Thick-skinned:
Using EnerPHit to conserve culture and carbon for sustainable affordable housing

by

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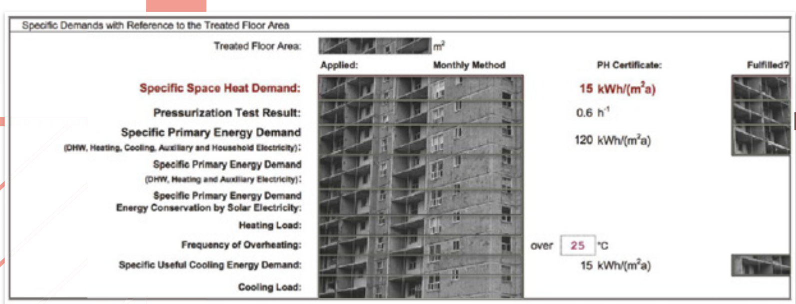

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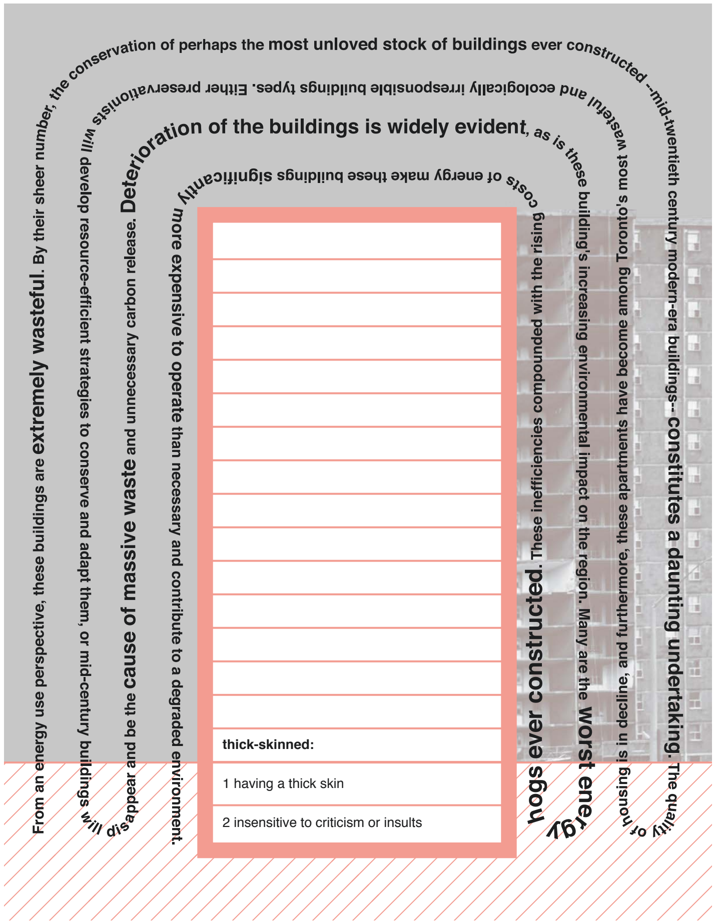
1 Abstract

Canada's existing postwar modern building stock contributes greatly to climate change through greenhouse gas emissions but also represents a large resource of embodied carbon. The Ottawa Community Housing Corporation, the second largest housing provider in Ontario, owns much of this building stock. The buildings in this large portfolio are aging and in need of repairs; the average age of an OCH building is 45 years. Passivhaus provides a retrofit standard (EnerPHit) with which to retrofit buildings to the highest practical energy efficiency without discarding the technical and cultural assets they possess. These buildings can be retrofitted to provide or preserve affordable housing with low operating expenses while simultaneously addressing the conservation of embodied carbon and revitalization without gentrification.

This thesis hypothesizes that the sustainable route to affordable housing is in creating buildings with long-term cultural and economic value and attempts to propose some measures and strategies for retrofitting a postwar modern building to the EnerPHit standard in Ottawa's cold climate

without rendering it vacant for renovation. To this end, the design project is a consideration of possible interventions for an Ottawa Community Housing building intended to lower its total carbon emissions through energy reduction and the conservation of its embodied carbon. The goal of this project is to present interventions that balance high technical achievement in energy reduction with important cultural and social considerations.



Why "thick-skinned"*?

- It is a common assumption that Passivhaus buildings, since they often require high levels of insulation to achieve the standard's envelope performance, have thicker walls than average construction.
- The over-cladding of pre-existing concrete and masonry structures results in a deep wall assembly.
- There is a lack of esteem and affection for deteriorating postwar modern tower buildings that show no obvious architectural merit despite the abundance of energy they embody. We're lucky they haven't all crumbled under the weight of our criticism and deferred maintenance.
- Canadian citizens who need our social housing system are unjustly required to develop skills or lifestyles to cope with the low supply and quality of our social housing stock, or they suffer.

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* *Illustration quotes from* Carl Elefante's "Changing World, Evolving Value: A Historic Preservation Roadmap Toward 2050" and Theodore Jonathon Kesik's and Ivan Saleff's Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-unit Residential Buildings in Cold Climates.

2 Acknowledgments

It's been my pleasure to benefit from the help, advice, and wisdom of many people as I worked on this project. I am especially grateful to those who generously donated their time to meet with me: many thanks to both the Director of Development for Ottawa Community Housing, Barron Meyerhoffer and my Carleton peer, Johanna Abril, for facilitating access to information from OCH as well as to Building Conservation Specialist James Maddigan for his advice on project scope.

Thanks, of course, to my advisors, Prof. Mariana Esponda and Prof. Scott Bucking, for being supportive and inspirational. Many thanks as well to Prof. Susan Ross for always being a helpful and engaged critic as well as for the resources on modern conservation she provided.

And lastly thanks to my dear friend, Jessie, for her keen eyes and kind words, and to my husband, Alexander, for his indispensable insight and dedication.

3 Preface

This project is one result in my pursuit of arriving where I want on the spectrum of future architects who care about sustainability. The initial motivation was informed by my desire to define sustainability for myself as I begin my career in architecture.

So far, one of the lessons I am learning is that real sustainability is impossible when poverty, homelessness, and wealth disparities exist. These conditions signal systemic flaws which preclude the long-term societal thinking that is so necessary for realizing long-term sustainability goals. If society is unable to provide healthy homes for each of its members in the presence of extreme wealth, it will be unable to fully address environmental issues in the presence of obvious solutions.

My current definition for sustainability is a process which marries technical excellence with social and ecological responsibility. When the economy infringes on an architect's ability to achieve this, it becomes more detrimental to sustainability than any other factor. An architect's deft navigation of the world of finance is prioritized over that of the world of resources, and this will not be solved with the economical installation of green roofs, heat recovery ventilators, or superinsulation.

However, if the battle ground of sustainability must be won on cost, it is our job and moral imperative as architects to become so good at it that it becomes the cheapest option. It is this thought that makes me interested in the developing industries of passive houses and retrofitting the old concrete towers.

4 Thesis Question

This thesis hypothesizes that the sustainable route to affordable housing is in creating buildings with long-term cultural and economic value and attempts to propose some measures and strategies for retrofitting a postwar modern building to the EnerPHit standard in Ottawa's cold climate without rendering it vacant for renovation.

Contents

5 Introduction

This thesis attempts to integrate two architectural disciplines, building conservation and environmental sustainability, in order to address two primary research motivations:

- the prevention of erosion of affordable housing
- decreasing the impact of architecture on climate change

It begins with a brief look at the characteristics that define affordable housing (in Ontario and in Ottawa) as well as at the changing understanding of the priority of architecture's carbon performance with regard to climate change mitigation in Canada. Following that is an overview of existing ideas (some well-established, some new, some practical, and some theoretical) that hint at the combination of these two motivations, or even explicitly combine them, to the benefit of each. The work done in these examples supports the thesis hypothesis and informs the goals and method for the proposed interventions.

5.1 What is housing affordability?

> "Housing affordability is about how productive and appropriate the supply of current housing is."[1]

In May 2017 a comprehensive study of the factors affecting housing affordability in Ontario was published. It was conducted by the independently contracted Canadian Centre for Economic Analysis (CANCEA) and was commissioned to examine the interrelatedness of factors affecting affordability within a systems thinking[2] framework. The report is intended to aid policymakers and to combat the dissemination of the myopic views of what contributes to affordability by the apparent experts and stakeholders. The tools involved were the SCAR index (the Shelter Consumption Affordability Ratio), a measure of affordability which divides shelter consumption costs by discretionary income, and *Prosperity at Risk*, CANCEA's robust simu-

[1] *Understanding the forces driving the shelter affordability issue: A linked-path assessment of housing market dynamics in Ontario and the GTHA*. The Canadian Centre for Economic Analysis. May 2017, p. iii.

[2] A holistic method of analysis that considers how all of the parts of in a system affect each other over time.

lator which uses big data to analyze how policies and markets affect economic development.

What CANCEA found was that housing affordability in Ontario has worsened 40% since the 1980s and 15% since 2000. They also found that shelter prices have been rising faster than incomes, that the shelter market is more sensitive to the needs of wealthier households, and that the ability to make ends meet is distributed unevenly. Due to these factors they noted that many families that should be renting are forced into buying because of a significant lack of suitable options for families with more than four members.

Since the report was conducted with the intent to aid policy makers, the concluding recommendations focus on areas for realistic policy intervention (though the analysis includes other contributing factors[3]). The recommendations emphasize that policies should address tenure-matching, right-sizing, and curbing speculation since housing affordability is about how productive and appropriate the supply of housing is (as opposed to

[3] Such as a rapid increase in wages to decrease wealth disparity.

the common ideas that affordability is about housing cost or supply). It concludes that the expansion of the purpose-built rental stock with multi-bedroom units in the near future is key to significantly improving housing affordability in Ontario.

Some 2017 Ontario Housing Affordability Facts[4]

- Less than 1/3 Ontarians are suitably housed.
- 8% of households (13% of population) are underhoused. This is higher in urban areas.
- Getting more households to rent and developers to build more purpose-built rentals would almost get the SCAR index back to levels seen in the 1990s in the next 15 years, and therefore substantially improve housing affordability.
- There is a significant difference between owned and rented shelter available for larger households: large renter households do not have the same options as owners.
- Affordability for households with below median incomes is highly sensitive to average wages, labour participation, and rental stock quality.

[4] All from: *Understanding the forces driving the shelter affordability issue: A linked-path assessment of housing market dynamics in Ontario and the GTHA*.

5.1.1 Affordable Housing in Ottawa

With some context now established, it is important to actually define what affordable housing, for the purpose of this thesis, *is*. In Canada, the specific definition for affordable housing is

> "if shelter costs account for less than 30 percent of before-tax household income."[5]

This definition is obviously applicable to the entire range of available shelter types considering it is based on shelter cost alone. However, the Canada Mortgage and Housing Corporation (CMHC) acknowledges that it's common to conflate "affordable housing" with "social housing". Social housing, indeed a shelter type within the continuum of affordable housing, is perhaps more technically referred to as "subsidized housing". One provider of this type of housing in Ottawa is Ottawa Community Housing (OCH). Subsidized housing provided by OCH works on a "rent-geared-to-income" basis and rent is calculated to be 30 percent of total household

[5] *About Affordable Housing in Canada*. Canada Mortgage and Housing Corporation, 2017. URL: `https://www.cmhc-schl.gc.ca/en/inpr/afhoce/afhoce_021.cfm`.

income. As of 2017, there is a waitlist for this type of housing with special priority being given to victims of abuse, a medical urgency that requires a change in housing, or homeless status.[6,7]

Despite some improvement in the availability of subsidized housing options, demand remains high and interest in correcting this imbalance has prompted the government to spend considerable money over the coming decade in a variety of initiatives.[8,9] In line with the affordability difficulties affecting them as reported by CANCEA, families in Ottawa are increasingly accessing emergency shelter and, at the end of 2016, 3421

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[6] *Subsidized Rentals*. Ottawa Community Housing, 2015. URL: `http://www.och-lco.ca/subsidized-rentals/`.

[7] *Assigned Priorities*. The Registry - Centre d'enregistrement, 2014. URL: `http://www.housingregistry.ca/what-is-the-registry/assigned-priorities/`.

[8] "$30 billion over the next 11 years"; see www.letstalkhousing.ca for National Housing Strategy initiatives.

[9] More than $11.2 billion over 11 years in the national budget for a variety of initiatives designed to build, renew and repair Canada's stock of affordable housing. *Budget 2017: Chapter 2 - Communities Built for Change*. Mar. 2017. URL: `https://www.budget.gc.ca/2017/docs/plan/chap-02-en.html`.

families were on the waiting list for subsidized housing.[10] In terms of affordable housing in Ottawa, it's this subset of subsidized housing that will be the concern of this thesis as it represents the largest stock of buildings devoted to the most underserved segment of the population.

When looking at the CMHC's market rental and housing outlooks for Ottawa, it's clear that there is no corrective feedback mechanism between apparent market conditions and a reality where everyone has a home.[11] This is shown when the forecast makes observations like,

> " . . . rising mortgage rates in 2017 and 2018 from historic lows may swing the pendulum toward increased rental demand as some households opt to rent rather than own."[12]

without understanding the affordability factors affecting *why* house-

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[10] *2016 Progress report on Ending Homelessness in Ottawa*. Alliance to End Homelessness Ottawa. URL: `http://endhomelessnessottawa.ca/`.

[11] Independent of any governmental incentives for provision of below-market rent by the rental market.

[12] Canada Mortgage and Housing Corporation. *Housing Market Outlook: Ottawa*. Fall 2016.

holds may *opt* to rent rather than own. In this 2016 forecast the apparently rising rental demand will again be measured yearly and compared with the supply of all the new apartment starts prompted by this earlier forecast of demand so that a new forecast is created. And, in fact, the 2017 report already anticipates rental market downturn, suggesting that “unabsorbed” rental units could be converted into condominiums. This points to CANCEA’s study being correct when it reports that markets disproportionately respond to the wealthy. Another measurement of demand frequently mentioned in these forecasts is the vacancy rate, but a vacancy rate cannot effectively capture aspects of affordability when even a below median market value is above a sustainable percentage of a household’s income.

In sum, the warning signs that current members of the rental market may slip into the “market” for subsidized housing are being ignored.[13] In the mean time, subsidized housing in Ottawa will remain the only viable option for many people and demand seems unlikely to ebb (evidence sup-

[13]The segment of the population who require subsidized housing are actually considered as being “households whose needs cannot be met in the marketplace” by the CMHC.

porting this is the mounting $3.1 million in OCH tenant debt at the end of 2015).[14] This suggests that, in addition to other government housing initiatives, the preservation of the existing building stock in portfolios such as the OCH's will be an important tool moving forward in any realistic housing strategy, especially if those apartments with family-sized accommodations can be maintained.

5.1.2 Housing and Climate Change

The OCH Corporation is the second largest housing provider in Ontario; they own and manage over 14,800 units.[15] They also happen to have a large portfolio of aging buildings in need of repair; the average age of an OCH property as of 2017 is 45 years.[16] In the past decade they have

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[14] Jon Willing. *Ottawa Community Housing tenant debt: 3.1 million at the end of 2015*. June 2016. URL: http://ottawacitizen.com/news/local-news/ottawa-community-housing-tenant-debt-3-1-million-at-the-end-of-2015.

[15] *Client Profile: Ottawa Community Housing Corporation*. URL: http://www.infrastructureontario.ca/Ottawa-Community-Housing-Corporation/.

[16] *Ottawa Community Housing Makes Historic Announcement About a Major New Development Project*. Ottawa Community Housing, May 2017. URL:

made significant progress in expanding their opportunities for development as well as addressing the renovation needs of their assets, but they still face a major deferred maintenance backlog.[17,18] It is imperative that the needs of these aging buildings continue to be addressed, even in the face of new affordable housing being built, considering currently they provide a remarkable number of homes for Canadians. The provision of housing is not the only reason the preservation of OCH's building stock is important: the renovation of these properties is linked explicitly with environmental sustainability as well.

In 2017 the Canadian Green Building Council (CaGBC) put forward

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http://www.och-lco.ca/ottawa-community-housing-makes-historic-announcement-about-a-major-new-development-project/.

[17] CNGRP. "OCH to spend 30.5 million on 450 capital projects". In: *Ottawa Construction News* (July 2015). URL: https://www.ottawaconstructionnews.com/local-news/och-to-spend-30-5-million-on-450-capital-projects/.

[18] $140 million as of 2016 Jon Willing. *Ottawa Community Housing promotes 20M in upgrades for aging housing stock*. June 2016. URL: http://ottawacitizen.com/news/local-news/ottawa-community-housing-promotes-20m-in-upgrades-for-aging-housing-stock.

a roadmap for retrofit projects in Canada that acknowledges the potential of large buildings to help achieve global sustainability goals. A key point of this document was to guide the discussion from the idea of “energy performance”[19] towards the idea of “carbon performance”[20]. The CaGBC recommends that those in the building sector shift the priority from terms like “energy efficiency” to “total carbon footprint”[21] and “carbon performance” so that the focus on reducing carbon emissions is not lost in the quest to achieve energy performance.[22]

To this end, the second of four actions in their plan is to

> “Undertake deep retrofits in buildings to high-performance standards such as LEED, focusing on energy reduction and ensur-

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[19]Or Energy Use Intensity (EUI), the total amount of energy a building requires; the energy consumed divided by the built area.

[20]A metric that measures a building’s carbon emissions per unit built area.

[21]The total amount of greenhouse gas emissions of a specific activity, population, or system.

[22]*A Roadmap for Retrofits in Canada: Charting a path forward for large buildings*. Canada Green Building Council. 2017, p. 3.

ing that key building systems such as lighting, HVAC and envelopes are upgraded."

CaGBC's recommended path for the transition to low-carbon buildings involves the creation of a future retrofit code, which should include a greenhouse gas (GHG) metric, and the prioritization of investments in retrofit projects that can scale, in order to increase investor confidence in Canada's retrofit economy.[23] Despite the emphasis on both retrofitting and carbon performance, the roadmap fails entirely to mention the impact of embodied carbon in existing buildings and focuses solely on GHG emissions from operations (the idea of embodied carbon will be returned to soon).

Two facts from this roadmap stand out as being pertinent to the renovation of the OCH buildings. The first is the report's classification of Ontario residential buildings as being part of the top eight prioritized building asset classes with the highest GHG emissions and the highest potential

[23] *A Roadmap for Retrofits in Canada: Charting a path forward for large buildings*, p. 23.

for carbon emission reduction by 2030.[24] The second is that buildings constructed between 1960-1979 represent the largest share (37%) of large building GHG emissions, due to the fact that buildings constructed during this period had lower energy efficiency standards.[25] The OCH building stock is comprised of 56% highrises, many of which must have been built between 1960-1979.[26] Retrofitting them to address their operational efficiency represents a significant opportunity to reduce the nation's GHG emissions.

5.2 Existing Ideas

Building initiatives and standards for building that combine housing affordability and energy retrofitting exist, both in a Canadian and international context. Some explicitly address these two motivations, while others just

[24] *A Roadmap for Retrofits in Canada: Charting a path forward for large buildings*, p. 7.

[25] Ibid., p. 9.

[26] *Housing Options*. Ottawa Community Housing, 2015. URL: `http://www.och-lco.ca/housing-options/`.

happen to be applicable. This section starts with an overview of a few examples of existing ideas or projects concerning these motivations as well as the previously mentioned issue of embodied carbon. Following that is a brief look at some real examples of energy efficient affordable housing which serve to prove such projects are possible. It concludes with an overview of Passivhaus as an example of an energy and comfort standard frequently held as the benchmark of good building practice in many North American and international locations.

5.2.1 Retrofitting to Mitigate Climate Change and Address Embodied Carbon

The idea that provides the main impetus for this thesis project is the work done in Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-Unit Residential Buildings in Cold Climates, by Ted Kesik and Ivan Saleff at the University of Toronto in 2009. Tower Renewal Guidelines is a document that provides motivations and methods for retrofitting the thousands of deteriorating and extremely energy inefficient postwar modern concrete highrise apartments in Ontario. It presents these buildings as cultural and environmental resources due to the robustness of their interior structure, significant percentage of family sized apartments, and potential to fulfill their original purpose as humane urban environments. The authors believe the towers represent not only an indispensable housing resource but also the critical mass necessary to create and sustain an innovative retrofitting industry. The main method proposed for tower renewal is addressing their deterioration and inefficiency from the outside-in: the recladding of the exterior using the existing masonry as a substrate with the end goal of developing a future-proof system wherein the facade is a replaceable skin for the building, changed as technologies and needs change (see fig. 1).[27] This method eliminates the challenge of displacing people from their homes for renovation and, if done in time, saves building owners from needing to conduct essential repair work that results in zero

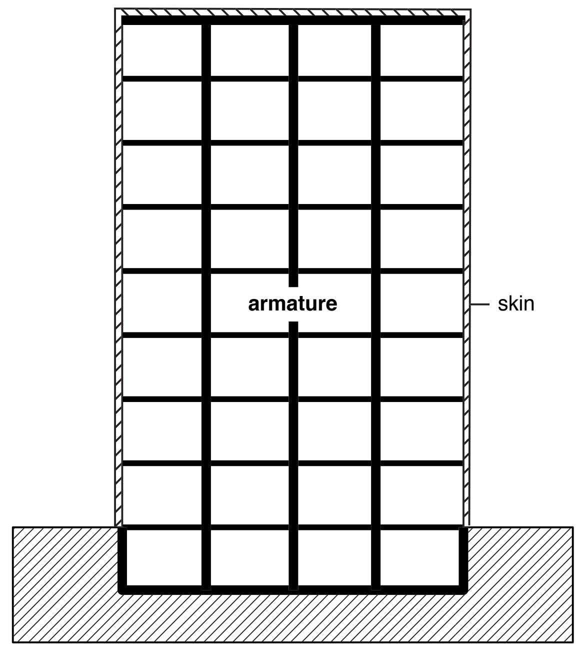

Figure 1: principle of tower renewal.

[27]This building-focused procedure is part of a more comprehensive site strategy outlined in the guidelines.

payback.[28]

This comprehensive strategy can be contrasted with another more limited in scope initiative from Natural Resources Canada, the PEER (Prefabricated Exterior Energy Retrofit) project. This project focuses on reducing energy consumption and GHG emissions from Canadian homes with the vision of commercializing prefabricated facade retrofit kits and creating a new market.[29] Regardless of initiative scale, iteration and attention to design detailing for this style of retrofit is recently proven essential in the wake of disasters like London's Grenfell Tower tragedy, where an overcladding retrofit that allowed fire to spread resulted in the deaths of 79 people.[30]

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[28] Theodore Jonathon Kesik and Ivan Saleff. *Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-unit Residential Buildings in Cold Climates*. Tech. rep. 2009, pp. iv,36.

[29] *PEER: Prefabricated Exterior Energy Retrofit*. Government of Canada. Oct. 2017. URL: `http://www.nrcan.gc.ca/energy/efficiency/housing/research/19406`.

[30] Alex Bozikovic. *Lessons of the Grenfell blaze: How can Canada's thousands of aging towers be kept safe?* June 2017. URL: `https://beta.theglobeandmail.com/life/home-and-garden/architecture/lessons-of-the-grenfell-blaze-how-can-canadas-thousands-of-aging-towers-be-kept-`

Both of these projects, explicitly or implicitly, address the issue of embodied carbon. The importance of conserving existing material has long been recognized in the fields of historic building conservation. More recently, the American Institute of Architects 2018 President-elect Carl Elefante, aside from dubbing mid-twentieth-century modern-era buildings "perhaps the most unloved stock of buildings ever constructed", declared

> "The importance of historic-preservation practices in meeting this [rehabilitation] challenge should not be undervalued. Conserving the enormous investment of material resources embodied in mid-century buildings, and thereby avoiding wholesale consumption of even more resources in new structures, must play a role in curtailing climate change."[31]

In his 2017 article Changing World, Evolving Value: A Historic Preservation Roadmap Toward 2050, he points out the urgency with which

safe/article35445378/?ref=http%3A%2F%2Fwww.theglobeandmail.com&.

[31] Carl Elefante. "Changing World, Evolving Value: A Historic Preservation Roadmap Toward 2050". In: *APT Bulletin: The Journal of Preservation Technology* (2017), pp. 9–12, p. 10.

preservationists need to attend to these buildings in order to stop them from resulting in “massive waste and unnecessary carbon release”. Here he is referring to material conservation’s ability to limit non-operational carbon footprints of buildings. He even goes so far as to assert

> “In this new context, materials conservation is more relevant than cultural preservation. Our primary task will be to serve as steward of the massive material and energy investments made in mid-century structures.”

