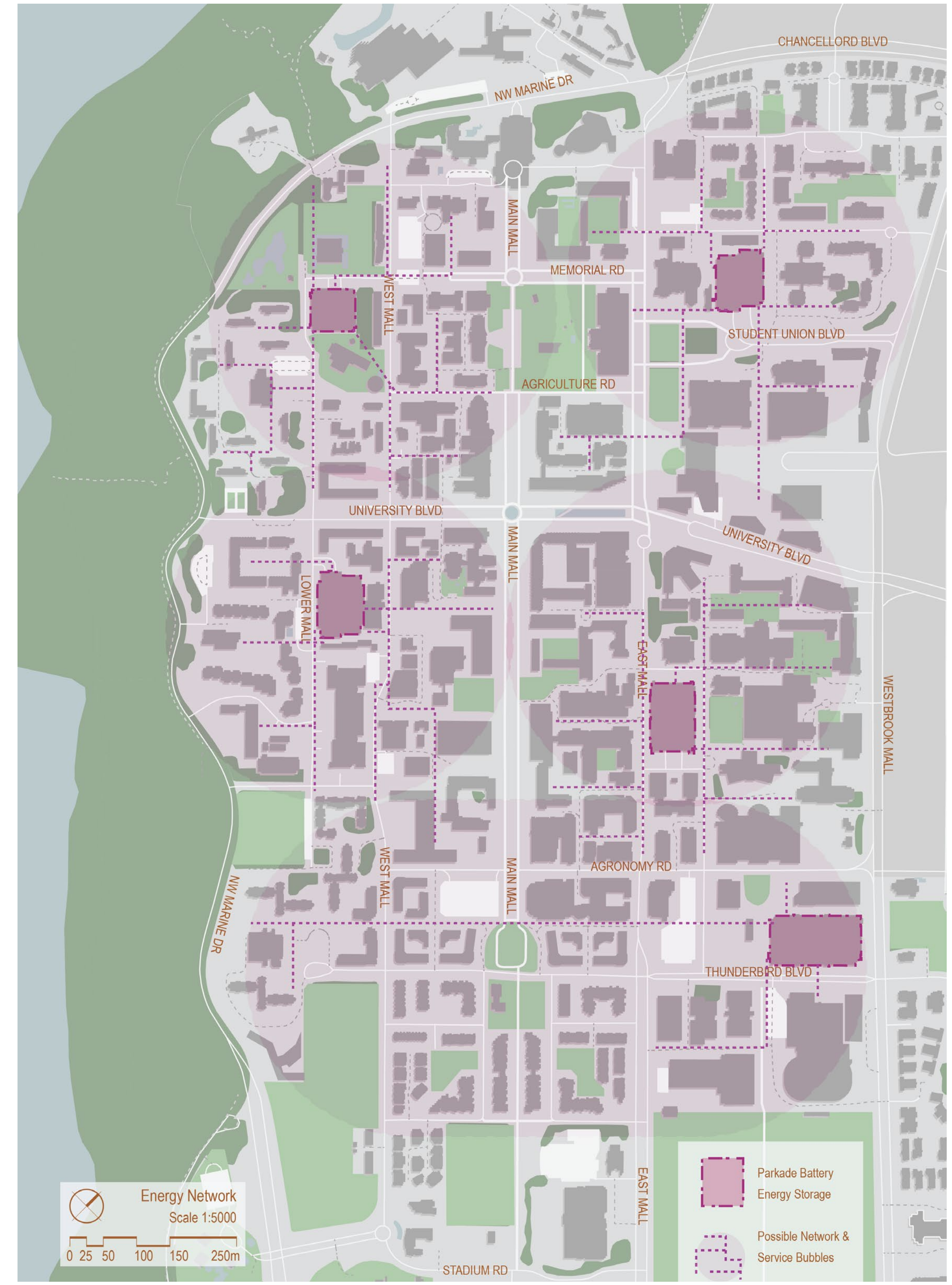


Figure 80. Parkade and Energy Network Plan. 2022, by author. (not to scale on a 8.5x11 sheet)

array of suitable locations in its parkade structures. The UBC parkades are in centralized locations across and can be tied into current infrastructure lines located below road grades.

Large format battery storage can easily fit into a few parking stalls worth of space, and has the capability of storing up to days worth of energy. The network could eventually support almost any solar roof structures in the main UBC academic campus. As a quick example of how much energy a battery storage network could accommodate, I've mapped out rooftops within UBC's academic campus that have favourable conditions to host industry standard Solar PV arrays (figure 81). These buildings have nominally flat roofs, with few large shaded obstructions around them. I've estimated that the total roof area that could accommodate panels in this area is roughly 0.35km square. With the Sun emitting approximately 1GW (that's 1,000,000,000 watts!) of energy per square kilometer, and today's Solar PVs operating at 20% efficiency, we are able to capture about 200MW of solar energy per square kilometer[41]. So on these roofs, we're looking at about 70MW of energy being captured at any one time in absolutely perfect conditions. In comparison, BC Hydro's new Site C dam is providing 1,100MW of capacity, or 5,100GW each year to power over 450,000 homes[42].