In the urgency to act on behalf of climate change mitigation and in the face of the disdain for this building stock, it seems easy to prioritize actions directly addressing environmental sustainability rather than cultural preservation. It might, however, be interesting to see what other than carbon is embodied in these buildings or what they might, post-renovation, come to embody. Do these buildings have any embedded principles worth keeping? Which ideas from the past were thrown away by the architects or developers of these modern buildings and can they be reintroduced to positive effect? What ideas can these buildings bring forward? Tower Renewal

Guidelines puts forward the idea that its method is as much a social as technological intervention and envisions a world where "inherited infrastructure is a legacy rather than a liability".[32] In How Buildings Learn Stewart Brand conveys the need for a conversion of an architecture based on image to one of process, and asks what an aesthetic of transience might look like; this sounds precisely like what could be achieved with the Tower Renewal Guidelines method of lasting armature and replaceable skin.

5.2.2 Social Housing and Sustainability

Brand also uses Jane Jacobs' conjecture that "new ideas must come from old buildings"[33] to explain how old, temporary, or undesirable structures often serve as incubators for new kinds of culture due to their adaptivity and lack of esteem. Though that sentiment is taken somewhat out of context here, one could argue that turning a poorly performing and uncomfortable

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[32]Kesik and Saleff, *Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-unit Residential Buildings in Cold Climates*, p. 29.

[33]Stewart Brand. *How buildings learn : what happens after they're built*. New York, NY: Viking, 1994. ISBN: 0140139966, p. 57.

building into a truly environmentally responsible building that is comfortable and healthy to the highest standard, future-proofing it with the ability to adapt to changing technologies, and then using it to provide homes to the poorest segment of society is to create a new type of culture out of an old building.

Retrofit projects that achieve some of these aims can already be found internationally and at home. Treviana Social Housing in Madrid, Spain, is a deep energy retrofit to a highrise built in 1968, completed in 2015 (see fig. 2). This social housing retrofit significantly reduced the original building's annual heating demand by nearly 70% (from 150 kWh/(m^2a) to 47 kWh/m^2a)), considerably improved its air tightness, as well as reduced its primary energy demand (fig. 3).[34] In much colder Hamilton, Ontario, the Indwell mixed use with affordable housing redevelopment is an under construction retrofit of a group of buildings from the 1880s, 1960s, and 1970s (see fig. 4 and fig. 5). It's predicted annual heating demand is

[34] *OP23 Treviana Social Housing in Madrid*. EuroPHit. URL: http://europhit.eu/op23-treviana-social-housing-madrid.

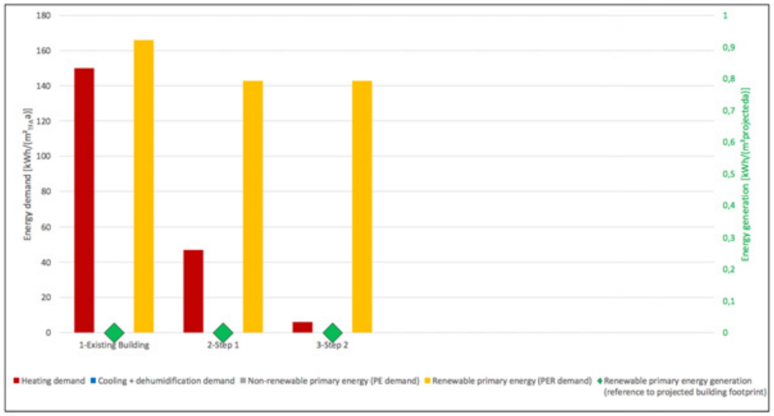

Figure 2: Treviana Social Housing, 2015. Source: EuroPHit.
Figure 3: Treviana heating demand reduction. Source: EuroPHit.

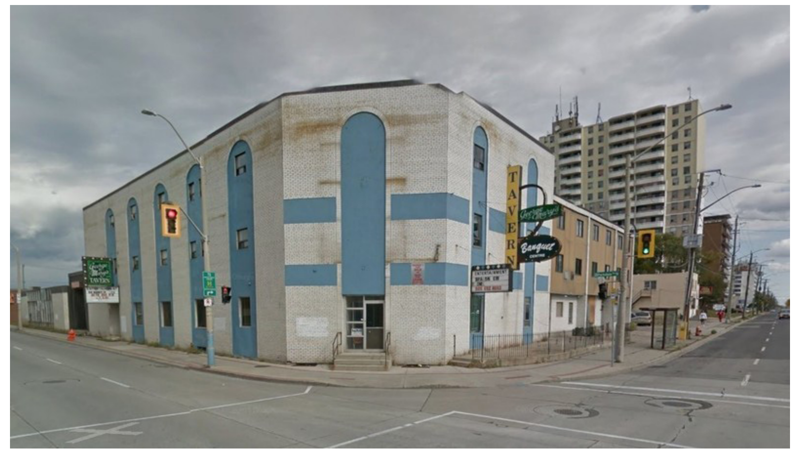

Figure 4: Indwell affordable housing in Hamilton, 2018. Source: Indwell.
Figure 5: original Indwell building. Source: Indwell.

20 kWh/(m^2a) that, while impressive in its own right, is especially so when compared to the project in Madrid's warmer climate.[35] While these projects are examples of energy efficiency achievements that successfully reduce GHG emissions, there isn't enough information available yet to suggest how they might be successful by other sustainability metrics.

Sometimes new ideas can come from new buildings too: there are also many examples of new build affordable housing that aspire to sustainability. Obviously these projects miss out on the good things that get embodied in retrofits (carbon or otherwise), but their achievements are worth examining. Austria, for example, has an incredible track record for creating affordable housing.[36] The 354 rental apartment Lodenareal building complex for low-income residents in Innsbruck (see fig. 6 and fig. 7) has an astounding 7 kWh/(m^2a) heating demand alongside other environ-

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[35] *ID: 5498*. Passive House Database, 2017. URL: `http://www.passivhausprojekte.de/index.php?lang=en#d_5498`.

[36] In Vienna, 3 out of 5 people (rich or poor) live in public city-managed housing due to the high quality of life. Denise Hruby. *Why rich people in Austria want to live in housing projects*. 2015. URL: `https://www.pri.org/stories/2015-10-26/why-rich-people-austria-want-live-housing-projects`.

Figure 6: Lodenareal social housing in Innsbruck, 2009. Source: DIN A4 Architektur.
Figure 7: Lodenareal social housing, 2013. Source: Wikimedia Commons.

mentally responsible features.[37] A North American example is the newly constructed Salus Clementine housing project and it is particularly interesting because it is in Ottawa (see fig. 8 and fig. 9). This 42 unit apartment building was created for residents with mental health needs and achieves a 13 kWh/m^{2}a) heating demand in Ottawa's cold climate.

5.2.3 Passivhaus and EnerPHit

The examples in the previous section all have another thing in common: they were all built, or retrofitted, and certified, or are in the process of being certified, as Passivhauses to the Passivhaus standard (or it's accompanying retrofit standard, EnerPHit).[38] It is not a narrow view of sustainability that causes the previous section to emphasize each building's annual

[37] Eurbanlab. *Lodenareal — Innsbruck (Austria)*. URL: http://eurbanlab.eu/library/lodenareal-innsbruck-austria/.

[38] Passivhaus is German for passive house; this thesis will use "Passivhaus" when referring to the standard, the German Passivhaus Institute, or buildings certified/attempting certification in order to distinguish them from the American passive house standard (see Appendix 1). Neither of these standards should be confused with general "passive solar building design".

Figure 8: Salus Clementine, 2015. Source: Taplen Construction.
Figure 9: Salus Clementine, 2015. Source: CSV Architects.

heating demand but rather that happens to be the primary criteria of the Passivhaus standard.

The primary definition for a Passivhaus, according to the Passivhaus standard, is a building that is able to deliver its heating via the ventilation.[39] The consequence of this is that the building does not require a conventional heating system; it relies primarily on external and internal heat gains (from people, animals, appliances, and the sun). What supplemental heating is required is provided by a very small heat source. A more comprehensive definition from the Passivhaus Institute (PHI)'s Jürgen Schnieders is:

> "The various components of the Passivhaus approach can be classified under the following basic elements. The first three (superinsulation, heat recovery and passive solar gain) are cru-

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[39] Heating delivered via ventilation air must be no more than 55°C due to potential carbonization of dust; this indicates how very little heat is necessary to heat a Passivhaus and is the purpose for the 10 kWh/m²a maximum heating load. Jurgen Schnieders and Andreas Hermelink. "CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building". In: *Energy Policy* 34 (2006), pp. 151–171, p. 157.

cial to the Passivhaus concept. To fully minimize environmental impacts, however, the other two are necessary (electrical efficiency) or expedient (meeting remaining energy demand with renewables)."[40]

In order to be certified by the PHI, there are three main criteria that must be met:

- an annual heating demand of no more than 15kWh/(m^2a) or maximum heating load of 10 W/m^2
- an airtightness of no greater than 0.6 air changes per hour at a pressure of 50 Pa
- and a primary energy demand maximum of 120 kWh/(m^2a)

It's important to note that Passivhaus does not ignore factors like occupant behaviour, lighting, or appliance use as it accounts for overall en-

[40]Schnieders and Hermelink, "CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building", p. 152.

ergy efficiency in its primary energy demand criteria. The Passivhaus standard mandates using electrically efficient appliances and lighting as well as insulating hot water carrying pipes. Since heating accounts for the majority of building energy usage, the dramatic reduction of its energy use in combination with other energy efficiency measures results in a building that uses considerably less energy compared with average construction.

A Passivhaus building achieves these goals by having a high quality thermal envelope with exceptional airtightness while maintaining a sufficient air exchange rate. This task requires an integrated design process with an above-average attention to building construction. A building that meets these criteria has remarkably good indoor air quality and is free from temperature stratification or cold surfaces.

Since Passivhaus is an energy and comfort standard it can also be combined with any other “sustainability” or “green” standard, like LEED or the achievement of net zero energy. A certifiable Passivhaus can be built in any climate using whatever construction method desired because there is nothing about the certification criteria that mandates one particular construction method or material selection.

This standard's fabric-focused approach leads to a low-energy building that addresses each component of sustainability: environmental, economic, and social. In terms of the environment, its demonstrably low energy usage[41] provides the best basis for improved total carbon performance.[42] Economically, Passivhauses have low life cycle costs due both to their low energy usage and their lack of a conventional heating system.[43] The social component of Passivhaus sustainability is fundamentally the "the affordability of comfortable living".[44] A Passivhaus provides not only

[41]80 percent less space heat consumption and 50 percent less total primary energy consumption than new conventional buildings. Schnieders and Hermelink, "CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building", p. 1.

[42]I.e. additional net zero energy and net zero carbon measures are more impactful when the building is already using as little energy as possible.

[43]This is a credit toward the initial investment cost but also contributes to the low life cycle cost since it means the building doesn't rely on complex technologies with relatively short lifespans.

[44]Schnieders and Hermelink, "CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building", p. 170.

the physical comfort of good air quality and a pleasant thermal environment, but also financial protection from rising energy prices at little to no extra cost as compared with conventional construction.[45] [46]

As mentioned earlier, the Passivhaus standard catering specifically to retrofitting buildings is called EnerPHit. Since there are several reasons why existing buildings would find it burdensome to achieve the regular Passivhaus criteria, there are a couple of alternate paths to compliance.[47] The resulting EnerPHit building has many of the same advantages as the new construction standard: excellent thermal environment and air quality, significantly reduced heating demand and therefore significantly reduced GHG emissions, as well as the additional advantages of the prevention of

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[45]Schnieders and Hermelink, "CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building", p. 169.

[46]This is highly dependent on the availability of knowledge and critical components.

[47]Lack of a compact form, significant thermal bridging, poor airtightness, inappropriate window orientation, inadequate space for insulation, and historic preservation requirements, or the inability to mitigate any of these, are contributing reasons. Zeno Bastian, ed. *Step by Step Retrofits with Passive House Components*. Passive House Institute, 2016, p. 18.

structural damage and mould growth caused by moisture and condensation.[48]

A standard like EnerPHit is important to the formation of a high-functioning retrofit industry because, in addition to substantially reducing required energy, inherent to its design process is the avoidance of "lock-in effects". Lock-in effects are the penalties paid for engaging in shallow or poorly planned energy renovations.[49] They can result in inadequate reductions of energy use by the existing building stock so that energy targets are unmet over time or they create uneconomic situations that cause buildings to be stuck with inferior components until the next renovation cycle. Even though it is the nature of Passivhaus to be thorough in the design process, special care must still be taken during a phased EnerPHit project to ensure that the proper installation of future components is anticipated.

Indispensable to any Passivhaus project is the Passivhaus Planning

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[48] Ibid., p. 17.

[49] Bastian, *Step by Step Retrofits with Passive House Components*, p. 6.

Package (PHPP) design software. [50] This software provides an accurate steady-state building energy analysis that allows designers to iterate for the appropriate combination of interventions to achieve the Passivhaus criteria efficiently and cost effectively. A recent innovation in the Passivhaus design process is the creation of a plugin for SketchUp (called designPH) that considerably simplifies the calculations required to properly account for shading.

5.3 Putting it together: the Project

As stated in the thesis question, this project will attempt to propose some measures and strategies for retrofitting a postwar modern Ottawa Community Housing property to the EnerPHit standard. The intent is to lower the total carbon emissions of the OCH property through energy reduction and the conservation of its embodied carbon. The project goals are:

1. Understand what, if anything, is historically or culturally important

[50] It is an excel file and the latest version (v9.6) is currently sold for $260 (CAD).

about these buildings. (What can they bring forward or what can they come to represent?)

2. Present interventions that balance high technical achievement in energy reduction with important cultural and social considerations.

3. Understand which interventions provide the greatest impacts and what represent the largest challenges. (Especially with regard to keeping the building occupied while renovating.)

Ideally the conclusion will provide some idea as to what the properties of a successful modern retrofit in this context might be. There are often examples of what they are not, i.e. superficial retrofits that either do not address carbon performance deeply enough or else serve to primarily update the building's aesthetics in order to command higher rents (and thereby replace less profitable occupants). The title of the project, "Thick-skinned", refers to the project's goal: that the interventions create a building with improved thermal comfort (due to improved insulation) and better resiliency (due to less energy reliance and increased livability).

5.3.1 Challenges

There are certain challenges to anticipate in the combination of the Passivhaus standard, affordable housing, and this thesis' hypothesis that the sustainable route to affordable housing is in creating buildings with long-term value. The more interesting of these challenges do not easily fall into categories like "technical" or "social" (although there are assuredly plenty of both), but as a direct result of the interaction between the two.

The internal temperature of dwellings is responsible for many of these interesting issues. A Passivhaus has a stable internal temperature without large fluctuations and while the market appears to appreciate that comfort, it is worth thinking about this temperature stability with respect to architectural theory. The idea of a temperature monoculture, that Andrew Michler describes in Hyperlocalization of Architecture as a culture where "people move from air-conditioned homes to cars to offices and never go outside",[51] seems to be a reason why Brand believes poorly performing

[51] Andrew Michler. *Hyperlocalization of architecture : contemporary sustainable archetypes*. Los Angeles: eEvolo Press, 2015. ISBN: 1938740084, p. 13.

buildings may attract us. He writes,

> “In fact, weather becomes a perverse attraction. Whereas competent sealed buildings lull us with their “perfect” climate, and incompetent ones drive us crazy with their uncontrollable heats and colds, a drafty old building reminds us what the weather is up to outside and invites us to do something about it- put on a sweater; open a window.”

While it is unlikely the occupants of OCH properties are enamoured with this particular aspect of their homes, it is important to consider how a varied thermal experience might be a beneficial addition to their lives. In her compelling 1979 work, Thermal Delight in Architecture, Lisa Heschong explains how delight and affection for various thermal environments underpins many customs in most cultures and is an important driver for community gathering.

It’s also important to recognize that the stability and comfort of the Passivhaus’ environment depends substantially on the number of occupants and their behaviour. The notable challenges here are the need to alter established and “common sense” behavioural patterns (e.g. opening the windows mid-winter for fresh air and losing the interior humidity vs increasing the mechanical ventilation rate for a brief period of time), as well as compensating for occupant lifestyles (e.g. owning pets, smoking heavily). Some individuals have needs that cause them to require a greater range of available temperatures.

In terms of creating buildings with long-term value, Passivhaus certainly lends itself well to creating a a durable and high-performance building with a long lifespan, but is that the best way to measure long-term value? This seems like a reasonable assumption. However, what is a Passivhaus’ ability to withstand a change in occupancy? Or space plan? How can a Passivhaus cope with the changing needs and desires of its tenants? Can the apartment retrofit project be designed such that it anticipates cultural changes and continues to positively impact housing affordability?

Interesting economic implications arise with the financial savings that accumulate from low energy use. In one scenario, the tenant pays the heating cost in addition to their rent and they end up benefiting from the energy savings. In another scenario, the landlord includes heating in the rent and, because Passivhaus results in such a comfortable and high quality dwelling, the landlord is able to command higher rents despite the money saved from the energy savings. The proliferation of sustainable and affordable housing may require policy intervention that addresses this kind of scenario.

5.3.2 Method

The project begins with a site analysis of a current OCH building that incorporates site specific, cultural/conservation, and Passivhaus criteria. The technical method of investigation is to use the PHPP (PassivHaus Planning Package) in conjunction with designPH (Passivhaus SketchUp plugin) to measure which interventions show a substantial improvement in the energy efficiency of the building. designPH is an iterative design tool and 3D modeling interface used in combination with PHPP, an excel-based program that is necessary for achieving the Passivhaus standard. designPH proposes to save a significant amount of time in the Passivhaus process, allowing for faster input and more iteration on building energy interventions, and this makes it a necessary component for the analysis portion of the project given the time frame.

These interventions will be evaluated according to the three dimensions of modernism (the social, technical, and aesthetic)[52] in terms of their impact on the building as a cultural resource.

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[52]Wessel de Jonge. "Sustainable renewal of the everyday Modern". In: *Journal of Architectural Conservation* 23.1-2 (2017), pp. 62–105.

5.3.3 Scope

The application of the EnerPHit comfort and performance standard on a Canadian post-war modern building represents one of the novel challenges of this project: the building-related interventions focus on those which are necessary to achieve the EnerPHit standard and substantially improve thermal comfort (with the exception of replacing the ventilation system). Focusing on exterior renovations has the advantage of eliminating thermal bridging (a main contributor to building heat loss) as well as allowing building occupants to remain during construction. The renovation of the building's interior will not be addressed in this project as Ottawa Community Housing addresses interior renovation to a limited degree through planned and regular upgrades (e.g. fixture replacement and wall painting). A new ventilation system is not proposed here as it is recommended by EnerPHit that replacement of the ventilation system occurs after thermal envelope improvement so that it can be sized accurately.

The other interventions presented in this project are site-related, with the goal of increasing the livability of the surrounding environment as per the original modernist intent; these interventions also have the advantage of maintaining occupant residency during construction.

6 Site

6.1 Selection Factors and Site Comparison

In the exploratory research phase of this project, a number of sites were compared under factors assumed to affect EnerPHit retrofitting and housing affordability before the specific criteria of being an OCH building was added.

- **Year of construction between 1960-1979**: Buildings constructed between 1960-1979 represent the largest share (37%) of large building GHG emissions.[53]
- **Concrete structure**: Buildings with a concrete structure are best suited for over-cladding style retrofits due to the robustness of their

[53] *A Roadmap for Retrofits in Canada: Charting a path forward for large buildings*, p. 9.

interior structures. They represent large sources of embodied carbon.

- **Adequate interior condition**: The building is currently occupied and serving as shelter, so a retrofit would ensure the building continues to be used for this purpose.

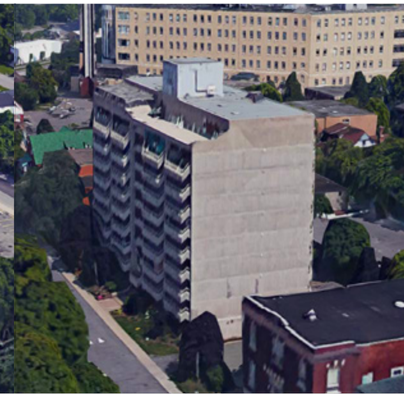
- **At risk for demolition**: A factor originally considered to be a positive characteristic as a retrofit of a building slated for demolition would save its embodied carbon from being wasted, however there was no coincidence of a building being both occupied and slated for demolition. The factor of having an adequate interior condition was deemed more important.

- **Opportunity to enhance urban ecology**: The ability to address site needs like storm water retention or adequate outdoor social spaces on a large lot was considered positive.

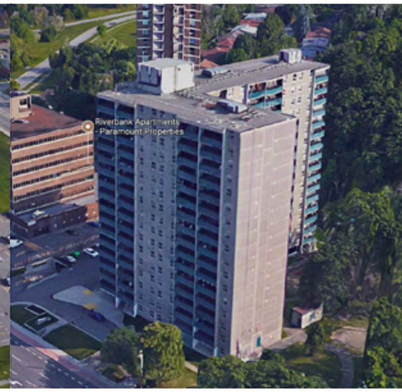
- **Access to building information**: A factor originally considered important before collaboration with OCH.

- **Other factors addressing affordability**: Factors like belonging to subsidized housing associations or co-ops or containing a mix of family sized apartments.

	Centretown	Riverside Park	Lowertown
South-Facing Façade	**Centretown** 361 Queen	**Riverside Park** 2660 Norberry Cr	**Lowertown** 380 Murray St
Building Factors			
Year of Construction: 1960-79	+	+	+
Structure: concrete	+	+	+
Condition: adequate interior condition	?	+	+
Site Factors			
At risk for demolition	+	-	-
Opportunity to enhance urban ecology	+	+	+
Other Factors			
Access to building information online	-	partial (unit plans)	-
Other factors addressing affordability	abandoned large hotel and office complex	-	OCH property: most property standard violations of any OCH property (2009): not enough heat in building & apt. problems 2BR and 3BR units



200 Friel St	**Alta Vista** 860 Blackthorne	100 Empress	**Hawthorne Meadows** 1971 & 1975 St Laurent
+	+	+	+
+	+	+	+
+	+	+	+
-	-	-	-
+	+	-	+
-	partial (unit plans)	-	plans (typical floor & units)
OCH Property	-	housing co-op for retired/semi-retired	-
2BR and 3BR units			

Elmvale-Eastway-Riverview 2035 Othello Ave	**Billings Bridge** 1365 Bank St	**Whitehaven Queensway** 1065 Ramsey Cr	**Carlington** 1465 Caldwell Ave
+ + +	+ + +	+ + +	+ + +
- +	- +	- -	- +
partial (unit plans) 2BR units	- OCH property 2BR and 3BR units	- OCH property 2BR units	- 2BR units

All images from Google.

6.2 Selected Site

The property at 1365 Bank Street was chosen due to its mix of family sized units and potential challenges it poses to a Passivhaus retrofit (e.g. the L-shape form, lots of eastern and western exposure, and possible shading issues). Properties that had clear heritage value or were particularly unique were avoided in order to pursue interventions that would have a more general applicability. This concrete highrise tower was designed by Howard Rafael from Miska & Gale Architects and constructed in 1972. This places it within the architectural period of postwar modernism.

Figure 10 (left): looking south to 1365 Bank Street (middle building). Figure 11 (right top): ground level apartment facade. Figure 12 (right bottom): facade repair.

Figure 13 (top): looking north into the building's front and back yards. Figure 14 (right bottom): mostly west street-facing facade. Figure 15 (left bottom): mostly north facade.

Figure 16 (left): exterior building services. Figure 17 (top right): inside building lobby.
Figure 18 (bottom right): under window baseboard heaters in lobby.

Figure 19 (top left): south facade. Figure 20 (top right): facade texture and construction.
Figure 21 & 22 (bottom): damage and/or poor construction of parking entrance walls.

6.3 Site Analysis Method

The site analysis is divided into site specific, conservation/cultural, and Passivhaus criteria. The following is the set of considerations that were applied to the analysis.

6.3.1 Including a Conservation Approach to Site Analysis

> *"Conventional retrofits to achieve envelope efficiency and durability are often producing unacceptable aesthetic outcomes."* [54]

- **Goal**: determine what technical and cultural assets an unlisted and cheaply built postwar modern building has from a modern conservation perspective

- **Why**: it's anticipated that retrofits of everyday postwar modern buildings will increase and considering the lack of esteem for these buildings, there's a chance something they contribute might be overlooked.

[54] Ted Kesik, Durability is Only Skin Deep in Concrete Toronto (2007).

To achieve the goals of the "conservation" site analysis, a set of common heritage characteristics for the postwar modern period must be developed. The following works informed the ensuing discussion of postwar modernism:

The "heritage character" in postwar modern concrete buildings, as identified by James Ashby in Concrete, Conservation, and Continuity, typically consists of

- bold monumental forms
- details that express the method of construction
- the integration and expression of the building systems (structural, heating, plumbing)
- a tough, robust quality in the details[55]

In The Age of the Modern High-Rise Construction, Ivan Saleff lists the virtues of concrete towers as being the inclusion of

[55] *Concrete Toronto: A Guidebook to Concrete Architecture From the Fifties to the Seventies*. Coach House Books and E.R.A. Architects, 2007.

- a “sublime non-stylistic aesthetic”, as in the grain elevators that inspired Le Corbusier
- panoramic views
- car storage
- speedy elevators
- swimming pools, landscaping, furnished lobbies, entry canopies, multi-purpose rooms
- the ideal of slum replacement, even if the reality was merely a rapid response to demand[56]

According to the DOCOMOMO article Sustainable renewal of the everyday Modern by Wessel de Jonge, the three essential dimensions of modernity are: social, technical and aesthetical.[57] Judging the values of

[56] *Concrete Toronto: A Guidebook to Concrete Architecture From the Fifties to the Seventies*.

[57] Jonge, “Sustainable renewal of the everyday Modern”, p. 64.

the building according to these dimensions, rather than particular style, “allows you to define a system of values for the building that can be more directly linked to the analysis and (re-)design phase".[58] De Jonge also suggests that using these three dimensions to create a rationale, or storyline, of the building can prove useful in the design process.

6.3.2 Baseline PHPP Analysis for EnerPHit Retrofitting

In order to determine what design interventions will have the greatest effect on energy use and comfort, a baseline PassivHaus Planning Package (PHPP) model of the existing building must be developed. The goal is to use the PHPP to illustrate the effects and variations of specific interventions on energy flows and not, in this case, to deliver rigorous and accurate data. Therefore the PHPP baseline analysis will endeavor to include climate data, building areas, u-values of the building elements, window characteristics, shading, and ventilation of the building for energy flow measurement as best as possible. Thermal bridge data will be included based

[58] Jonge, “Sustainable renewal of the everyday Modern”, p. 100.

on best estimations and existing evidence.

6.3.3 EnerPHit vs Heritage Conservation

There is a large body of work on the issues of reconciling heritage conservation methods with energy efficiency measures and there are many case examples involving historically designated buildings. Understandably, comparatively little has been developed for undesignated buildings. Achieving the EnerPHit standard usually requires a deep retrofitting process while a conservation approach requires balancing the environmental benefits against the impact on the site's heritage value before proceeding with a retrofit.[59] A visual comparison of the priorities and features of each model can be found on the following pages. One of the most obvious challenges, as summarized by Susan Macdonald, is the modern building's expressive use of concrete:

> "It is the emphasis on the honest expression of concrete that

[59] *Standards and guidelines for the conservation of historic places in Canada : a federal, provincial and territorial collaboration*. Ottawa: Parks Canada, 2010. ISBN: 978-1-100-15953-9, p. 43.

> is the crux of the problem in terms of material authenticity for many postwar Modern buildings. The concrete surface expresses not only the conceptual and structural intention but also the detail. Here material authenticity and aesthetic authenticity are inseparable."[60]

It is important to remember however, that this project is for an undesignated building and as such, there is an opportunity to experiment with alternate interpretations of the goals or rationale of the existing building's design, or even embedding new ideas, like that of building layer transience. Equally important to remember is that all interventions should work to promote the retention and quality of affordable housing.

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[60] Susan MacDonald. "Authenticity Is More than Skin Deep: Conserving Britain's Postwar Concrete Architecture". In: *APT Bulletin: The Journal of Preservation Technology* 28.4 (1997), pp. 37–44, p. 39.

Figure 23: concrete block facade.

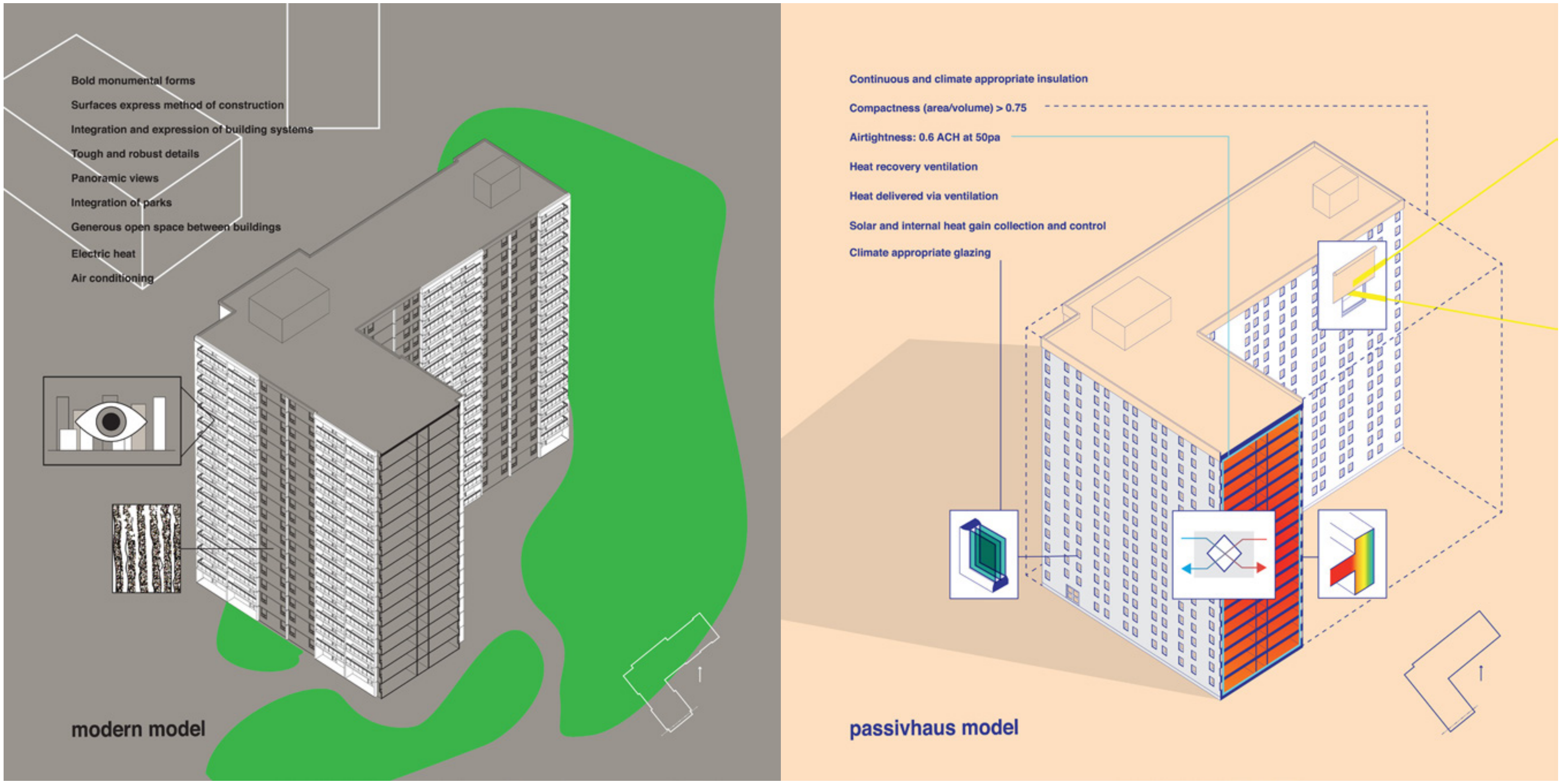


Figure 24: comparison of modern and passivhaus principles.

6.4 Site Analysis

Building Context

Official Plan
Zoning: AM8
Arterial Mainstreet Zone (Sec. 185-186)
The purpose of the AM – Arterial Mainstreet Zone is to:
(1) accommodate a broad range of uses including retail, service commercial, offices, residential and institutional uses in mixed-use buildings or side by side in separate buildings in areas designated Arterial Mainstreet in the Official Plan; and
(2) impose development standards that will promote intensification while ensuring that they are compatible with the surrounding uses.

Flood zones
- Flood zones: next to flood plain (Sec. 58)
- Ruisseau Sawmill Creek runs to the west
- Rideau River ~ 250 m NW

Building Information

Property Type	High-Rise Apartment Building
Neighborhood	Billings Bridge
Location	1365 Bank Street, Ottawa
Seniors Only	no
Number of Units	230
Number of Stories	17
Market units	no
Subsidized units	yes
Hydro paid by tenant	no
Heat paid by tenant	no
Parking on site	yes

Urban Pattern

Bus routes, train stations, cycle routes, pedestrian walkways
- 300 m from Billings Bridge Bus station

Existing buildings, car parking, roads
- Intersection of Transitway and Bank
- Traintracks parallel to intersection

Zoning of Surrounding
- Heritage zoning to the east (EP, Sec. 60)
  - Environmental Protection Zone (Sec. 183-184)
- AM8, MC[1341] to west
- O1, EP to the south
- O1, DR, L1 to the north

Figure 26 (left): surrounding area. Source: Google.
Figure 27 & 28 (right): pedestrians crossing roads unsafely.

6.4.1 Site Visit: February 6, 2018

The following observations were taken from a tour of the building, provided by the OCH:

Surrounding Area

- Pedestrian access to the site is dangerous and the building is adjacent to high speed roads (fig. 26). Pedestrian crossings are missing and many pedestrians are seen crossing the roads unsafely (fig. 27 and fig. 28).
- The property line around the tower is entirely enclosed by fencing and disconnected from the park to the northeast.

Building

- The building has two mechanical rooms due to the significant downsizing of replacement equipment. The original mechanical room is approximately 8m x 9.5m, while the new mechanical room is about 2.5m x 5m.

Figure 29 (left): renovations.
Figure 30 & 31 (right): multipurpose rooms.

- The three levels of parking available (above ground, and two levels underground) are under-utilized and excessive for the needs of the building's users.
- The OCH conducted lighting renovations and replaced common area lighting with led and sensors.
- Many of the units are currently empty as they undergo superficial renovations (e.g. drywall replacement)(fig. 29).
- The multi-purpose rooms, while large, appear neglected and unused (fig. 30 and fig. 31).
- The ground floor is made up of the multi-purpose rooms, a commercial kitchen and daycare area (which appear unused), as well as the OCH South Division Office (which handles maintenance and tenancy).
- There is only one garbage chute and it does not include recycling or organic waste.


Figure 32 (left): interior showing elevator lobby.
Figure 33 & 34 (right): existing baseboard heaters.

Figure 35 (left): sliding door closet. Figure 36 (top right): kitchen windows with high sills.
Figure 37 (bottom right): balcony windows.

- None of the units in this building are considered accessible.
- The building's interior is generally well-maintained (fig. 32), with the exception of some older appliances (like baseboard heaters) showing disrepair (fig. 33 and fig. 34).

Apartments

- The sound separation between apartments is not bad, however the units' entrances are directly across from each other and sound travels through the doors.
- The apartments do not have appropriate or dedicated hookups for air conditioning. Individual unit air conditioning cannot be considered due to electrical overloading potential on the building's original hard-wiring.
- The apartments are not individually monitored for energy usage.
- Apartments have built in floor to ceiling sliding door closets (fig. 35), windows have high sills (fig. 36), and original windows have been

replaced with double glazing (fig. 37).

Ottawa Community Housing Management

- Individual monitoring of tenant energy usage would require a release of information to be signed by the tenant.
- Units are painted every seven years (tenants are allowed to choose a paint colour).
- OCH occasionally conducts interesting renovations (e.g. replaced 16,000 toilets across properties, made back the expense in a very short time frame from water savings, and recycled the crushed old toilets for aggregate).
- OCH prioritizes renovations that can centralize maintenance to lower operating costs.

Common Needs and Considerations for OCH Tenants

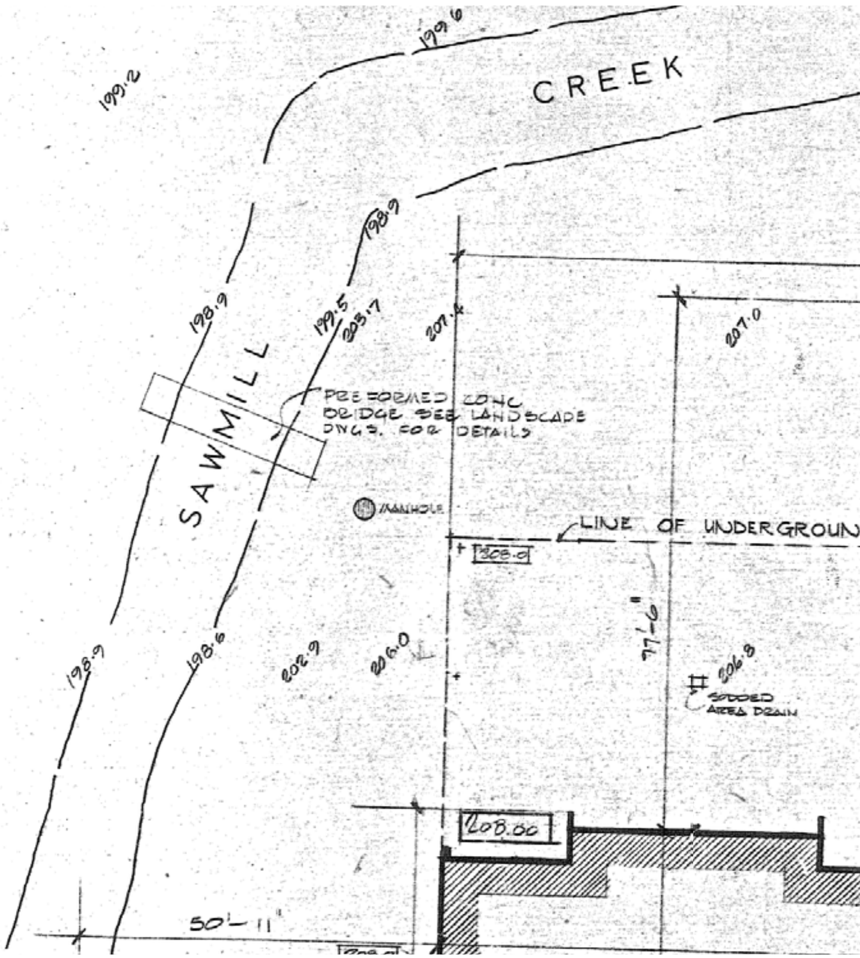
- OCH tenants frequently have respiratory illnesses.

- Apartments with barrier-free access are important and there is a long waiting list.
- Tenants often require storage for scooters and wheelchairs.
- Some units are subject to considerably more condensation than average from the frequent boiling of water. [61]
- There are often difficulties with the tenant/building operation relationship when new building technologies are introduced.

6.4.2 Cultural Analysis

With information from the site visit and the original/subsequent drawings (see Appendix 3: Building Evolution), the embodied heritage characteristics of 1365 Bank Street as classified by the three dimensions of modernity are:

[61] This is an anecdote from discussions with the OCH but illustrates the importance and challenges of understanding tenant behaviour.



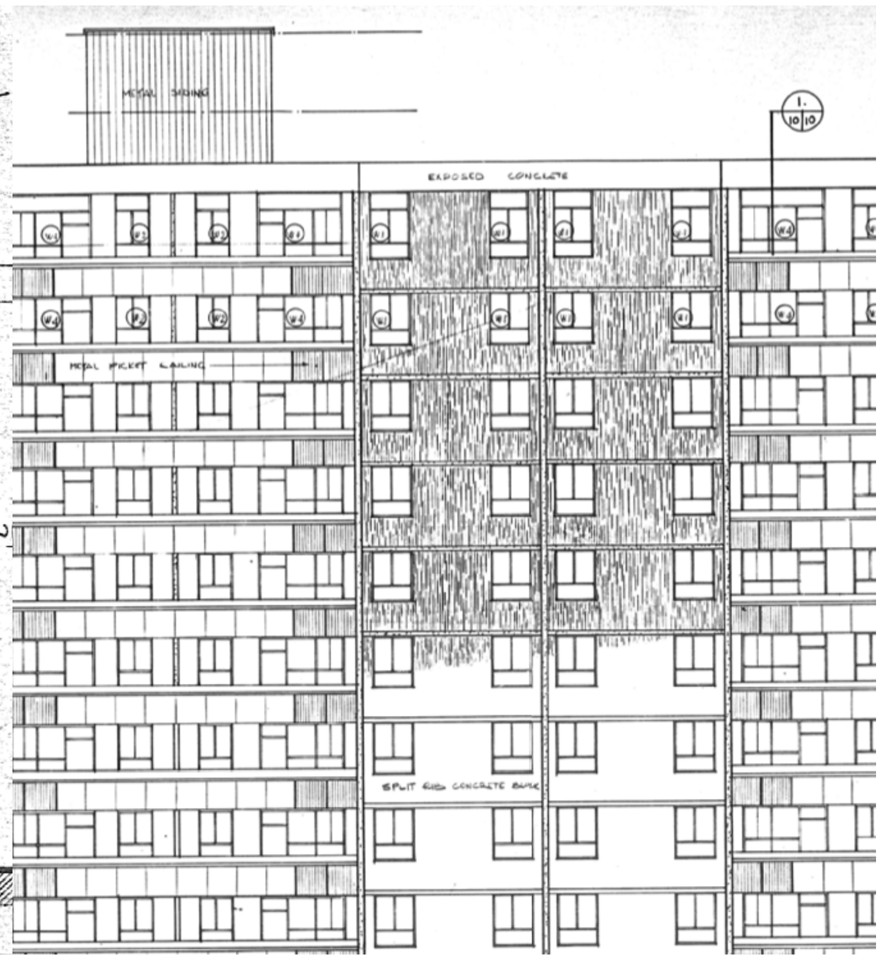


Figure 38 (left): bridge over Sawmill Creek. Source: OCH.
Figure 39 (right): details expressing method of construction. Source: OCH.

Figure 40: bold facade forms.

Social: Panoramic views, parking (above and below ground), elevators, park space and outdoor amenities (bridge connection to the historic park in the original plans that was removed in the 1990s as seen in fig. 38, basketball court added sometime before 1994), the ideal of slum replacement (attractive facade, landscaping, multipurpose rooms, laundry, proximity to transit and shopping)

Technical: Details expressing method of construction (split rib concrete block with bare concrete & slabs marking stacked floors and acting as lintel as see in fig. 39)

Aesthetical: Bold facade forms (balconies forming vertical forms with contrasting facades as seen in fig. 40)

6.4.3 PHPP Baseline Analysis

The limited PassivHaus Planning Package (PHPP) baseline analysis was conducted in two parts: the first part was an experimental usage of the designPH plugin for SketchUp [62], and then adding more data to the imported designPH data within PHPP itself.

designPH Process designPH is a plugin for SketchUp which claims to "simplify the process of entering building geometry into PHPP, and provide preliminary feedback on the performance of the design".[63] It provides a 3D interface for the Excel-based PHPP, and while it doesn't imply verification, it provides an easier way to calculate the effects of shading on the building as well as a simplified energy balance and specific space heating demand. The process for analyzing 1365 Bank Street was developed through trial and error as sparse documentation for the plugin exists within the context of a retrofit. Four models were developed before the model was able to be analyzed.

The designPH modeling process:

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[62] This usage is experimental as the plugin seems to cater to suitability studies for new builds.

[63] 2018. URL: `https://www.designph.org/`.

1. Draw the Treated Floor Area (TFA) and categorize according to the use (e.g. corridors have a 60% utilization rate and living spaces are 100%, see fig. 41).

2. Model the thermal envelope and exterior doors as simply as possible, only modeling those surfaces which have a clear interior and exterior component (e.g. the projecting shear walls were only modeled in as far as they joined to the perpendicular exterior wall adjacent to them, see fig. 42).

3. Place the PH window components onto the faces of the thermal envelope, and adjust their dimensions through Component Options. Select the appropriate glazing and frame values (e.g. 1365 Bank Street has double glazing and metal frames with a thermal break, see fig. 43).

4. Draw all shading objects and categorize them as Non-Thermal (e.g. the remainder of the projecting shear walls are now drawn, along with balcony railings and the projecting balcony slabs, see fig. 44).

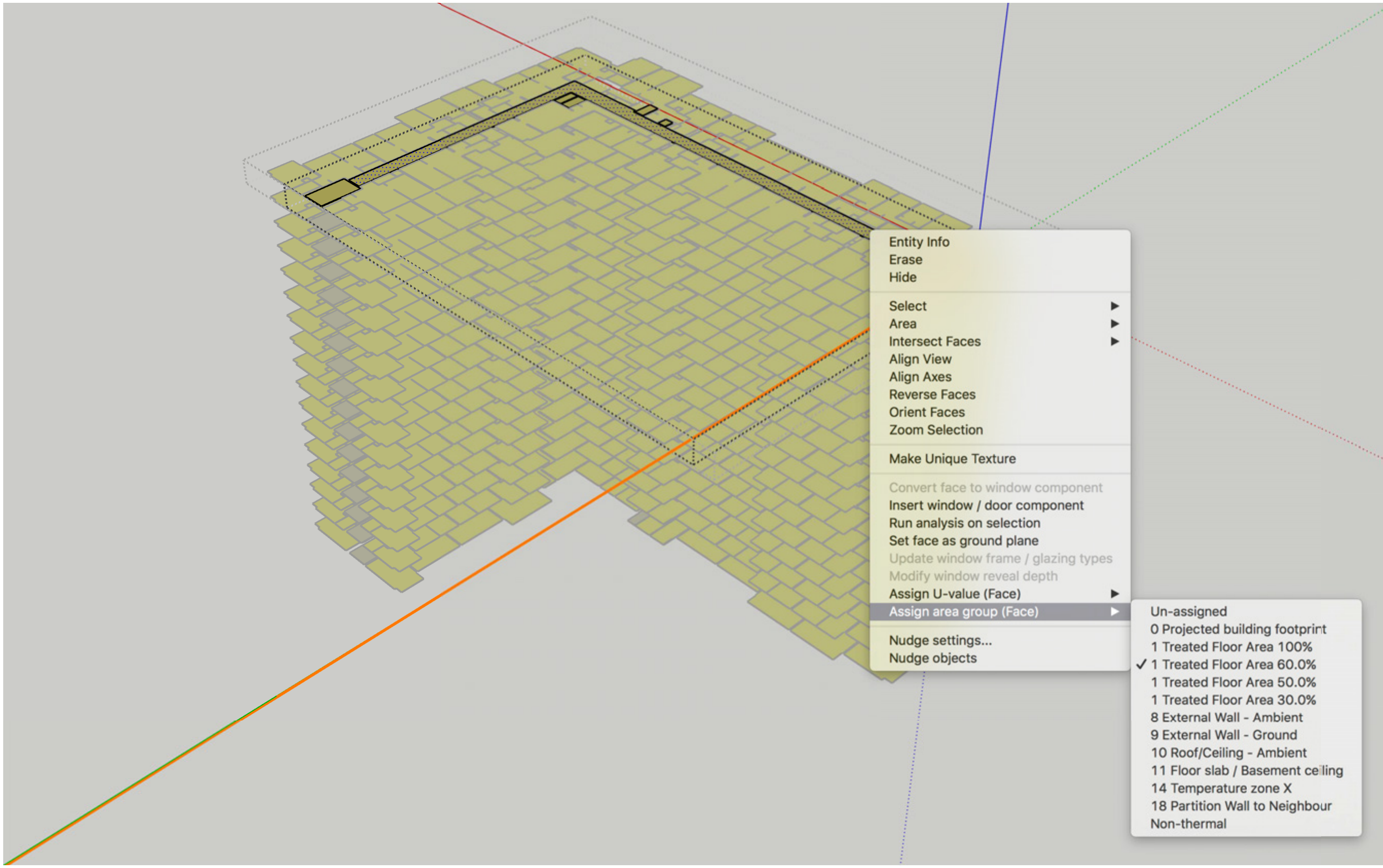


Figure 41: treated floor area.