This reserve battery store would also be key in providing renewable energy to campus areas or buildings that may not be capable of generating their own renewable energy. Furthermore this store can serve as an added layer of resiliency should the campus power go out such as in large storm events, or even during natural disasters.

[41] NASA Earth Observatory, "Climate and Earth's Energy - Incoming Sunlight," NASA Earth Observatory (NASA, 2021), https://earthobservatory.nasa.gov/features/EnergyBalance/page2.php.

[42] Energy Mines and Low Carbon Innovation, "Factsheet: Site C Hydroelectric Project," (Government of British Columbia, February 6, 2018), https://news.gov.bc.ca/factsheets/factsheet-site-c-hydroelectric-project.

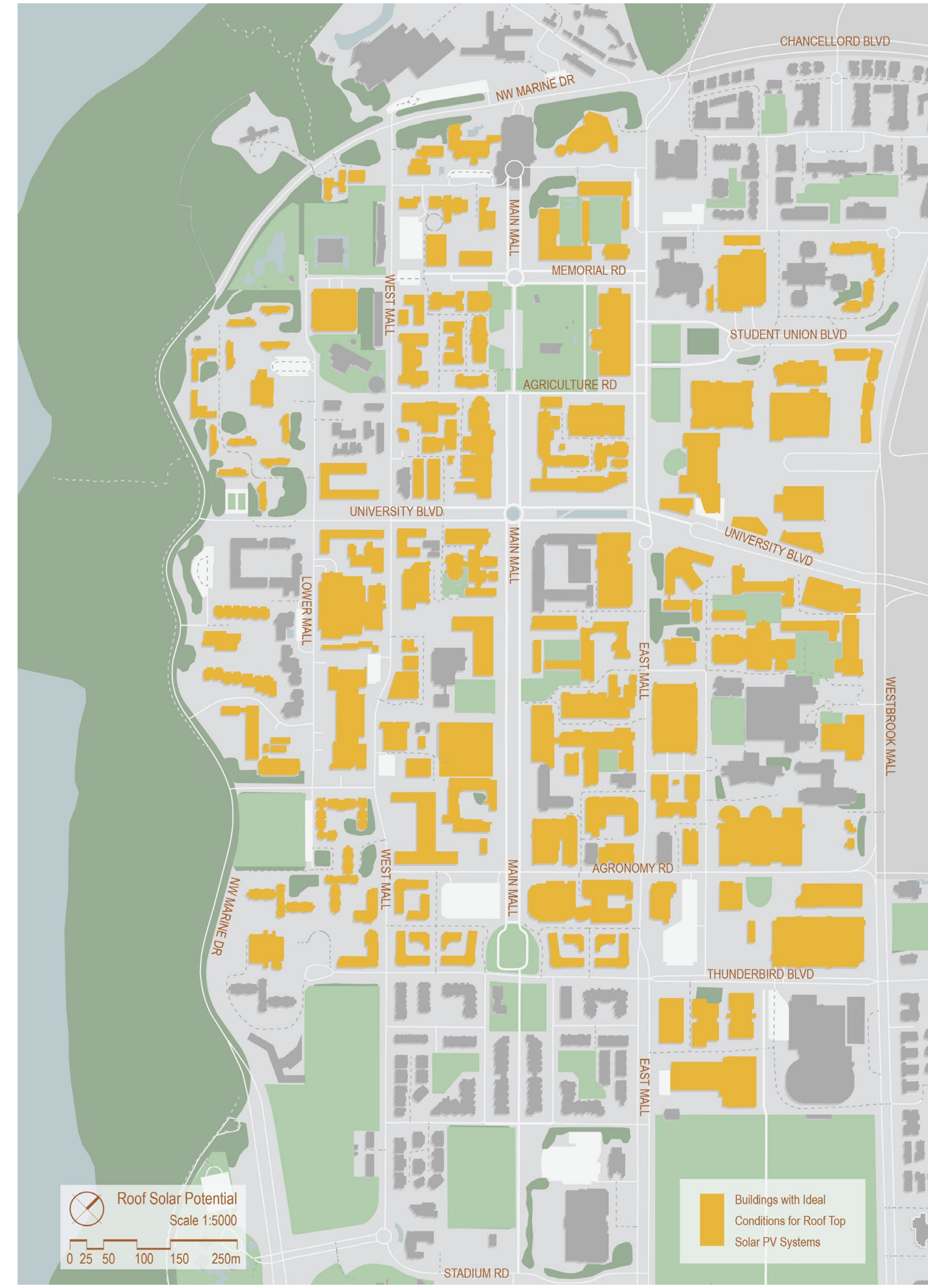


Figure 81. Solar Roof Potential diagram. 2022, by author. *(not to scale on a 8.5x11 sheet)*