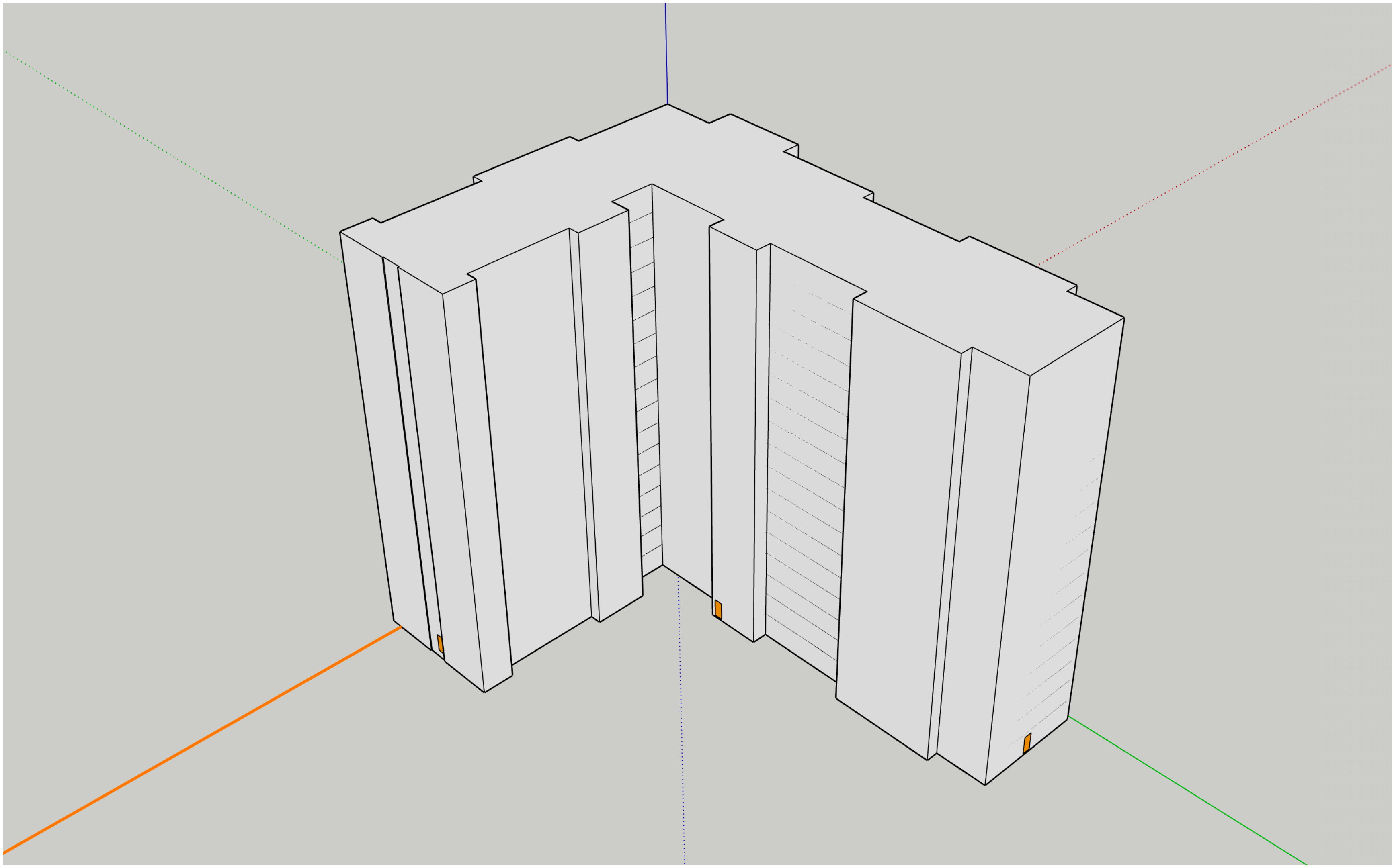


Figure 42: modeled thermal envelope.

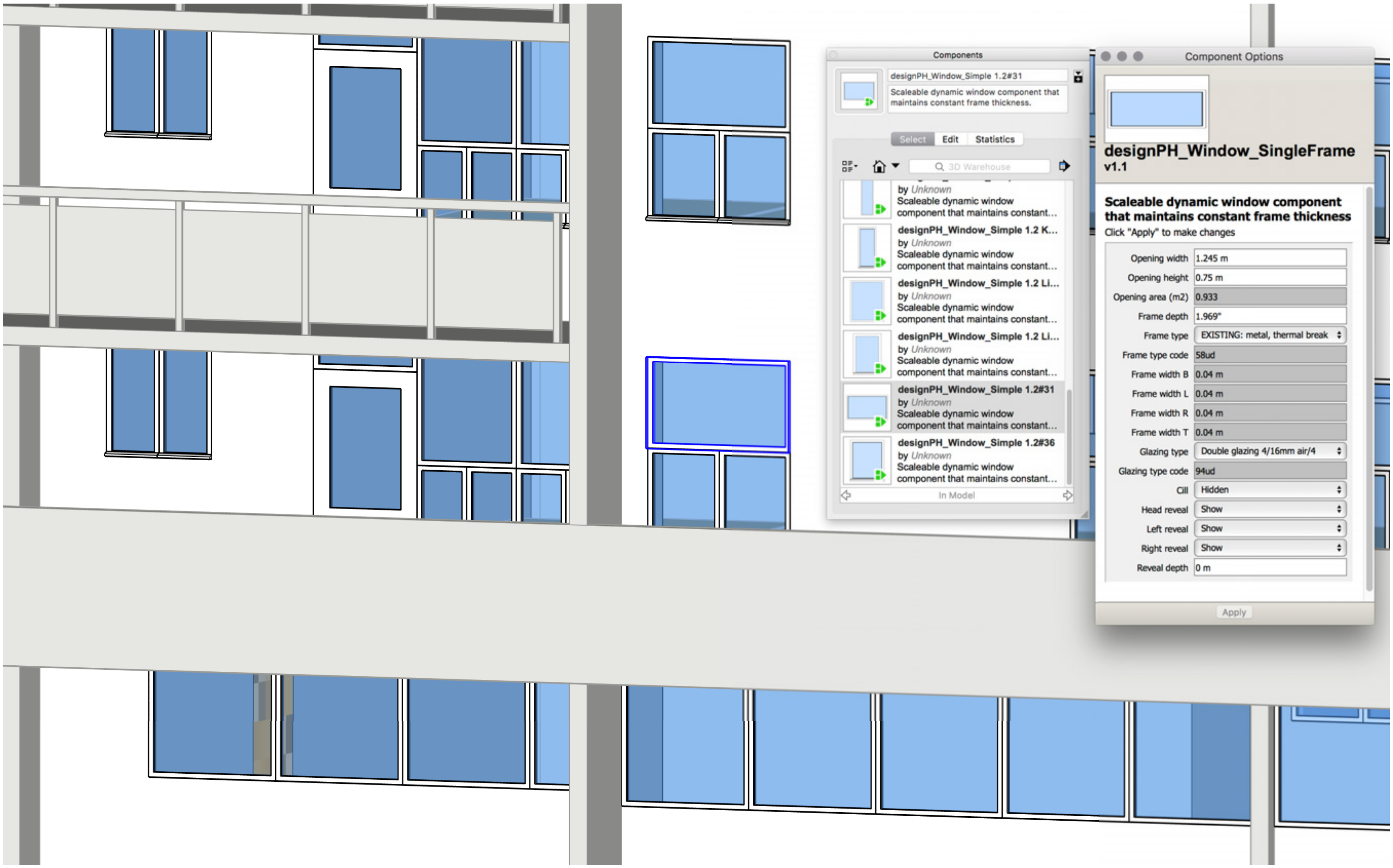


Figure 43: selecting the frames and glazing.

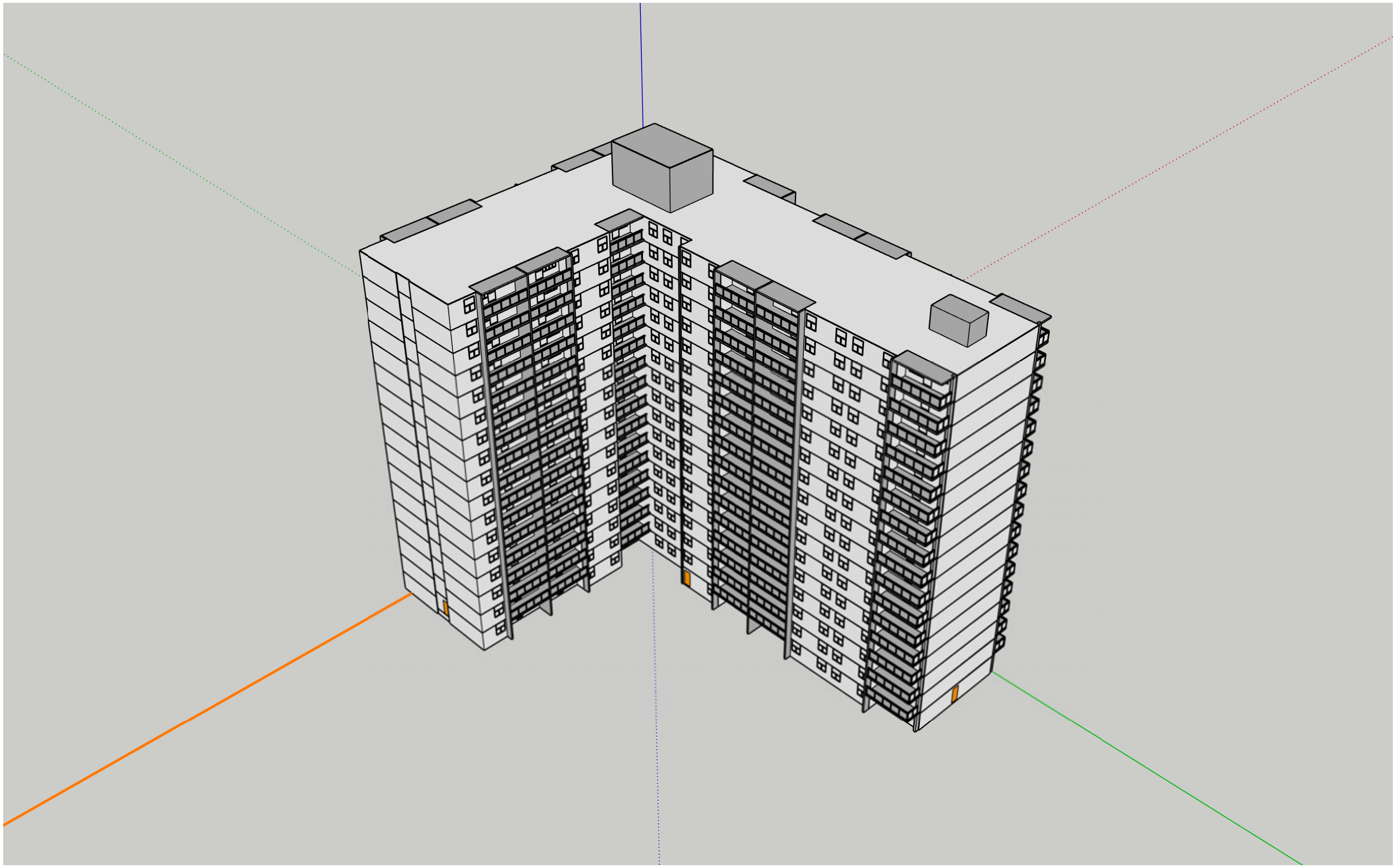


Figure 44: shading objects.

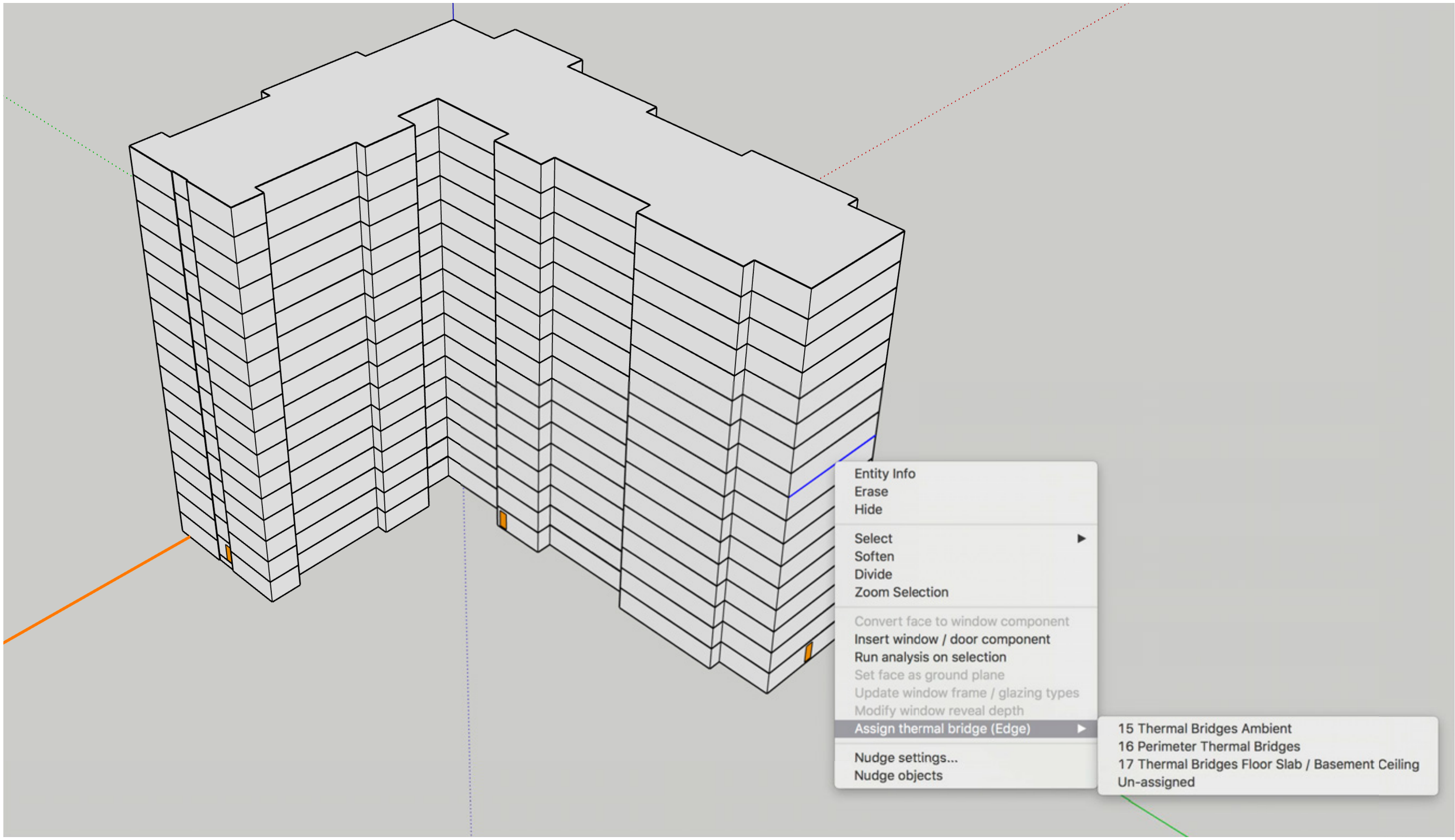


Figure 45: setting the thermal bridges.

5. Select or draw the existing thermal bridges. Thermal bridges can be categorized as Perimeter, Slab, or Ambient (e.g. in this case, the only thermal bridges included are the exposed floor slabs, and these are classified as Ambient, see fig. 45).

6. Define wall assemblies in the designPH dialog window (e.g. the existing assemblies were pre-modeled in U-Wert and so only their thickness and total U-value were included in PHPP).

7. Import the location data and set solar north (e.g. the imported terrain was turned off in this case due to inaccuracy and a plug-in called Solar North was used to correctly orient the imported map, see fig. 46).

8. Set the occupancy values, number of floors, average number of rooms, and climate in the designPH main dialog (e.g. 1365 Bank Street has 17 floors, 230 units with an average of 14 rooms per floor).

9. Run the analysis (see fig. 47, 48, 49, and 50; the black guides represent shading information that is imported to PHPP).

10. Export the results to the PassivHaus Planning Package in order to

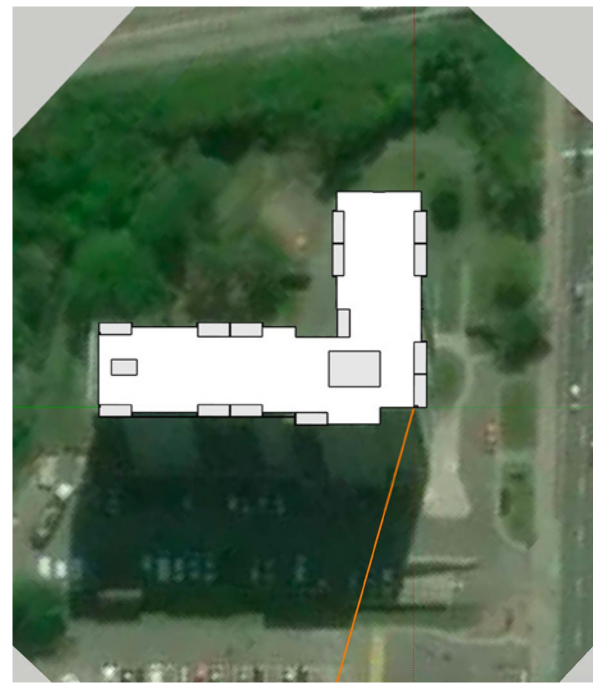
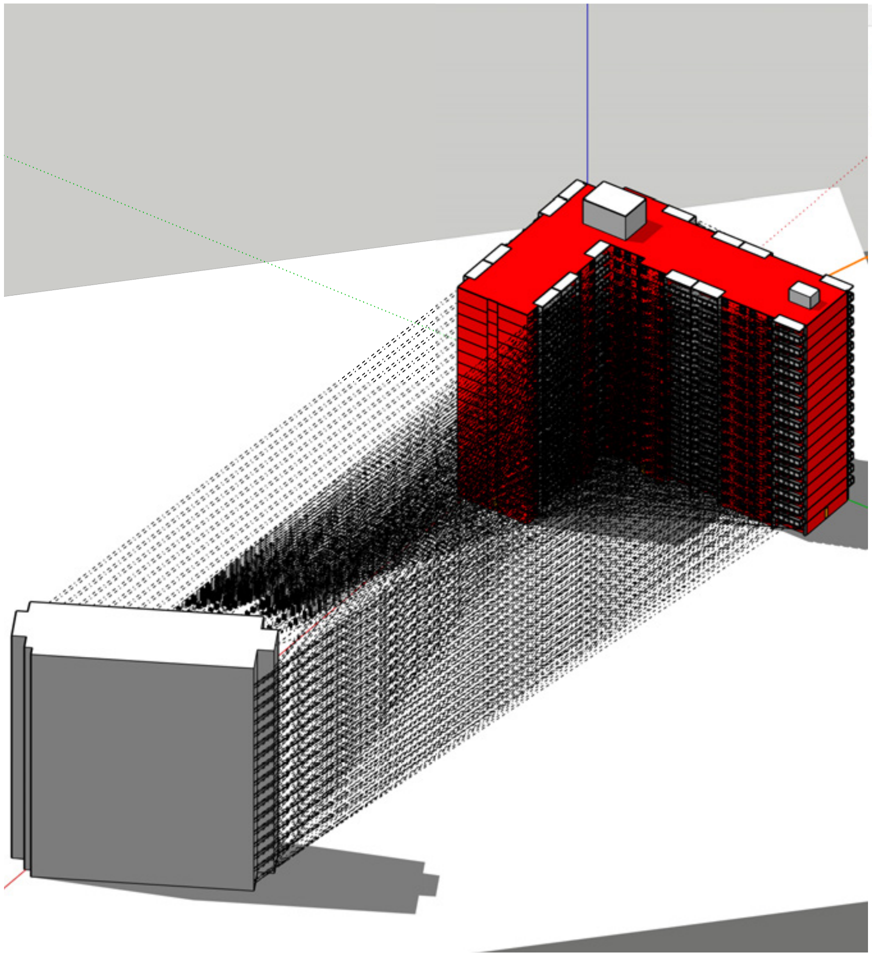


Figure 46: setting solar north (indicated in orange).



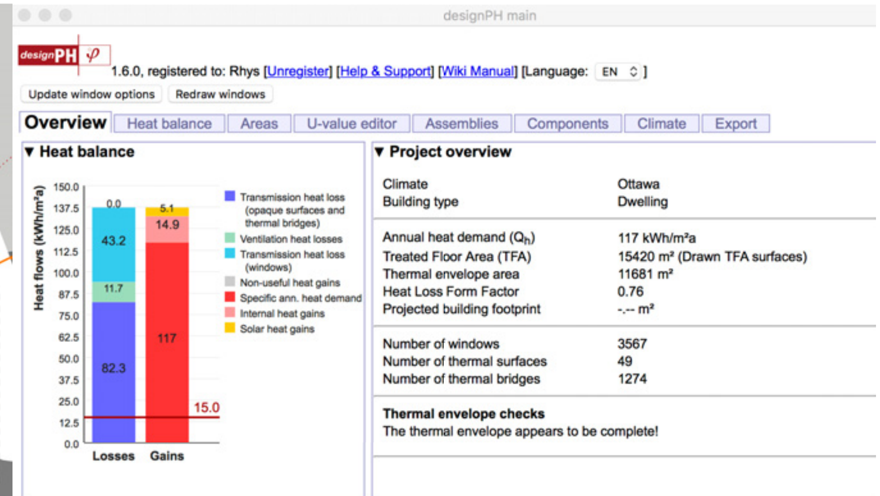
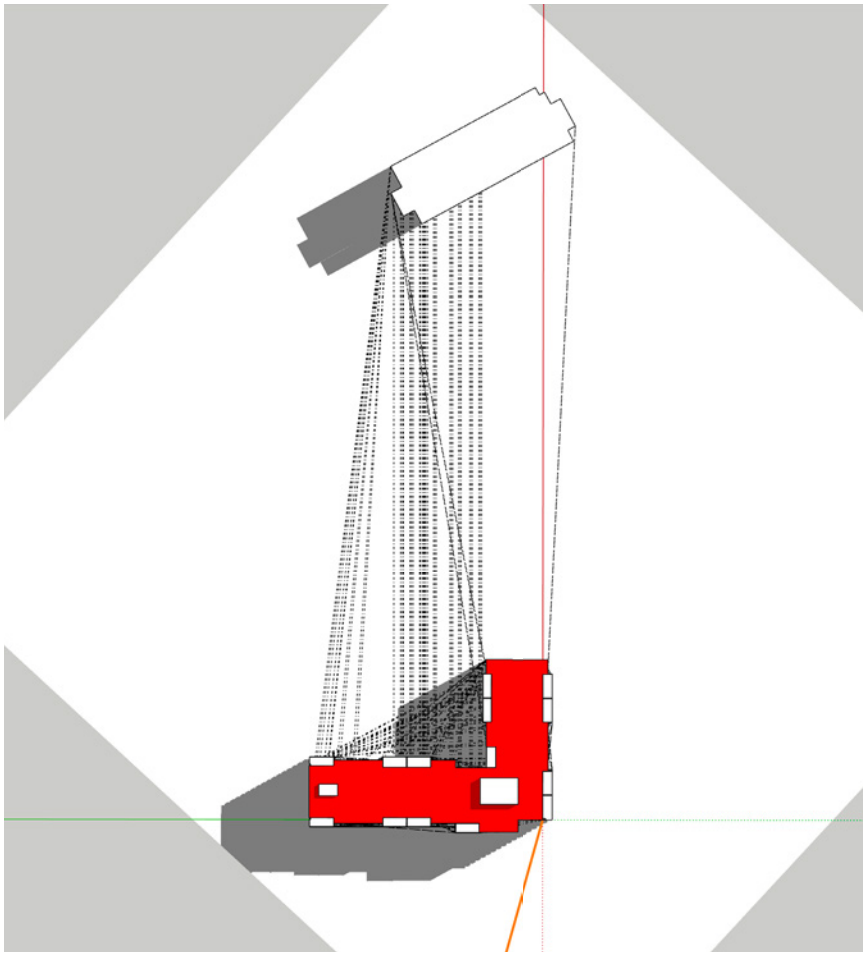


Figure 47 & 48: PHPP analysis.



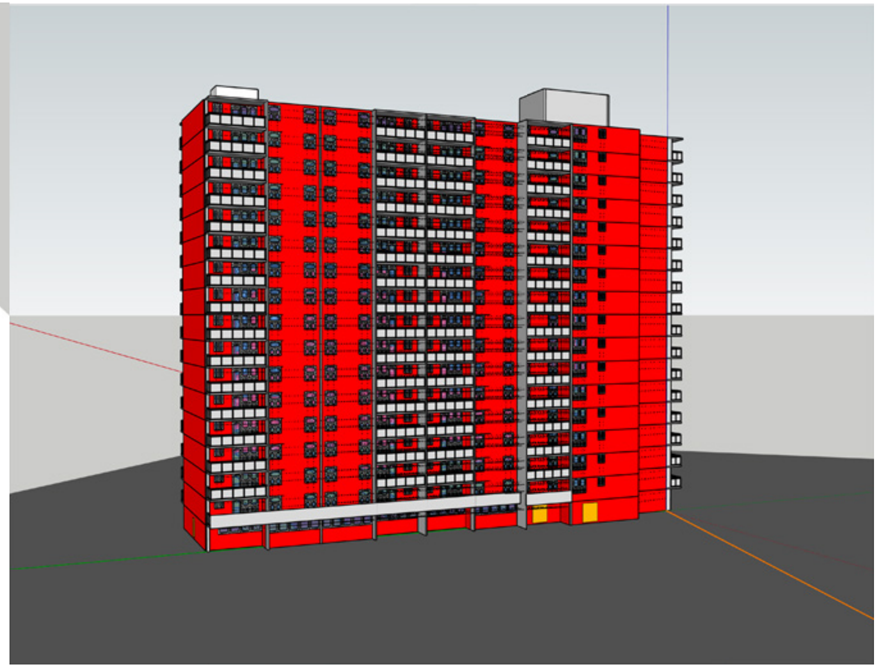


Figure 49 & 50: PHPP analysis.

input the remainder information in the PHPP model (e.g. thermal bridge values, ventilation, direct hot water and distribution, electricity, renewable energy sources, etc.).

PHPP Process After importing the climate, geometry, shading, and thermal bridge locations from designPH, a lot of additional data must be added to the PHPP file, such as:

- information about the style of EnerPHit project being pursued: choosing the Component Method of retrofit displays the target U-values for the building envelope components
- what the "Specific Capacity" of the building is: this is an estimate of the amount of massive construction that is included inside the building envelope as this has some effect on the building's thermal qualities
- the thermal bridge values: a psi value of 1.040 W/(mK)[64] was used

[64] Graham Finch. "The Important of Balcony and Slab Edge Thermal Bridges in Concrete Construction". In: *14th Canadian Conference on Building Science and Technology*. RDH. 2014.

for estimating the ambient thermal bridges of the slab edges

- shading factors, exterior emissivity and exterior absorptivity of components
- the ventilation system: the baseline model is set to “window”

Other steps include:

- double checking the imported areas to make sure they are categorized correctly in PHPP and assigned the appropriate U-values and orientations (for air film coefficients)
- double checking that the windows are assigned the appropriate frames and glazing (e.g. a large number of the 3580 windows[65] in the model were miscategorized as triple pane glazing, and this would have an effect on the heating demand)
- verifying all errors on the PHPP Check worksheet have been addressed

[65]designPH recognizes multipane windows as separate window instances and hence the large number of windows.

The next steps for a complete PHPP and retrofit design includes designing the ventilation system [66] and the integration of renewable energies.

designPH and PHPP Analysis Limitations

- Existing conditions: Conducting an accurate building analysis would require as-built data but this model was a combination of historical drawings and site visit experience. For example, the roof insulation wasn't specified in the drawings and so was assumed to be rigid polyurethane (fig. 51). All of the baseline assemblies were modeled in U-Wert, an online composite assembly U-value calculator, and are included in Appendix 4: Historic Wall Assemblies.

- Thermal bridges: all thermal bridging must be taken into account in the PHPP. An attempt has been made to include the thermal bridging of the exposed floor slab edges since it would make up an appreciable amount of the existing thermal bridging and the value can be es-

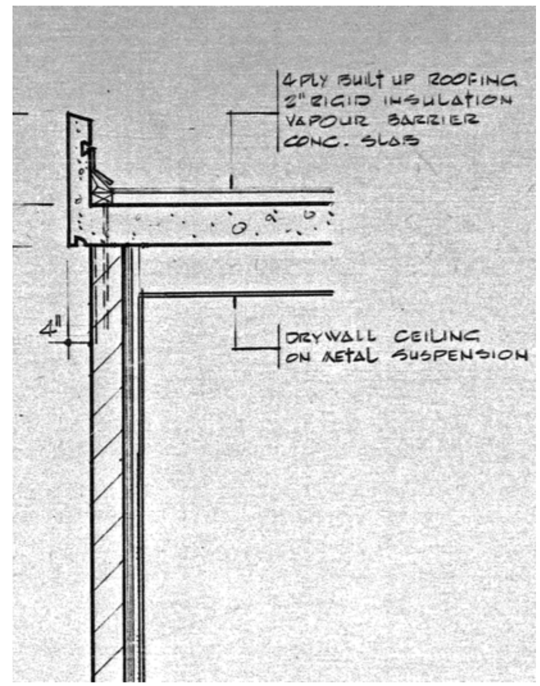


Figure 51: roof assembly in original drawings. Source: OCH.

[66] Appropriate airflow volumes for Passivhaus need to be determined and duct insulation/lengths need to be entered into the PHPP for heat loss calculation.

timated from existing sources (the exposed shear wall edges, pipes, and other penetrations have not been included). More complex or unique thermal bridging situations must be analyzed by a product that measures heat transfer effects, like THERM. Additionally, the below grade parking garage has not been included in the analysis because its location in the thermal envelope is ambiguous though it will obviously account for some heat loss. Not including all thermal bridges means that the final calculated heating demand is lower than it would be in reality.

- Treated Floor Area: Assumptions were made for the calculation of treated floor area because it is unclear how much of the building is used for residential and what the nature of the non-residential areas is.

- Shading objects: The surrounding trees were not included due the amount of computing time required to analyze them but the large highrise to the south was included. PHPP has shading factors that can be added to faces, and these were added to the southern and eastern walls where they would be exposed to the trees.

- Ground Worksheet: this worksheet, which calculates the heat losses of below-ground elements, was not included in the analysis.

- Primary Energy Demand and Direct Hot Water: missing information about the direct hot water system and electricity usage in the buildings means these sheets can not be filled out. While these are critical for optimizing the building and obtaining a PH certification, this analysis focuses on the more broad aim of building envelope improvement.

Software specific Limitations: designPH is optimistic when the advertising material says “create your SketchUp 3D model or use with minor adaptations an already existing model”.[67] The process is not as simple as using a previously created model and it requires a nuanced understanding of how to build it (see a comparison between the building fully modeled

[67] 2018. URL: https://www.designph.org/.

Figure 52: first sketchup model with top floor and east section views, rendered.

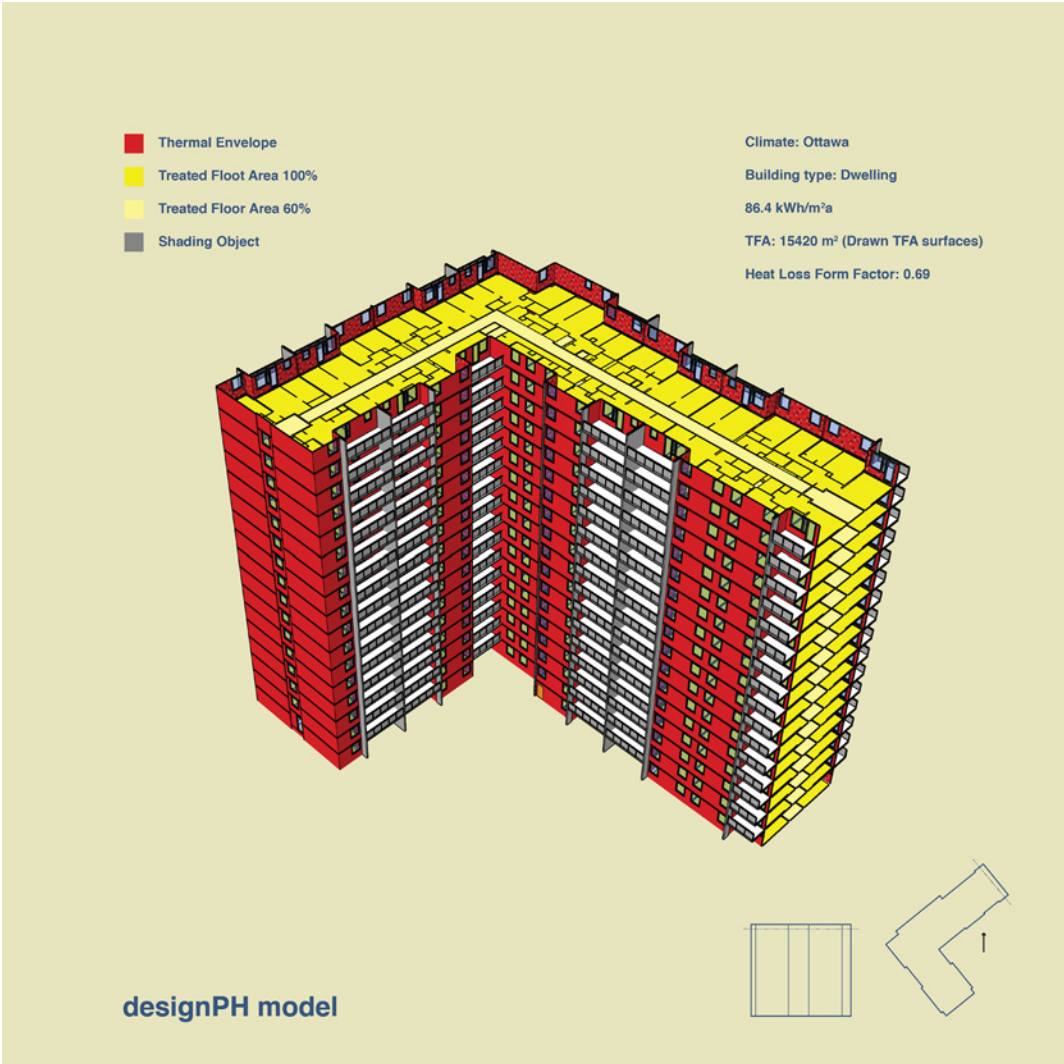


Figure 53: final designPH model with top floor and east section views.

Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	15419.8				
Space heating	Heating demand	kWh/(m²a)	151	≤	-	-	-
	Heating load	W/m²	60	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	3	≤	10		yes
	Frequency of excessively high humidity (> 12 g/kg)	%	10	≤	20		yes
Airtightness	Pressurization test result n_{50}	1/h	0.6	≤	1.0		yes
Moisture protection							
	Smallest temperature factor $f_{Rsi=0.25\,m^2K/W}$	-	-	≥	0.75		-
Thermal Comfort	All requirements fulfilled?	-			yes		no
	U-value	W/(m²K)		≤	0.70		
	U-value	W/(m²K)		≤	0.83		
	U-value	W/(m²K)		≤	0.91		
	U-value	W/(m²K)		≤	0.38		
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	472	≤	283		no
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	279	≤	-	-	-
	Generation of renewable energy (in relation to pro-jected building footprint area)	kWh/(m²a)	-	≥	-	-	

EnerPHit (retrofit): Component characteristics

Building envelope to exterior air[1] (U-value)	W/(m²K)	0.52	≤	0.12		no
Building envelope to ground[1] (U-value)	W/(m²K)	2.27	≤	0.51		no
Wall w/int. insulation in contact w/exterior air (U-value)	W/(m²K)	0.41	≤	0.3		no
Wall w/interior insulation in contact w/ground (U-value)	W/(m²K)	-	≤	0.95		-
Flat roof (SRI)	-	45	≥	-		-
Inclined and vertical external surface (SRI)	-	45	≥	-		-
Windows/Entrance doors ($U_{W/D,installed}$)	W/(m²K)	2.82	≤	0.75		no
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.80		-
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.90		-
Glazing (g-value)	-	0.77	≥	2.70		no
Glazing/sun protection (max. solar load)	kWh/(m²a)	185	≤	-		-
Ventilation (effective heat recovery efficiency)	%	0	≥	80		no
Ventilation (humidity recovery efficiency)	%		≥	-		-

[1] Without windows, doors and external walls with interior insulation
[2] Empty field: Data missing; '-': No requirement

Figure 54: baseline PHPP results. Source: PHPP.

and the final designPH model in fig. 52 and 53). Part of this challenge is being able to determine the position of a continuous thermal envelope, and this can be made difficult or impossible without ensuring all surfaces are precisely joined. Component selection (e.g. windows and doors) in the software is also limited to the available options and these may have a geographical bias. However, new components can be modeled and have thermal values assigned to them. Additionally, it's important that the exported PHPP file must be reviewed carefully by a PH professional in order to verify any results for an actual PH or EnerPHit project.

PHPP Results The pertinent information on the baseline verification page is highlighted in fig. 54. The results show the required space heating demand and heating load but most interesting is seeing how the existing building U-values compare with those required to reached the EnerPHit certification.

While the heating demand is shown on the verification page, a more useful PHPP output for the purposes of this project is heat flow energy balance (see fig. 55). From this chart we can see that thermal bridges ac-

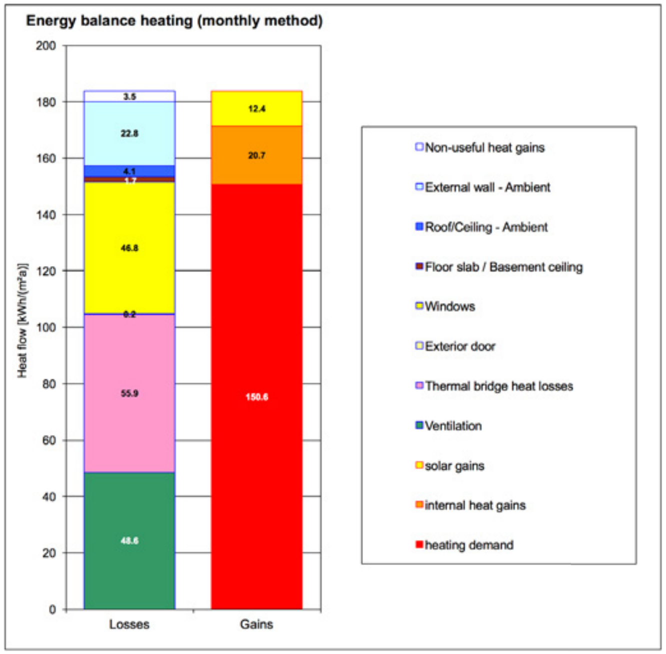
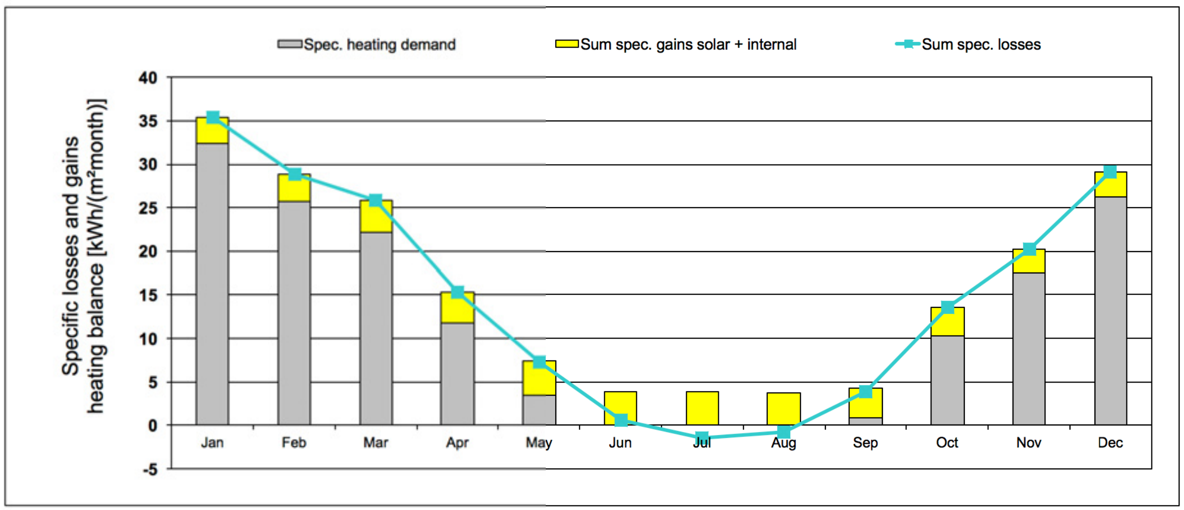


Figure 55: energy balance. Source: PHPP.



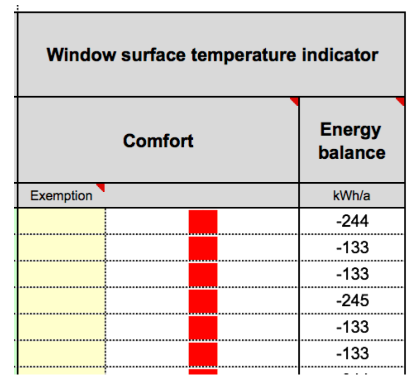


Figure 56 (left): monthly heat losses and gains.
Figure 57 (right): window comfort indicator. Source: PHPP.

count for the largest amount of heat loss, with ventilation and heat loss through windows representing similar values. Combined, these three areas represent over 80% of heat loss. The next leading source of heat loss it through the external walls. This information is summarized monthly in fig. 56.

The existing windows are responsible for 25% of the heat loss. In the Windows worksheet, PHPP shows both the energy balance for all windows individually as well as whether they meet the comfort criteria of PH (shown in fig. 57). None of the windows in the baseline analysis were appropriate for the PH comfort criteria nor did any have a positive energy balance (none provided more solar gains than heat transmission losses). The solar heat gains are further compared with the windows' transmission heat losses over the building's heating period in fig. 58, illustrating the limited effect of solar gains in the building.

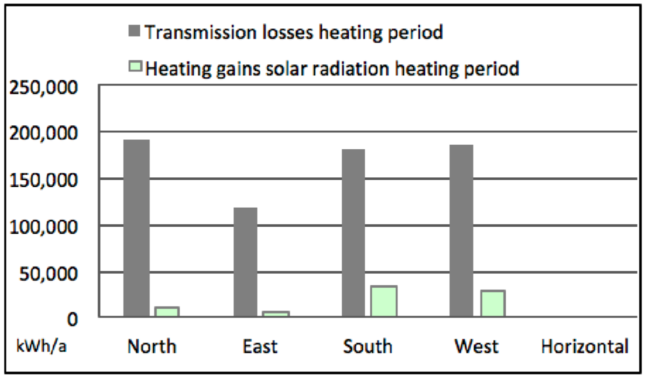


Figure 58: solar gains during the heating period. Source: PHPP.

7 Interventions

7.1 Evaluation Method

So far, much has been said about the need to balance and evaluate interventions according to how they answer the following primary evaluation questions:

- Do they push the building towards the EnerPHit standard?
- Do they preserve cultural value?
- Do they influence housing affordability?
- Are they economically feasible?

But how to actually evaluate them? During the conservation of the enormous Lignon satellite precinct in Geneva, an historically relevant housing development completed in 1971, preservationists developed a tool for analysis to balance energy improvement measures with the values of the site as an historical document (fig. 59).[68] They see this table as a decision-making tool able to assist building owners on intervention decisions because it makes the three variables of heritage, economy, and energy visible. The existing state of the building is found in the left column, with interventions to the right (in this case, categorized as maintenance, rehabilitation, renovation, and facade replacement).

This tool is a visually succinct way of representing the options available to balance cost and energy, however it needs to be modified in order to represent the values of embodied culture and carbon that can be found in a much more mundane piece of architectural history. In the Lignon example, the only indicator of historical relevance is the overall cost of the intervention, since it is taken for granted that the most appropriate conservation solution will be conducted in all scenarios. This would not be the case in a building like 1365 Bank St. as it is not a recognized heritage building, and so there is no requirement to balance energy efficiency measures with

[68] Franz Graf and Giulia Marino. "Modern and Green: Heritage, Energy, Economy". In: *docomomo* 44.1 (2011), pp. 32–39, p. 34.

anything. A modified version of this table, that accounts for cultural values and embodied carbon, would be a useful tool for intervention evaluation.

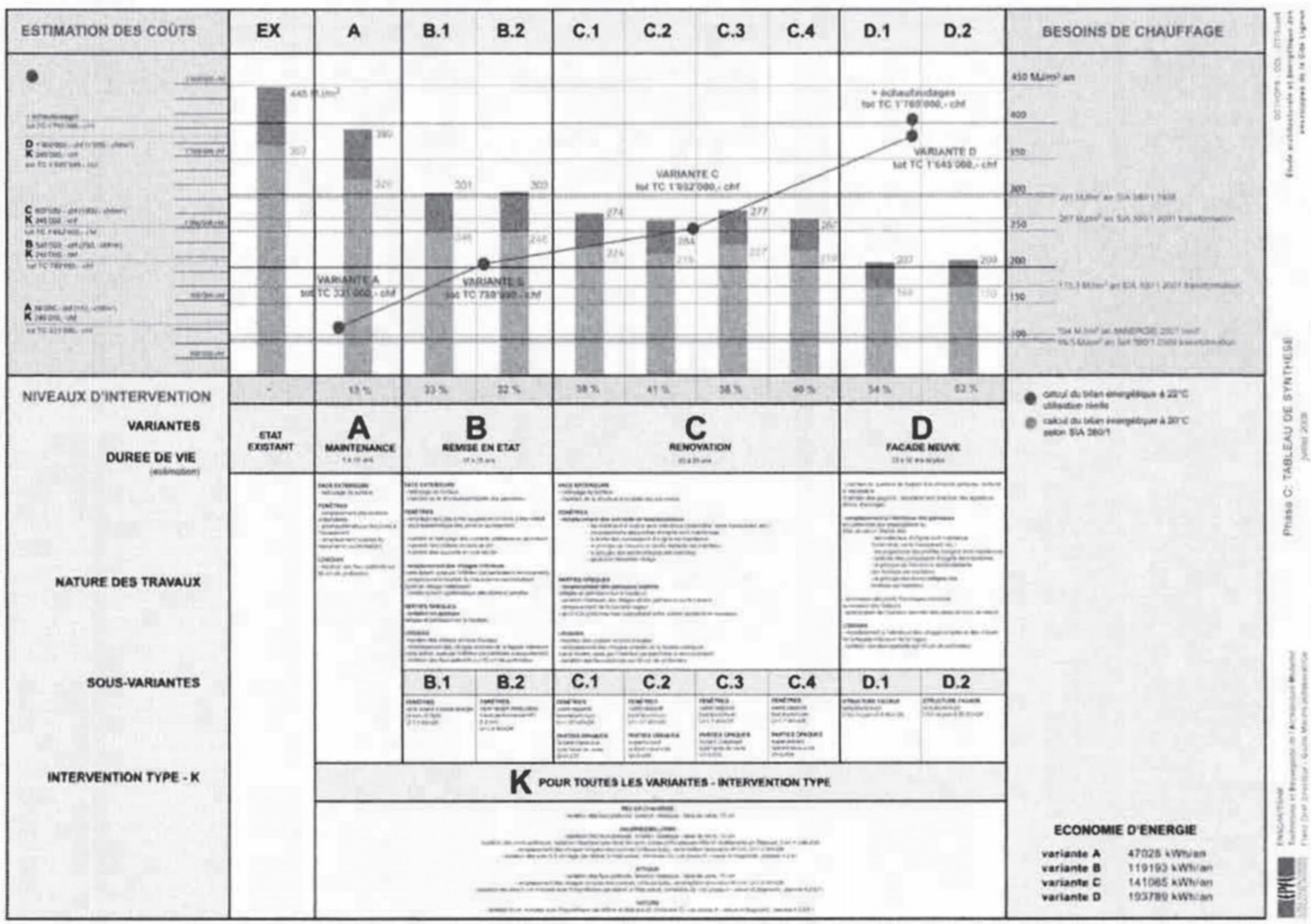


Figure 59: EPFL-ENAC-IA-TSAM guidance table: cost estimates/ levels of intervention/ heating needs, June 2009.
Source: Modern and Green: Heritage, Energy, Economy.

7.1.1 Performance Dimensions

Intervention

- Name of intervention, list of the work to achieve intervention.

Cultural Performance

- **Heritage Characteristics:** List of social, technical, and aesthetical modernist principles observed.
- **Health and Comfort Improvements:** List of health and comfort benefits to users.

Economic Performance

- **Cost of Intervention:** Approximate and relative to other interventions (Low to High).
- **Ability to Affect Future Cost:** Interventions ability to prevent recurring costs over building's lifespan, including component replacement and operational costs, relative to other interventions. (Low to High).

- **Cost of Future Energy Usage:** Simplified cost of total energy usage over 50 years to indicate magnitude of savings. Measured in dollars.

Technical Performance

- **Embodied Carbon Released:** List of removed materials. See Appendix 2: Embodied Carbon.
- **Heating Demand:** Measured in $kWh/m^2/a$ as per PHPP calculations.
- **Primary Energy Demand:** Measured in kWh/a.