Conclusion

In all, small scale renewable energy solutions are a unique and powerful way to provide resiliency and new forms of renewable energy to any site or situation. While still in a development and prototyping phase, many of the solutions explored in this project will only get better over time. As we begin to push the boundaries of how these technologies function as well as where they can be deployed, there is no limits to how much clean energy we could produce for ourselves. It is my deepest hope that I've sparked the curiosity of designers and industry professionals to consider exploring small scale renewable technologies in their future work. Micro hydro, wind and solar are becoming more and more affordable and with our growing energy needs, these technologies could be the solutions we are seeking to curb our greenhouse emissions within the energy sector.
With multiple different solutions available, and having proved they can be deployed in a range of ways, there really is no better time to transition everyone and everything to renewable energy.

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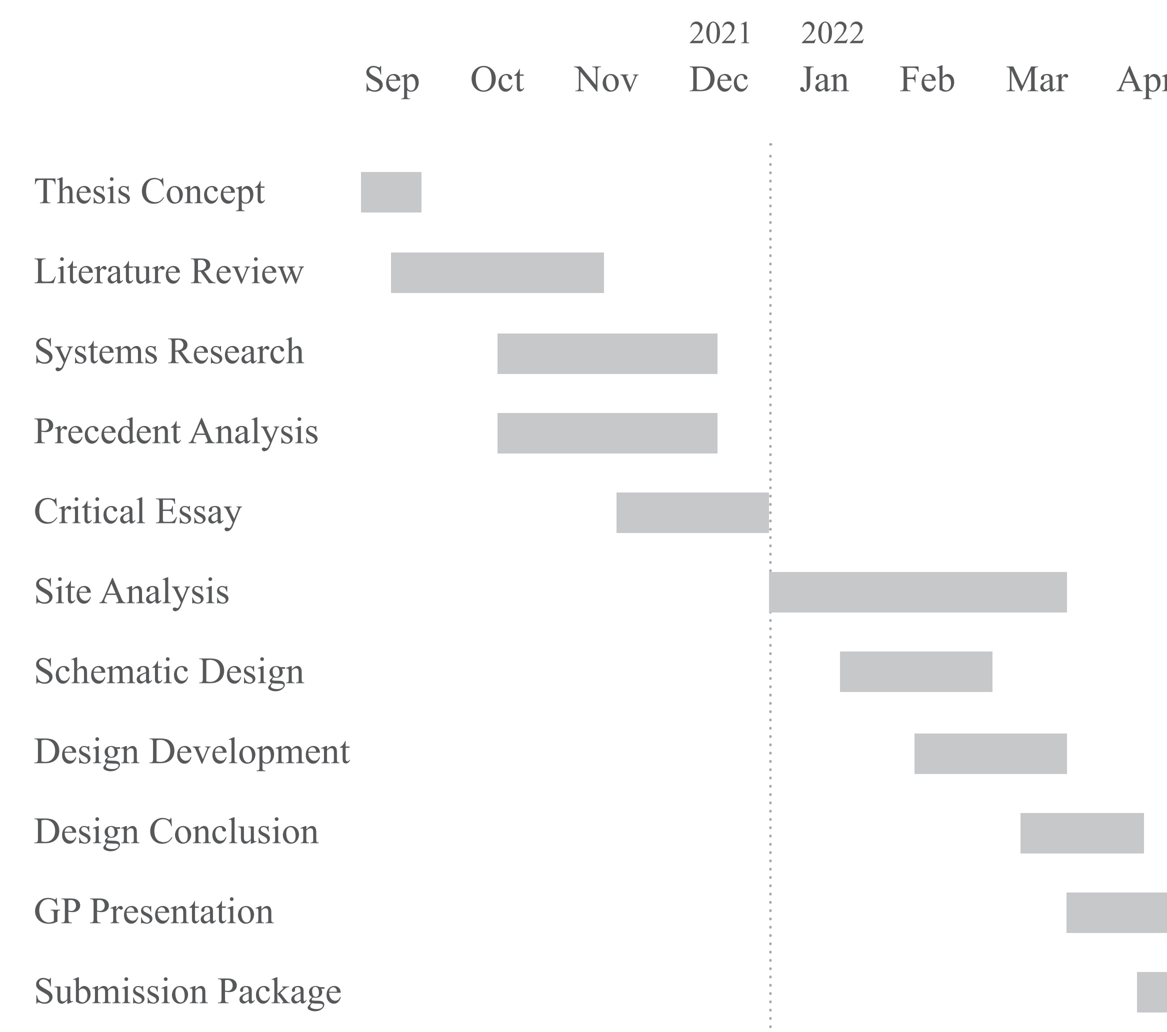
Schedule



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