The performance dimensions and the questions they address:

Do they push the building towards the EnerPHit standard?	**Heating Demand, Primary Energy Demand**, **Health and Comfort Improvements**
Do they preserve cultural value?	**Embodied Carbon Released, Heritage Characteristic**
Do they influence housing affordability?	**Cost of Future Energy Usage**
Are they economically feasible?	**Cost of Future Energy Usage, Cost of Intervention**, **Ability of Intervention to Affect Future Cost**

7.1.2 What about other evaluation methods?

Other methods of intervention analysis, such as the EFFESUS method[69], have been developed to help building preservationists maintain clearly identified heritage characteristics while conducting essential building repairs or pursuing better building operation (either in terms of health, comfort, building envelope performance or energy usage). The buildings that these methods apply to have been judged to be of specific and clear cultural value according to analysis and consensus and so maintaining those defining characteristics becomes of paramount importance. Clearly it is permissible to have a relative few buildings from humanity's past that use more resources than ideal if the remaining resources are enough to provide for the rest.

The building in this project has not been judged to have specific and

[69] In the Energy Efficiency Solutions for Historic Urban Districts: A Practical Guidance (EFFESUS) project, a framework of methods and tools was created in order to inform an evidence-based diagnosis and decision making process for prioritizing retrofit measures in historic urban districts. EFFESUS lists the indicators for selecting the best solutions and technologies as: habitability and indoor environment, energy savings, and economic feasibility. It lists the constraints on the decision making process as: respect for heritage significance and observance of conservation principles.

clear cultural merit, but it is part of a typology that was imbued with certain characteristics which risk being discarded if they are not openly named. Therefore it is more appropriate to develop a method for evaluating interventions that does not place the greatest amount of importance on identified heritage characteristics, but evenly reveals the cultural, economic, and technical performance of the interventions so that reasonable decisions can be made.

7.2 Interventions

The baseline PHPP analysis suggests that an overcladding of 1365 Bank Street's facade with superior insulation is justified given that 42% of heat loss occurs via thermal bridging and the opaque building envelope compo nents. A similar case can be made for window replacement.

Observations from the site visit make it clear that the building is suf fering from more than just inefficient energy performance: pedestrian safety makes this site's proximity to urban amenities pointless, the sur plus of parking and oversized mechanical room represent wasted space, there are no barrier free apartments nor is there easy access to recycling or compost, and what exists in terms of tenant recreational space is grim. These observations justify a site wide focus on tenant amenities.

If the observations from the cultural analysis are compared with the results of the PHPP and site analyses, it's clear that each of the dimen sions of modernity will be enhanced or in conflict with the previously sug gested interventions. The social aspect of modernism stands to be en hanced (i.e. if the landscaping, tenant amenities, and proximity to transit and shopping are improved). As expected, it also suggests that the aesthetical and technical aspects (the building's forms and expression of construction) may be in conflict with energy improvement interventions.

7.3 Testing Scenarios

7.3.1 Facade Overcladding

Important considerations:

- The cladding should show conceptual and structural intention to bring forward the interesting features of the original facade while enhancing aspects like repairability and durability.
- A recyclable and disassemblable overcladding will create a building that is less of a liability on future generation as needs, materials, and technologies change.
- Environmental barriers will be a source of complication: there is a vapour barrier on the interior (the original foil-backed gypsum), so the

added assembly must be vapour permeable. Additionally, the placement of the air barrier (behind the external insulation) will be difficult to access for repairs.

- Tower Renewal Guidelines suggests two methods for facade overcladding: EIFS with a rear drainage plane, or a panelized cladding system. The key recommendation is to assume water will enter the water assembly (i.e. face seal systems will fail) and redundancy for moisture control should be provided.[70]

- It is critically important that the wall is detailed to avoid catastrophic failure in case of fire. Exterior claddings must pass the performance requirement S134 ("Fire Test of Exterior Wall Assemblies") in Canada [71].

- While it is considered more expensive and less convenient to create

[70]Kesik and Saleff, *Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-unit Residential Buildings in Cold Climates*, A-1.

[71]See `https://www.scc.ca/en/standardsdb/standards/27081`

a foam-less exterior overcladding system, the use of plastic products is environmentally questionable, they're combustible, and they must be protected from UV rays to avoid thermal resistance degradation.

Summary of improvements tested:

1. Overcladding: Exterior building envelope components (roof and walls) upgraded to a U-value that meets the EnerPHit standard and eliminate slab thermal bridges, original windows remain

Results:

1. The facade U-values were adjusted to 0.116 using PHPP's predefined and certified EnerPHit external insulation system values for a massive wall with EIFS. Overcladding the facade resulted in a 48% reduction in heating demand and a 42% reduction in heating load (compare fig. 54 and fig. 60). However, the frequency of overheating [72] increased from 3% to 11%, which is considered unacceptable in the PH standard.

[72] In Passivhaus, this is defined as the number of days with a temperature greater than 25 degrees Celsius.

Specific building characteristics with reference to the treated floor area

		Unit	Value		Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	15419.8				
Space heating	Heating demand	kWh/(m²a)	78	≤	-	-	-
	Heating load	W/m²	35	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	11	≤	10		no
	Frequency of excessively high humidity (> 12 g/kg)	%	10	≤	20		yes
Airtightness	Pressurization test result n_{50}	1/h	0.6	≤	1.0		yes
Moisture protection							
	Smallest temperature factor $f_{Rsi=0.25\ m^2K/W}$	-	-	≥	0.75		-
Thermal Comfort	All requirements fulfilled?	-			yes		no
	U-value	W/(m²K)		≤	0.70		
	U-value	W/(m²K)		≤	0.83		
	U-value	W/(m²K)		≤	0.91		
	U-value	W/(m²K)		≤	0.38		
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	283	≤	196		no
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	169	≤	-	-	-
	Generation of renewable energy (in relation to pro-jected building footprint area)	kWh/(m²a)	-	≥	-	-	

EnerPHit (retrofit): Component characteristics

	Unit	Value		Criteria	Fulfilled
Building envelope to exterior air[1] (U-value)	W/(m²K)	0.12	≤	0.12	yes
Building envelope to ground[1] (U-value)	W/(m²K)	2.27	≤	0.5	no
Wall w/int. insulation in contact w/exterior air (U-value)	W/(m²K)	-	≤	0.3	-
Wall w/interior insulation in contact w/ground (U-value)	W/(m²K)	-	≤	0.94	-
Flat roof (SRI)	-	45	≥	-	-
Inclined and vertical external surface (SRI)	-	45	≥	-	-
Windows/Entrance doors ($U_{W/D,installed}$)	W/(m²K)	2.82	≤	0.75	no
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.80	-
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.90	-
Glazing (g-value)	-	0.77	≥	2.70	no
Glazing/sun protection (max. solar load)	kWh/(m²a)	141	≤	-	-
Ventilation (effective heat recovery efficiency)	%	0	≥	80	no
Ventilation (humidity recovery efficiency)	%		≥	-	-

[1] Without windows, doors and external walls with interior insulation
[2] Empty field: Data missing; '-': No requirement

Figure 60: overcladding PHPP results. Source: PHPP.

See Appendix 5: 1365 Bank Street for example overcladding details and images of 1365 Bank Street.

7.3.2 Windows and Balconies

Important considerations:

- Windows should be the first step in an EnerPHit retrofit, as this ensures the window reveals can be insulated. Since windows should be installed directly over the exterior insulation layer, they can be installed in a temporary frame if they are part of a phased retrofit.[73]

- Window replacement for PH necessarily involves changing the types of windows: 1365 Bank Street has multi-pane window styles and these should be simplified for economic and efficiency reasons. Larger windows perform better than smaller windows because the frame is the poorest performing part of the design and the assembly U-value changes according to the proportion of frame to glass.

[73]Janet Cotterell and Adam Dadeby. *Passivhaus handbook: a practical guide to constructing and refurbishing buildings for ultra-low-energy performance*. Green, 2012, p. 178.

- Enclosing balconies is considered cheaper than overcladding them,[74] however while this somewhat increases the interior living space, it also decreases the daylight penetration into the apartments, and in this case, may negatively affect the building's form factor[75]. Enclosing the balconies would also have a considerable impact on the deep relief and rhythm they provide to the facade; it also seems a shame to enclose balconies with such generous dimensions (5.7m x 2.1m).

Summary of interventions tested:

1. Existing windows and balcony doors (treated as windows) upgraded: framing U value of 0.75, glass U value of 0.80 (representative of av erage PH windows), framing reduced, subsequent decrease of glass' solar heat gain coefficient and increase of U value of glass on the

[74] Kesik and Saleff, *Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-unit Residential Buildings in Cold Climates*, A 48.

[75] The building's form factor is the ratio of the external surface area to the internal usable floor area; it is a measure of the building's compactness. It's unclear without dedicated testing whether the material saving but less compact balcony enclosuring or the better form factor but increased material usage balcony overcladding is the most economical or thermally advantageous option

north facade

2. Improved windows added to unglazed southern facade, subsequent increase of glass' U-value and glass' solar heat gain coefficient on south facade

Results:

1. In the first stage of the window interventions, the typical window framing was reduced, see fig. 61. This is more efficient, cost effective and maintains window operability (all but the largest pane should be tilt and turn or casement windows). The placement of the windows is constrained to the original window placement.

The windows were assigned average PH values (framing U-value of 0.75, glass U-value of 0.80, solar heat gain coefficient 0.5) in PHPP and this initial improvement resulted in a 22% reduction in heating demand and an 18% reduction in heating load over the baseline (see fig. 62). Over-heating increased from 3% of the time to 9%. The energy balance analysis shows that while window heat loss is down, there is still a net loss of heat

Figure 61: new window configuration (bottom) compared to original.

Specific building characteristics with reference to the treated floor area

		Unit	Value		Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	15419.8				
Space heating	Heating demand	kWh/(m²a)	118	≤	-	-	-
	Heating load	W/m²	49	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	9	≤	10		yes
	Frequency of excessively high humidity (> 12 g/kg)	%	10	≤	20		yes
Airtightness	Pressurization test result n_{50}	1/h	0.6	≤	1.0		yes
Moisture protection							
	Smallest temperature factor $f_{Rsi=0.25\ m^2K/W}$	-	-	≥	0.75		-
Thermal Comfort	All requirements fulfilled?	-			yes		no
	U-value	W/(m²K)		≤	0.70		
	U-value	W/(m²K)		≤	0.83		
	U-value	W/(m²K)		≤	0.91		
	U-value	W/(m²K)		≤	0.38		
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	386	≤	243		no
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	229	≤	-	-	-
	Generation of renewable energy (in relation to pro-jected building footprint area)	kWh/(m²a)	-	≥	-	-	

EnerPHit (retrofit): Component characteristics

	Unit	Value		Criteria	Fullfilled?
Building envelope to exterior air[1] (U-value)	W/(m²K)	0.50	≤	0.12	no
Building envelope to ground[1] (U-value)	W/(m²K)	-	≤	0.16	-
Wall w/int. insulation in contact w/exterior air (U-value)	W/(m²K)	0.41	≤	0.3	no
Wall w/interior insulation in contact w/ground (U-value)	W/(m²K)	-	≤	0.29	-
Flat roof (SRI)	-	19	≥	-	-
Inclined and vertical external surface (SRI)	-	45	≥	-	-
Windows/Entrance doors ($U_{W/D,installed}$)	W/(m²K)	1.01	≤	0.66	no
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.71	-
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.81	-
Glazing (g-value)	-	0.43	≥	0.80	no
Glazing/sun protection (max. solar load)	kWh/(m²a)	133	≤	-	-
Ventilation (effective heat recovery efficiency)	%	0	≥	80	no
Ventilation (humidity recovery efficiency)	%		≥	-	-

[1] Without windows, doors and external walls with interior insulation
[2] Empty field: Data missing; '-': No requirement

Figure 62: new window PHPP results. Source: PHPP.

through the windows (see fig. 63).

The next step in improving the heat balance was to simulate a low-E coating on the windows of the north facade (the windows were adjusted to have a solar heat gain coefficient of 0.42 and glass U-Value of 0.56). This has the effect of keeping the heat inside on the side of the building that receives little direct sun. This resulted in a heating demand reduction of about 1% and substantially reduces window heat loss on the north facade during the heating period, compare fig. 64 and fig. 65.

2. To further increase solar heat gain and improve the heat gain/loss balance, windows were added to the unglazed southern facade in the existing stairwell (see fig. 66). This placement would have the additional benefits of making the stairwell a more desirable method of circulation (see fig. 67) as well as minimal construction disruption to the tenants. With windows, the shaft could provide passive cooling via night ventilation during the warm season and require less electrical lighting during the day.

Using the average PH U-values for glass and framing, the additional

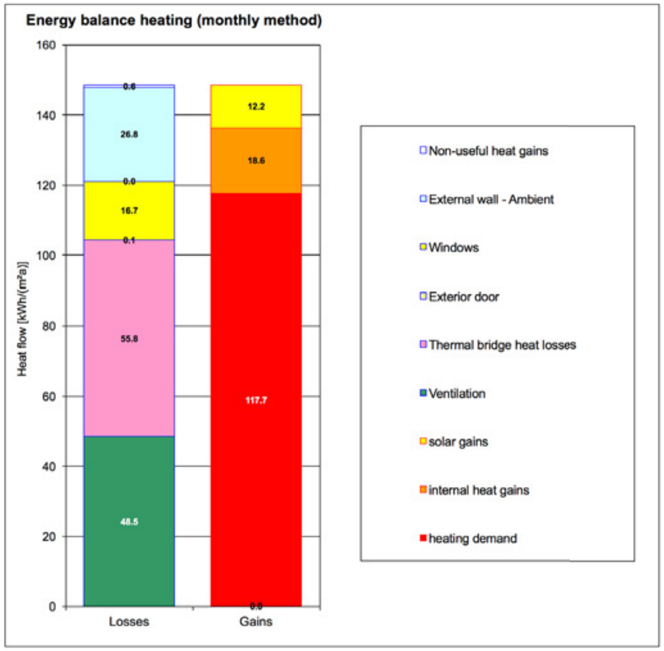


Figure 63: new window energy balance. Source: PHPP.

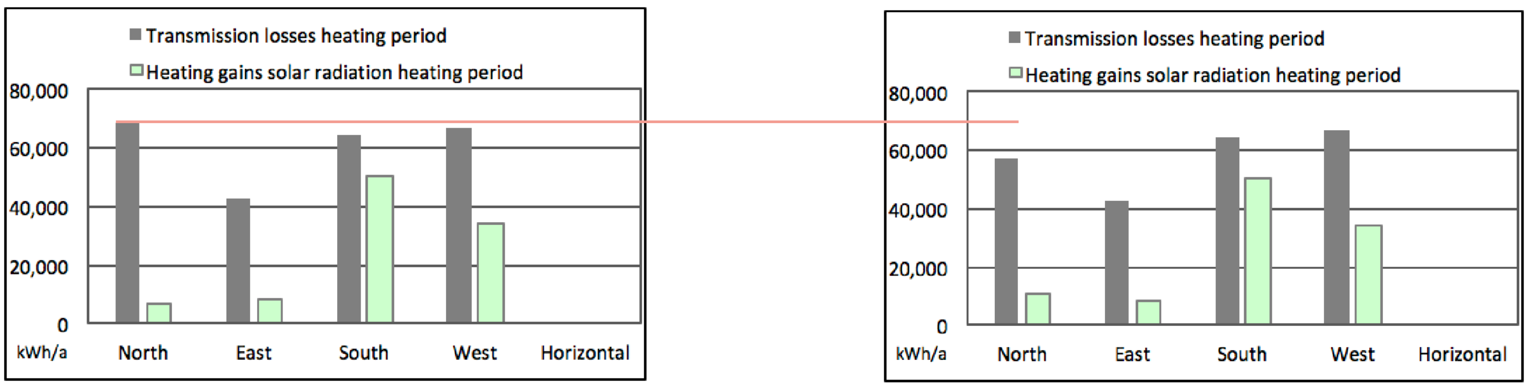


Figure 64 & 65: comparing heat losses and gains. Source: PHPP.

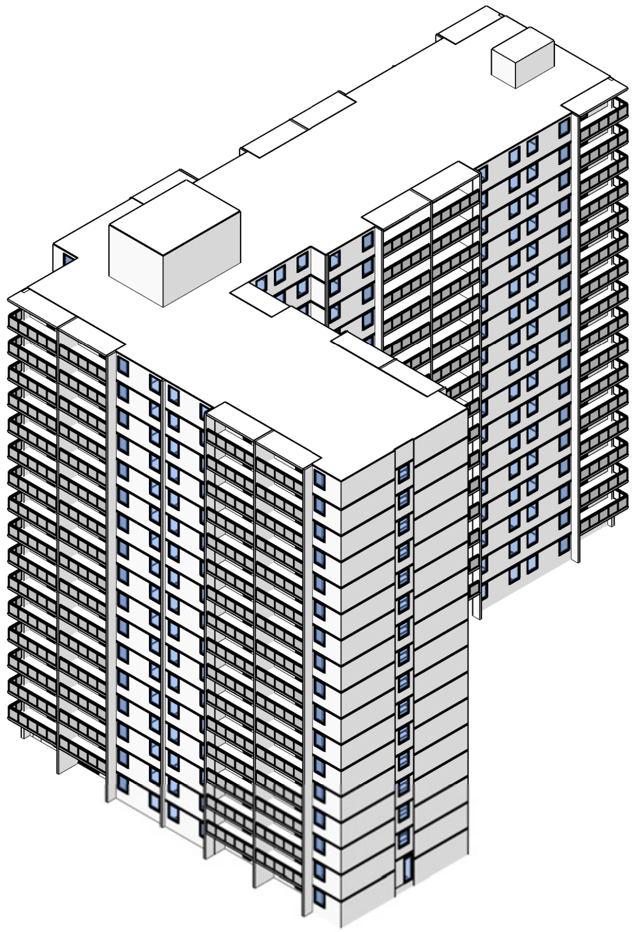
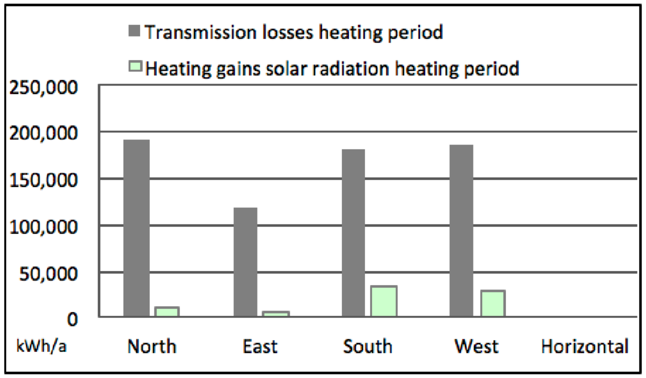


Figure 66 (left): added windows to southern facade.
Figure 67 (right): existing stairwell.

windows resulted in little additional solar gain and increased the window heat loss. To compensate, a higher performance glass was specified for those windows (a solar heat gain coefficient of 0.62 and a U-value of 0.64). Compared with the baseline analysis, this resulted in a 23% reduction in heating demand, a 20% reduction in heating load, reduced the solar losses to gains ratio from 3.77 to 1.26 (compare fig. 68 and fig. 69 to see this effect during the heating season). Though the project's solar gains are constrained by the difficulty of adding more glazing, additional window heat loss could be avoided if even better frames are specified.

With these interventions, overheating becomes a problem as it reaches 10% of days during the year. Even though this is permissible in the standard (it is the upper limit) it is discouraged because it means that the building will be uncomfortably hot for a substantial number of days. A solar shading strategy will be necessary.



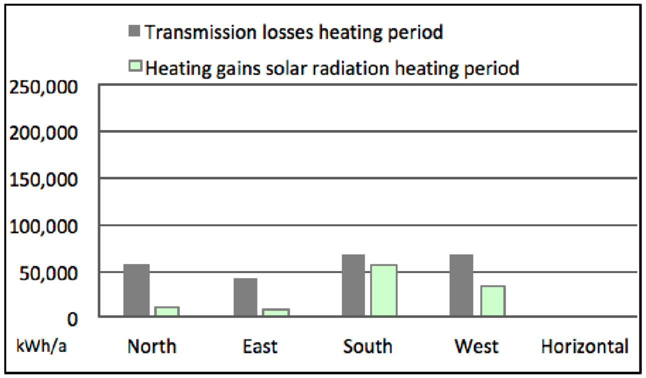


Figure 68 & 69: comparing baseline (top) with window intervention losses and gains (bottom). Source: PHPP.

7.3.3 Combined facade improvements

Summary of improvements tested:

1. Combined facade overcladding values with window upgrading

2. Add temporary sun protection to western, eastern, and southern windows of the combined facade overcladding with upgraded windows to simulate summer solar shading

Results:

1. Combining the facade and window renovations resulted in a 70% improvement in heating demand and a 62% reduction in heating load (see fig. 70). It is now apparent from the heating energy balance that the ventilation system represents the primary cause of heat loss (see fig. 71). The frequency of overheating is at an unacceptable 31% and interventions which either provide solar shading or mechanical cooling will be necessary.

Proper ventilation with heat recovery is a key part of the PH strategy as it ensures good indoor air quality, allows for substantial downsizing of the existing heat source, and helps with building envelope airtightness. In order to address these concerns as well as the remaining heat losses

Specific building characteristics with reference to the treated floor area							
	Treated floor area	m²	15419.8		Criteria	Alternative criteria	Fullfilled?[2]
Space heating	Heating demand	kWh/(m²a)	45	≤	-	-	-
	Heating load	W/m²	23	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	31	≤	10		no
	Frequency of excessively high humidity (> 12 g/kg)	%	10	≤	20		yes
Airtightness	Pressurization test result n_{50}	1/h	0.6	≤	1.0		yes
Moisture protection							
	Smallest temperature factor $f_{Rsi=0.25\ m^2K/W}$	-	-	≥	0.75		-
Thermal Comfort	All requirements fulfilled?	-			yes		no
	U-value	W/(m²K)		≤	0.70		
	U-value	W/(m²K)		≤	0.83		
	U-value	W/(m²K)		≤	0.91		
	U-value	W/(m²K)		≤	0.38		
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	198	≤	156		no
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	120	≤	-	-	-
	Generation of renewable energy (in relation to pro-jected building footprint area)	kWh/(m²a)	-	≥	-	-	

EnerPHit (retrofit): Component characteristics					
Building envelope to exterior air[1] (U-value)	W/(m²K)	0.12	≤	0.12	yes
Building envelope to ground[1] (U-value)	W/(m²K)	-	≤	0.16	-
Wall w/int. insulation in contact w/exterior air (U-value)	W/(m²K)	-	≤	0.3	-
Wall w/interior insulation in contact w/ground (U-value)	W/(m²K)	-	≤	0.3	-
Flat roof (SRI)	-	45	≥	-	-
Inclined and vertical external surface (SRI)	-	45	≥	-	-
Windows/Entrance doors ($U_{W/D,installed}$)	W/(m²K)	0.96	≤	0.66	no
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.71	-
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	0.81	-
Glazing (g-value)	-	0.48	≥	0.73	no
Glazing/sun protection (max. solar load)	kWh/(m²a)	118	≤	-	-
Ventilation (effective heat recovery efficiency)	%	0	≥	80	no
Ventilation (humidity recovery efficiency)	%		≥	-	-

[1] Without windows, doors and external walls with interior insulation
[2] Empty field: Data missing; '-': No requirement

Figure 70: combined intervention PHPP results. Source: PHPP.

from ventilation, the retrofit plan must include an improved ventilation strategy. Areas to consider for the installation of ducting are the existing shafts which are used to pressurize the building (see fig. 72).

2. Adding temporary sun protection to the western, eastern, and southern windows reduced the frequency of overheating from 31% to 18%, illustrating the effectiveness of this passive strategy (see fig. 73).

7.3.4 Landscape Revitalization

Important considerations:

- Surrounding tower landscape should serve its “original purpose of humane urban environment”.[76]

- The intersection at 1365 Bank Street before the Transitway overpass is a critical pedestrian crossing point given the location of the public

[76]Kesik and Saleff, *Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-unit Residential Buildings in Cold Climates*, p. 6.

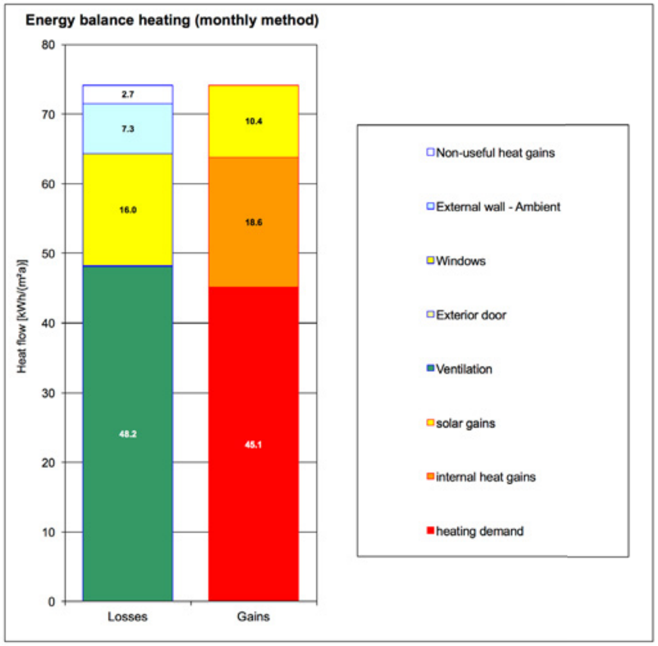


Figure 71: combined energy balance. Source: PHPP.

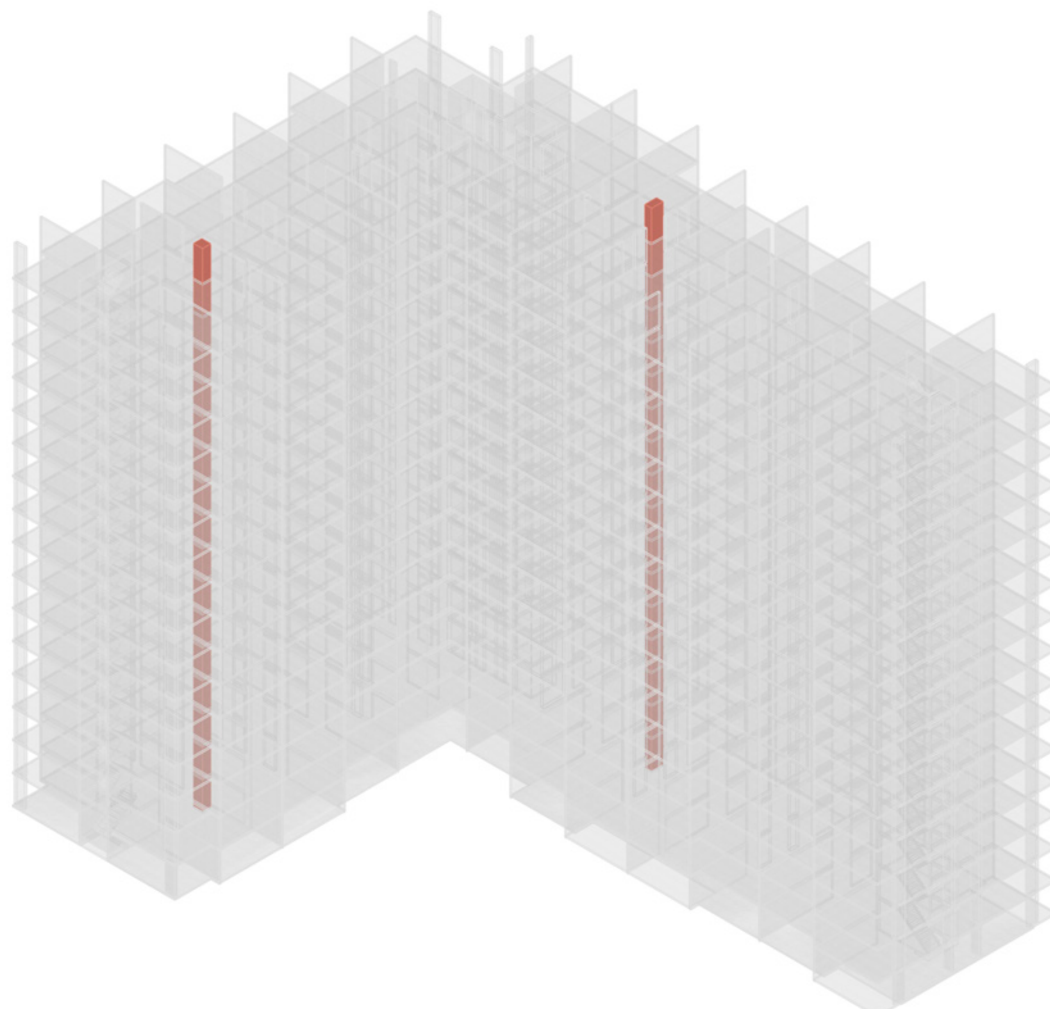


Figure 72: location for ventilation ducts (in pink).

Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	15419.8				
Space heating	Heating demand	kWh/(m²a)	45	≤	-	-	-
	Heating load	W/m²	23	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-	≤	-	-	-
	Cooling load	W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C)	%	18	≤	10		no
	Frequency of excessively high humidity (> 12 g/kg)	%	10	≤	20		yes

Figure 73: PHPP results with sunshading. Source: PHPP.

transit hub and stores/services of the Billing's Bridge Shopping Centre.

Improvements tested:

1. New pedestrian access routes: crosswalk markings provided at key intersections, speed limit reduction

2. Above ground parking annexed to green space, laundry/lounge connection to green space

Results:

1. The traffic crossing at 1365 Bank Street before the Transitway overpass does not necessarily need to be upgraded from a Full Traffic Signal to a different pedestrian crossing treatment but should be repainted with ladder crosswalk markings, see fig. 74. The Ontario Traffic Manual cites comfort and convenience as one of the factors influencing safety in pedestrian crossings and recommends safe, convenient, and unambiguous street crossings.[77] These markings

[77]Ontario. *Pedestrian Crossing Treatments: Book 15, Ontario Traffic Manual*. Ontario.

provide “enhanced visibility of the crosswalk and thereby increase drivers’ awareness of potential conflicts”.[78] While a relatively simple intervention, it’s suggested that designing intersections which improve pedestrian conspicuity not only help avoid crossing collusions but encourage pedestrians to use them.[79]

The vehicular speed on this section of Bank (50 km/h) should be reduced to 40 km/h due to the existence of several large highrise apartments and pedestrian-drawing features (the shopping centre and the bus station). The Ontario Traffic Manual finds that:

“Relatively small changes in speed can have a large impact on the severity of a pedestrian collision (particularly between 40km/h and 60km/h)”[80]

June 2016, p. 16.

[78]Ontario, *Pedestrian Crossing Treatments: Book 15, Ontario Traffic Manual*, p. 49.

[79]U.S. Department of Transportation. *Pedestrian Accommodations at Intersections*. Federal Highway Administration, p. 2.

[80]Ontario, *Pedestrian Crossing Treatments: Book 15, Ontario Traffic Manual*, p. 15.

Figure 74: location of new crosswalk markings.

and so a 40 km/h speed limit is a more prudent and equitable limit considering the degree of pedestrian-vehicle interaction (another Ontario Traffic Manual factor influencing pedestrian safety).

2. The above ground resident parking is removed and replaced with an enclosed green space (compare fig. 75 with fig. 76). To achieve this the existing garbage dumpsters are moved to the front of the lot and enclosed. The green space is accessed through the existing lounge and laundry rooms. The existing glazing in these rooms is replaced with full height glazing as per the original design for the north facade (compare fig. 77 and fig. 78).

This makes use of the unnecessary parking space while providing an area with a visual connection to the ground floor amenities (the interior courtyard has no visual connection to tenant amenities). Additionally, where the current garbage dumpsters are located is in the back corner of the above ground parking lot, far from the garbage room and not enclosed in the originally proposed enclosure. Moving it to the front of the site places it much closer to the existing garbage room.

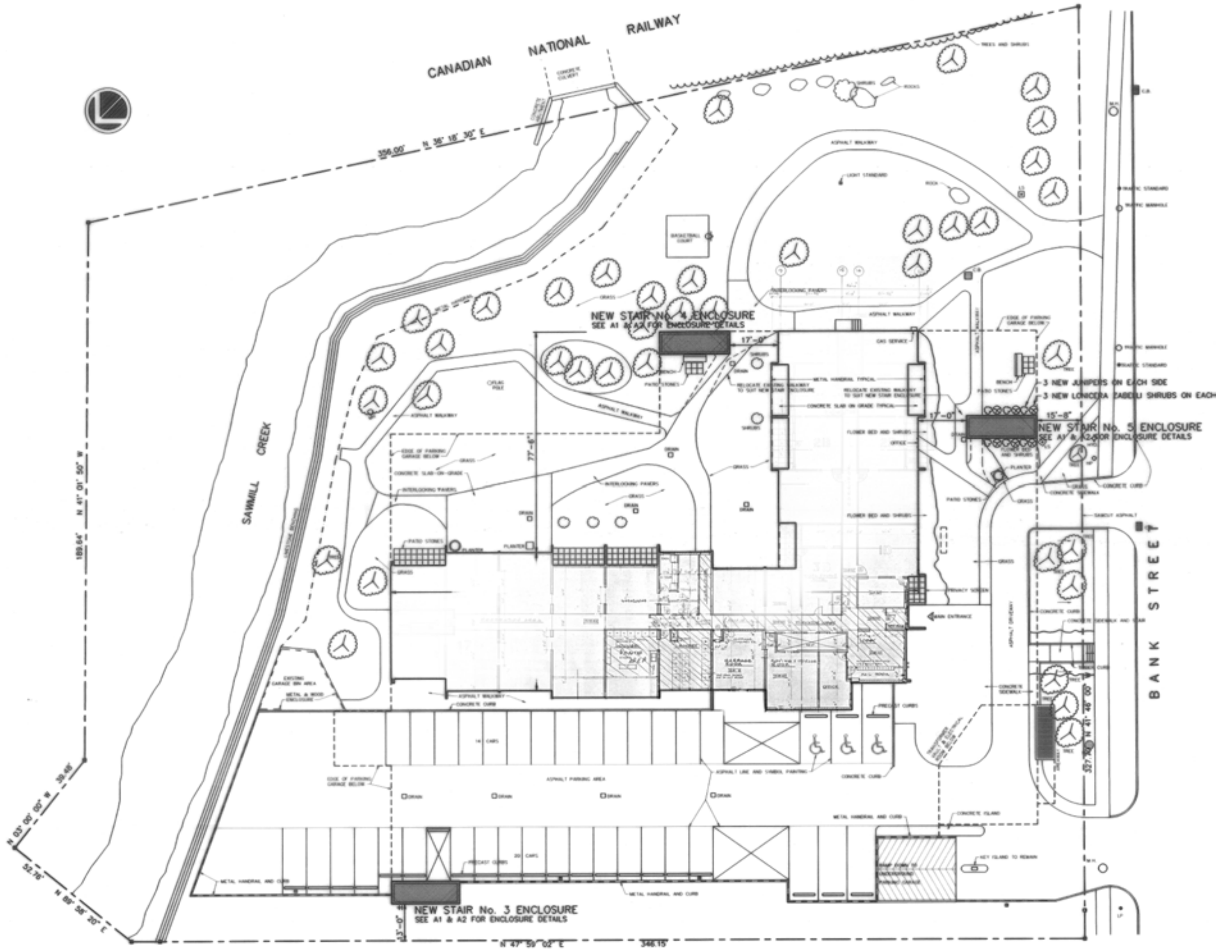


Figure 75: existing site plan with existing ground floor amenities. Source images for illustration: OCH.

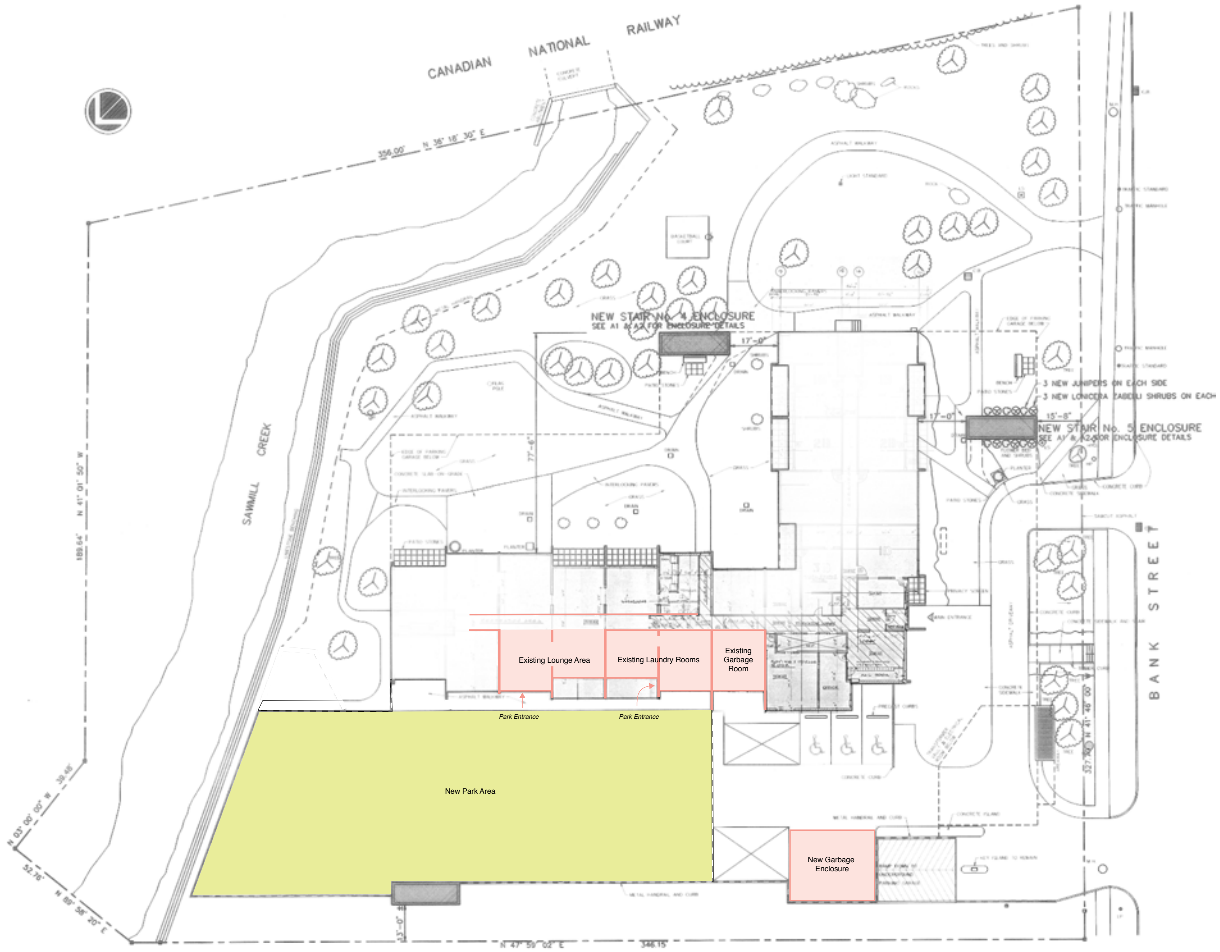


Figure 76: new site plan.

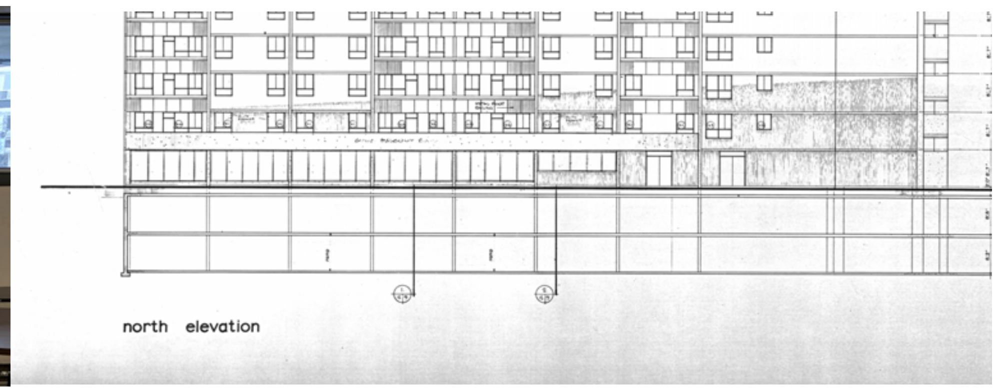


Figure 77 (left): existing window configuration from interior.
Figure 78 (right): original design for facade. Source: OCH.

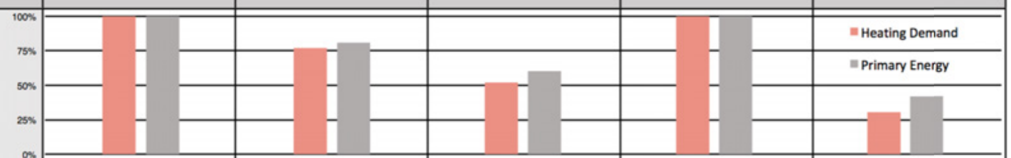
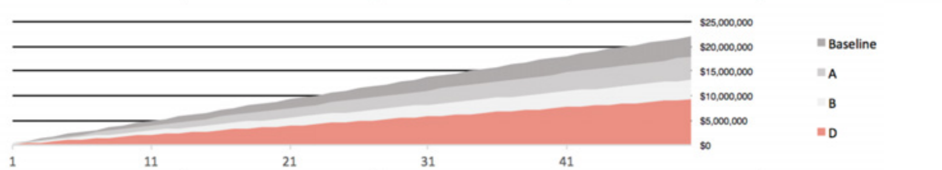
The new green space receives a variety of sun and shade conditions since the site is not oriented directly north, and the shade would provide a comfortable place to be during the summer heat. The green space would provide water retention and building water runoff could be directed to bioswales in the space for filtration. An area could be dedicated to collecting tenant compost.

This laundry room/park connection is inspired by the “safe park” in the Globale Hof, a public (subsidized) apartment complex in Vienna that was developed with migrant integration in mind. This feature was ranked positively by residents of the Globale Hof[81] and consists of a “laundry directed connected to the children’s playground – with a solar pump to create a small “river” – and directly connected to the interior playroom.”[82]

[81] Joachim Brech and Heidrun Feigelfeld. *Integrated on the Global Estate (Globale Hof)*. Sozialbau AG, 2016.

[82] Wolfgang Forster and William Menking. *The Vienna Model: Housing for the Twenty-First-Century City*. Jovis Verlag GmbH, 2016, p. 139.

7.4 Intervention Evaluation

INTERVENTION	BASELINE	A Windows	B Overcladding	C Landscape	D Total
LIST OF WORK	-	U-value of existing glazing and framing upgraded, framing reduced Windows added to southern façade	U-value of building envelope upgraded to EnerPHit standard with an external insulation system	Crosswalk markings added, speed limit in area reduced Above ground parking annexed to green space, amenity facades improved	Combination of all improvements External solar shading on west, eat, & south facades
PERFORMANCE					
TECHNICAL					
HEATING DEMAND PRIMARY ENERGY					
EMBODIED CARBON RELEASED	-	Removed 923 m^2 windows	-	Removed 30 m^2 windows Removed 8 m^3 masonry Removed 930 m^2 asphalt	Removed 930 m^2 windows Removed 8 m^3 masonry Removed 930 m^2 asphalt
CULTURAL					
HERITAGE CHARACTERISTICS	-	-	Maintained technical and aesthetical: bold façade forms, details expressing construction	Enhanced social: outdoor amenities, multipurpose rooms, proximity to transit and shopping	Enhanced social Maintained technical and aesthetical
HEALTH AND COMFORT IMPROVEMENTS	-	Thermal comfort Sound reduction Daylighting in stairs	Thermal comfort Sound reduction	-	Thermal comfort Sound reduction Daylighting
ECONOMIC					
COST OF FUTURE ENERGY USE (50 YEARS)					
ABILITY TO AFFECT FUTURE COST	-	HIGH	HIGH	LOW	HIGHEST
COST OF INTERVENTION	-	HIGH	HIGH	LOWEST	HIGHEST

Notes about future cost: In 2001, CMHC studied the annual energy and water consumption of 40 apartment buildings across Canada, ranging from six to 26 stories in height, from 3,345 m^2 to 26,795 m^2. They found the buildings from 1961-1980 used an average of 4,012,513 kWh/a. Despite the small sample size, they found this average energy use consistent with results from other studies on highrise and Ontario Housing Corporation apartment building energy use.[83]

PHPP calculates 7,277,768 kWh/a as the baseline energy usage for 1365 Bank Street, though this is calculated for the Passivhaus comfort standard. If the building is actually kept colder in the winter time, then this is an inappropriately large number. Considering this could greatly inflate the savings calculated, the average of 4,012,513 kWh/a will be used. This works out to about $159/month/unit. The blended rate of 11 cents/kWh, taken from Ontario Hydro online, is used for the cost of energy and this is kept static over a period of 50 years.

[83] Canada Mortgage Housing Corporation. “Analysis of the Annual Energy and Water Consumption of Apartment Buildings in the CMHC HiSTAR Database. Technical Series 01-142.” In: *Research Highlights* (2007).

8 Concluding Remarks

8.1 Results

The results of the evaluation chart are in line with the expectations developed throughout this thesis, and represent a significant improvement over the status quo. Despite the limitations of this study, it is certain that the building's carbon performance will be improved significantly from the interventions that decrease heating demand. This is an important result considering that as of 2015, space heating of residential buildings is second only to industrial mining in contributing to Canada's GHG emissions (by subsector; including electricity-related emissions).[84]

While this study was necessarily limited in scope, the process illustrates how guesswork can be taken out of energy interventions at the design stage by architects. The relative triviality of intervention testing versus the complexity of actual implementation is a particularly useful feature for

[84] Natural Resources Canada. "Canada's GHG Emission by Sector, End Use and Subsector". In: *National Energy Use Database* (2017).

designers. Future work that applies this approach should strive to make carbon performance more explicit as well as highlight the need for interventions to keep the building occupied during renovations.[85]

Renewable energy-producing technologies were not included in any of the interventions, primarily because the focus was on making the building use as little energy as possible. The author consider this to be in line with leaving the tower a “legacy rather than liability”[86]: leaving it with a well-designed envelope that requires less energy rather than relying on active technologies with shorter lifespans. Other more passive energy saving ideas the OCH might consider, however, include shower drain and washing machine heat recovery in addition to ventilation heat recovery.

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[85]A consideration that was taken into account for all the interventions developed in this project, and thus not one that was highlighted in the evaluation chart.

[86]As it’s phrased in Tower Renewal.

8.2 Cost

One thing that is made clear by the evaluation chart are the energy savings of each intervention over the baseline (with the exception of C). Keeping in mind the study limitations, the baseline building cost $22,068,820 to heat over a period of 50 years, while the combined window replacement and facade overcladding cost $9,268,904 to heat for the same amount of time. That is a savings of 58%, or about $13 million. These saving would be even greater if the interventions included heat recovery systems. Additionally, while difficult to assign a quantifiable economic impact, the interventions are expected to enhance the productivity and satisfaction of residents.

According to Tower Renewal, the cost per unit of a comprehensive tower renewal project ranges from $25,000 to $30,000 (inclusive of all interest charges, professional fees and permits).[87] Assuming the higher cost, a retrofit of 1365 Bank would cost $6 900 000. This would result in a pay-

[87] Kesik and Saleff, *Tower Renewal Guidelines: For the Comprehensive Retrofit of Multi-unit Residential Buildings in Cold Climates*, p. 42.

back period of approximately 15 years. This does not include any rehabilitation for the current building so the sooner the retrofit is conducted, the less money will be wasted for essential repairs.

One area of the retrofit plan that should be expected to be more expensive than average is the cost of the materials. The materials chosen should be such that repairs can be conducted easily without compromising the dignity of the building (i.e. repairs should not leave obvious discontinuities). Design for disassembly and repairability enhance the technical and aesthetical spirit of modernism in more than a superficial way by being transparent in their function. Having materials which achieve this goal may cost more upfront but represent less recurring maintenance costs.

8.3 Future Study

The work done in this project leaves open many avenues for further investigation. A few questions that require additional research are:

What is the suitability of adopting the EnerPHit standard for affordable homes? While it is clear from this project that retrofitting to this standard results in large operational benefits, it is important to note that the components used to achieve these energy and GHG reductions are Passivhaus certified and these are currently limited in availability or have a higher cost in North America. Retrofitting to a specific standard also carries the cost of consulting. The case needs to be made that the cost of the components/consulting is warranted in affordable home retrofits and scenarios involving components from local supply chains should be tested.

How is the EnerPHit ventilation system implemented in this type of retrofit? Once the thermal envelope is improved, it is essential that a renovation of the ventilation system occur in order to ensure hygienic air supply. Understanding the challenges and opportunities in implementing a Passivhaus ventilation system with heat recovery in a modernist apartment block is an area which requires study.

What are the architectural opportunities present in an exterior retrofit? The example design in this project is a conservative approach to a modernist building retrofit (see Appendix 5). However, it can be argued that this design does not amplify or enhance the design's underlying modernist principles by being derivative of the original design. The exploration of various design scenarios is needed and this is ideally conducted with participation of stakeholders at all levels but with emphasis on the tenants and caretakers. Understanding what is loved or unloved about the building by those who use it will create an exterior retrofit that is more than just an attempt to preserve an aesthetic or ideal.

How is exterior retrofit success evaluated? An important component in justifying this type of retrofit on a large scale will be post-retrofit monitoring studies which validate the testing scenario predictions as well as the perspectives of the occupants. The rigor necessary in the planning and execution in projects like this must be matched in the post-construction and occupancy evaluation of them, if not to provide proof that they meet some exact specifications but to confirm the validity of the retrofit decisions. An additional type of study, one that is conducted on occupant perspectives of ongoing construction in exterior retrofit situations would aid in understanding areas of tension during the process.

8.4 Future Applicability

1365 Bank Street was designed by the same firm, Miska and Gale, as 380 Murray Street (1973), another OCH property that was considered for this project (see fig. 80).[88] Considering these buildings were designed at around the same time and have similar facades (similar exposed slab floor separation and shear walls, window placement, use of contrasting brick elements and bold forms created by the balconies) it can be assumed that many of the technical details and construction methods developed for 1365 Bank Street could be carried over to a retrofit of 389 Murray. Other OCH properties by Miska and Gale include 215 Wurtemburg Street (1971, see fig. 81) and 160 Charlotte (1975, see fig. 82; already subjected to over-cladding without balcony protection); these properties also share many of the same facade characteristics as 1365 Bank Street. This suggests that design work for retrofits of this type of building will likely be broadly applicable to multiple buildings from the same firm, leading to overall lower costs.

[88] *Ottawa Community Housing in Lowertown East Heritage Walk* 9 (2018).

Figure 80: 380 Murray Street. Source: Google.

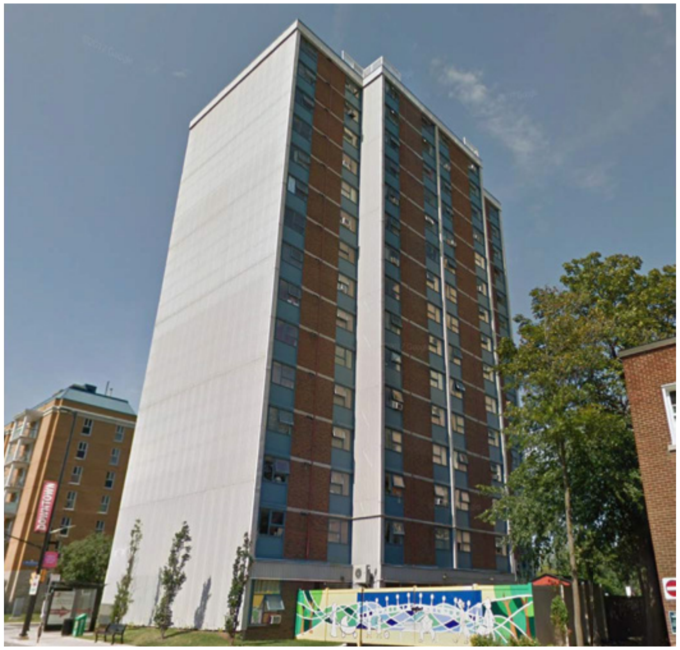

Figure 81: 215 Wurtemburg. Source: Google.
Figure 82: 160 Charlotte. Source: Google.

Low costs will be an important factor in order to see this crucial work carried out, but not the only one. A necessary driver for the retrofit industry will be optimism that these retrofits make sense culturally as well as environmentally. Negative public opinion of energy renovation can be found even in Germany, a country notable for its lead in building energy usage and the development of PH. In his article “Saving the climate or destroying culture? Energy renovation at the crossroads”, Jakob Schoof explains how recent public discussion in Germany often carries the message: “The energy renovation of buildings is damaging to building culture, does not make economic sense, and is ecologically absurd as a lot of the insulation material used is non-recyclable”. He points out the often reductivist nature of this kind of public discourse and calls for a “holistic consideration of all levels of energy renovation”.[89] In his view, two conditions are needed for increased cultural appreciation of energy retrofits: 1. there needs to be more examples of retrofits that are architecturally interesting (or “charming”), and

[89]Jakob Schoof. “Saving the climate or destroying culture? Energy renovation at the crossroads”. In: *Detail Green: Review of Sustainable Architecture and Energy-Efficient Refurbishment* (2015), p. 28.

2. construction measures for existing buildings must play a larger role in the curricula of architecture schools.[90]

Ideally the accumulation of negative public opinion can be avoided in North America as we learn from the efforts of other countries. Instead of, as Carl Elefante suggests, determining material conservation to be more relevant than cultural preservation, we must address the two synergistically.

It is also not evident whether higher standards of living for lower income people in North America will be possible without the reuse of a large part of the significant resources invested in the mid-century. Sensitive energy retrofits are able to contribute powerfully to cultural preservation and political action, but their ability to improve the housing situation for many through increased comfort and decreased operating costs is by far their most worthwhile social contribution. In their discussion on what criteria can be used to determine the success of Vienna's Globale Hof apartments, in

[90] Schoof, "Saving the climate or destroying culture? Energy renovation at the crossroads", p. 29.

terms of the integration of migrants and clients of subsidized housing, the authors Joachim Brech and Heidrun Feigelfeld hit on a lesson that should provide the basis for any approach to housing:

> "Whoever is treated without respect will also not meet others without prejudice. Here we are not speaking of obvious discrimination but of concealed cases of a lack of respect. Being classified as a "member of a target group" such as "migrant" is already part of this. Structurally there is a certain lack of respect inherent in every public subsidy. If this is also reflected in city planning figuration and architecture, residents must feel like objects of housing provision. Particularly in architectonic design there are numerous approaches which show respect to residents: by placing more value on their everyday life circumstances than on some extravagant architectural fashion."[91]

While there are clearly social issues at play that are larger than any

[91] Brech and Feigelfeld, *Integrated on the Global Estate (Globale Hof)*, p. 36.

one profession, architects have significant power over both the *environmental resources used* and the *cost* of structures that are at the same time one of the largest energy sinks in the world as well as the shelter for many. This paper suggests one approach to addressing the crucial need for conservation of carbon, while at the same time raising the standard of living of a vulnerable segment of the population. Many more such approaches will be needed if these goals are to be realized. Structural inequality and energy use are inextricably intertwined in the complex social fabric of North America, and we risk failing to address either issue if we do not seek mutual solutions.

9 Appendices

9.1 Appendix 1: Why the PHI standard?

This section explains why the European PHI standard is chosen over the American PHIUS standard. The purpose of this thesis is not to draw a conclusion over which between the American or European passive house standard is the better standard. Both standards are built on the same fundamental and unalterable principles with their differences existing in specific targets and methods. The Canadian Passive House Institute (CANPHI) is affiliated with PHI and their coursework and certification are taught and conducted to the PHI standard. As I, the author of this project, participated in the CANPHI Certified Passivhaus Designer course it is expedient that the project work follows this standard. Additionally, as the older organization, PHI is a more established and has a larger body of research with more case studies from which to draw from (e.g. the Cost Efficient Passive Houses as European Standards (CEPHEUS) project). It has proven its easy-to-use steady-state energy analysis software (PHPP) to be very accurate.[92]

Concerns regarding the arbitrariness of European energy targets for North American climates (as is made by proponents of PHIUS) are important to research, however, as the thesis project is a retrofit and this often precludes the achievement of the highest targets possible anyway, it's not pressing to conduct that research here.

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[92]Schnieders and Hermelink, "CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building", p. 158.

9.2 Appendix 2: Embodied Carbon

What is embodied carbon and how does it differ from embodied energy?

"Embodied carbon is the carbon impact associated with materials production, transport, assembly, use and disposal. It does not include the carbon emissions associated with the energy used for heating, lighting or cooling in the completed building."[93]

Embodied carbon is the CO_2 emissions[94] generated in the process of using energy to build something. The energy used is referred to as *embodied energy* (see fig. 83). Embodied energy is comprised of initial and recurring elements. The initial embodied energy is the direct non-renewable energy used (through transportation and construction) and the indirect non-renewable energy used (involving all processes

[93] *Methodology to calculate embodied carbon*. Tech. rep. Royal Institution of Chartered Surveyors [RICS], 2014.

[94] This usually the total set of greenhouse gases emitted, but expressed as a CO_2 equivalent.

concerning the origins of the materials used). The recurring embodied energy is the non-renewable energy that is used to maintain, repair, restore, refurbish or replace materials, components or systems during a building's lifetime.[95] While sometimes used interchangeably, the terms *embodied carbon* and *embodied energy* do not mean the same thing. This is because different types of energy sources (or fuels) generate differing amounts of carbon emissions. If a comparison about embodied carbon is being made from embodied energies, the embodied energies must be from energy sources that produce equivalent amounts of carbon emissions; it cannot be taken for granted that they represent the same thing.

How are embodied carbon and embodied energy measured?

Embodied carbon is expressed as tonnes of carbon dioxide created (tCO_2) per kilogram of material created. Embodied energy is typically expressed as megajoules (MJ) of energy required per kilogram of material

[95] *Measures of Sustainability: Embodied Energy*. URL: https://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_embodied.htm.

created. Both are difficult to calculate precisely and meaningfully for several reasons:

- There is no consensus on how they should be defined, i.e. which assumptions should be made or which boundary conditions should be used.[96]
- It is complicated to accurately predict the non-renewable energy content of materials.
- It is difficult to predict the recurring embodied energy, given the changing non-renewable energy content of material manufacturing over time,[97] i.e. advancements in material manufacturing technology change the embodied energy of a given material from one era to the next.

How will the dimension of embodied carbon be evaluated for this project's interventions?

[96] *Methodology to calculate embodied carbon*.

[97] *Measures of Sustainability: Embodied Energy*.

In this project, the embodied energy in the materials of the building's components *could* be compared with whether their presence has an affect on the building's operational energy usage (i.e. does replacing the materials outweigh the embodied carbon they represent?). This can be achieved by calculating the mass of the material multiplied by its embodied energy as found from material values in research, and then comparing this value with the reduction in non-renewable operational energy usage the building experiences but only after the embodied energy from the alternate materials used in the intervention is also considered. Additionally, an appropriate building lifespan must be estimated so that this energy amortisation and the evaluation of recurring embodied energy can be conducted. This quickly becomes very complicated and has the limitations of:

- the values of embodied energy must be taken from temporal and geographically local sources for any sort of accuracy
- the fact that some data just does not exist
- the fact that embodied carbon is not equivalent to embodied energy

- not considering that some interventions may improve social or cultural factors at the expense of embodied carbon retention

Even though the calculation of embodied carbon is complicated and has a large degree of uncertainty, we do have general ideas of what the embodied energy of certain materials are. We also know from research that the building's structure is typically the component with highest initial embodied energy and the longest lifespan, while building services and interior finishes represent the largest recurring embodied energy values.[98] This means it is possible to take for granted that the large amount of concrete and steel in the structures of the postwar concrete residential towers is worth preserving if the building's operational energy use can be substantially reduced. It also seems to indicate that focusing on using materials with low embodied energy in elements that are likely to be replaced in the future is important.

Ultimately, any evaluation of embodied carbon performance will be

[98] Raymond J. Cole and Paul C. Kernan. "Life-Cycle Energy Use in Office Buildings". In: *Building and Environment* 31.4 (1996), pp. 307–317.

subjective (for the above reasons), and lacking a robust and easily accessible method of analysis means that a qualitative measure will be used to evaluate embodied carbon in this project. The retention of the structure is a given, and so any reductions in the buildings materials or components (if any interventions call for it) will simply be listed. This is not to suggest that striving for exceptional carbon performance or conducting life cycle analyses is unimportant or a poor goal but that the rigor necessary pushes it outside of the scope of this project.

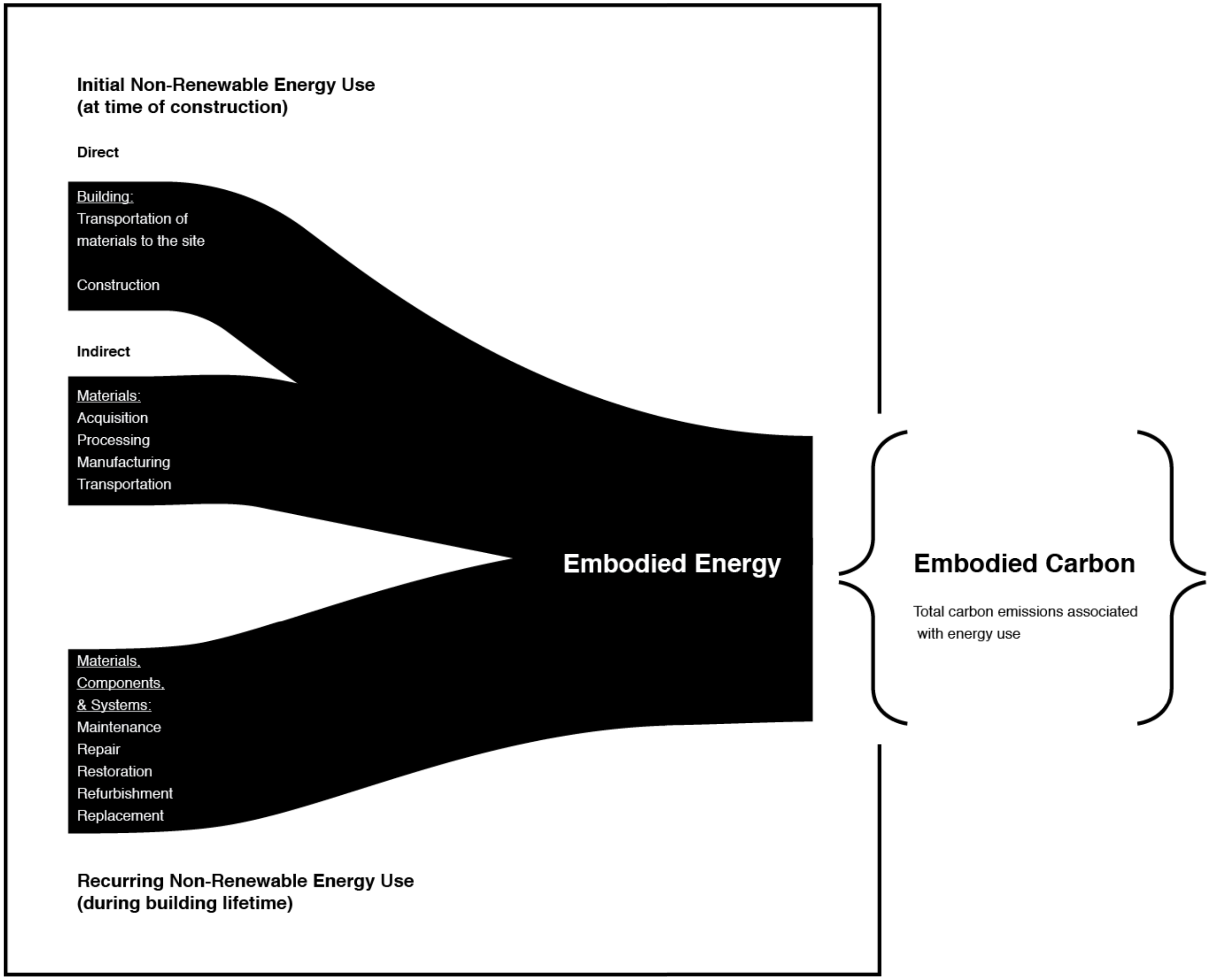


Figure 83: relationship of embodied energy to embodied carbon.

9.3 Appendix 3: Building Evolution

1972	1977	1983	1984	1986	1987	1990	1991	1992	1993	1994	1995	1996	1997	1998	2002
Building constructed	Reconstruction of bank (sawmill creek) protection	Temporary remedial measures in parking garage	Parking garage waterproofing, stream bank stabilization	Conversion of apartment 104 and 106 to office, Apt 102 converted from office back to apartment, new fire alarm and emergency voice evacuation system installed, floor slab repair to upper level of parking garage	DWH system conversion to natural gas structural modifications	New kitchen cabinets for 20 units	Electrical vault equipment repairs, outdoor parking lot repairs, last sighting of pedestrian bridge across sawmill creek	Parking garage lighting renewal on 1st and 2nd level	Parking Garage Rehabilitation (new stairs, podium waterproofing, new site lighting fixtures, new garage lighting fixtures and layout, new site drainage, new water heater power venting system, demolished and replaced parking slab, slab repairs, temporary parking lot established, bridge over sawmill creek disappears from site plan	outdoor stairwells enclosed, junipers and shrubs added, parking garage sprinkler system alterations and installations	ventilation revisions for laundry room and storage room	25 units had bathroom upgrades	office conversion to apartment units 104, 105 and 106 with asbestos abatement, boiler replacement in mechanical room	fire damage repairs and asbestos abatement for unit #1613, cladding and roof replacement for rooftop stairwell enclosure and elevator penthouse	additional electrical work on ground floor

9.4 Appendix 4: Historic Wall Assemblies

9.4.1 Methodology

The wall assemblies used in the analysis were remade from the historic building drawings (see fig. 84) using an online composite assembly U-value calculator from U-wert.net. Standard interior and exterior air film co-efficients were assumed when the assemblies were added to PHPP.

Thermal drift was factored into the calculated conductivity of these assemblies. Thermal drift is a process that can occur in spray foam insulations and it results in the insulation losing some of its insulative value as it ages. It is difficult to estimate the current U-value of the insulation without specific information from the manufacture so a conservative 10% increase in the thermal conductivity (from 0.022 to 0.024 W/mK) was added to U-Wert's standard value.

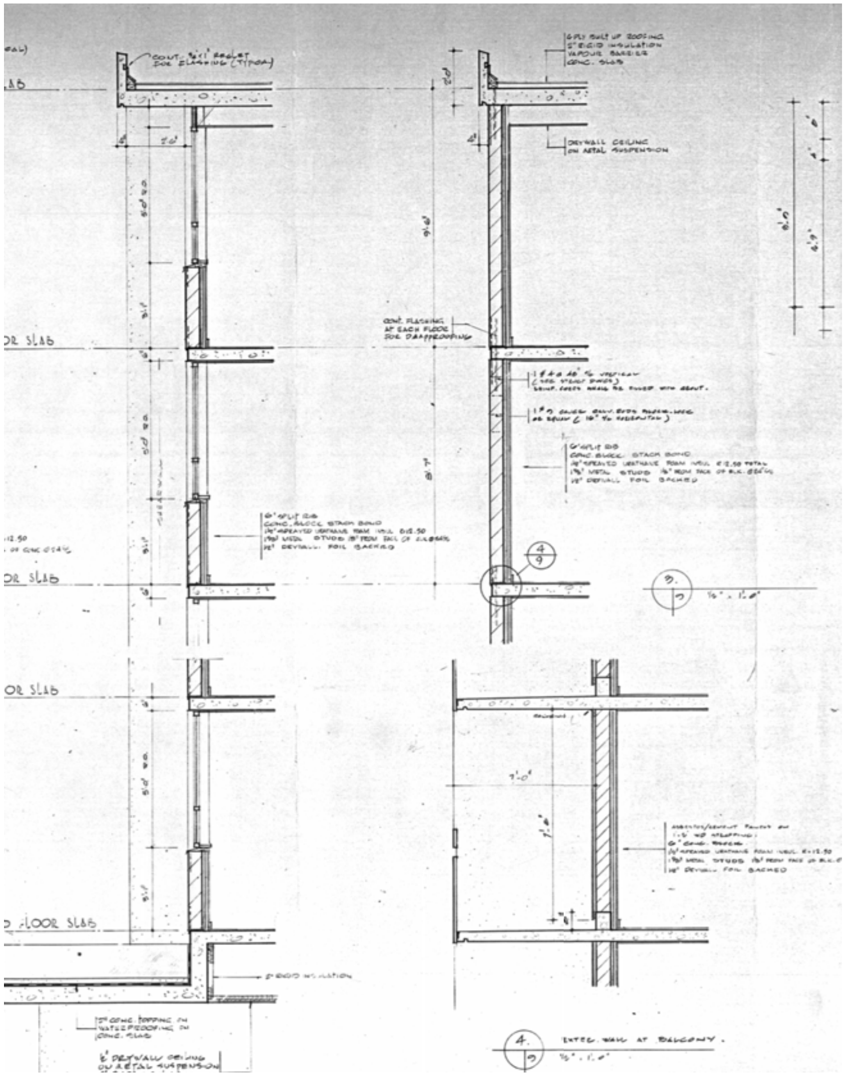


Figure 84: original wall assembly drawings. Source: OCH.

9.4.2 Assemblies

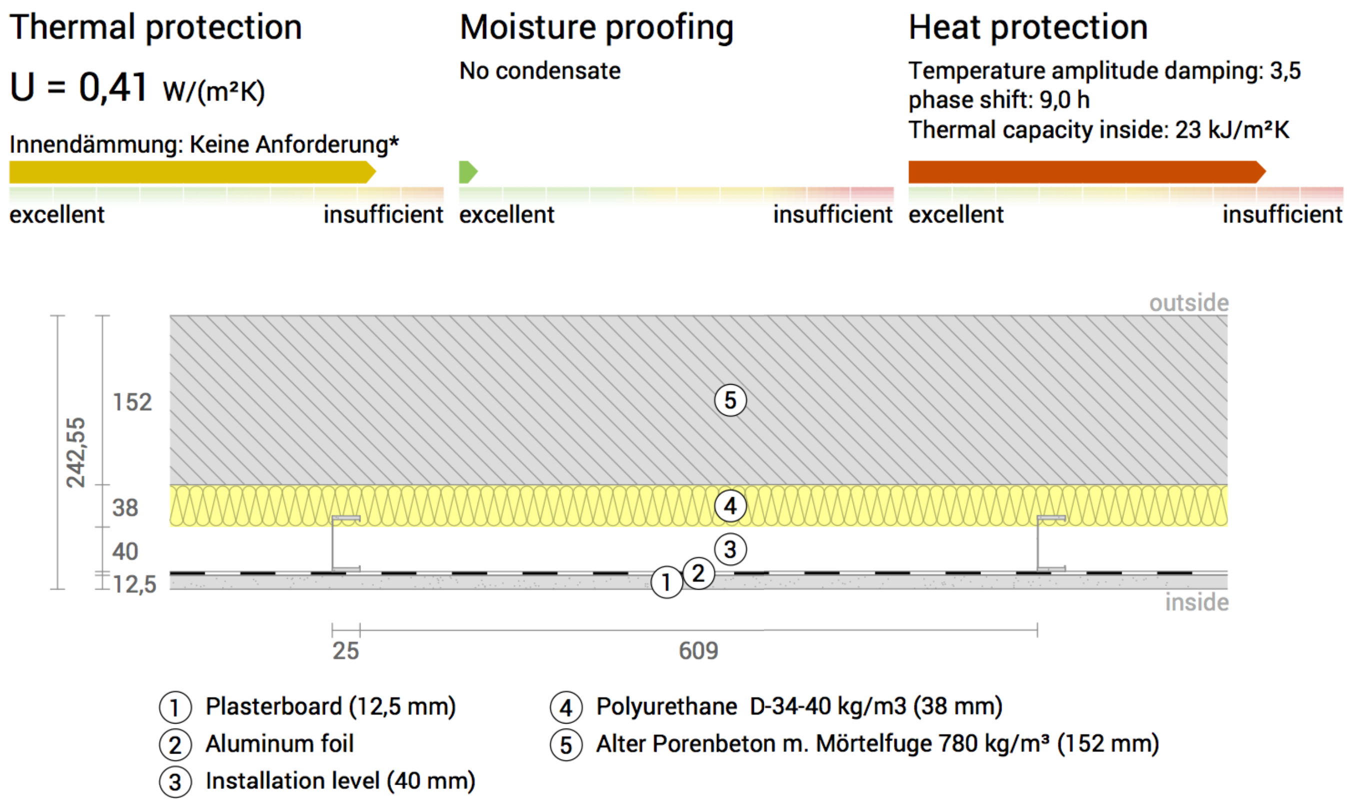


Figure 85: split rib concrete block wall. Source: U-wert.net.

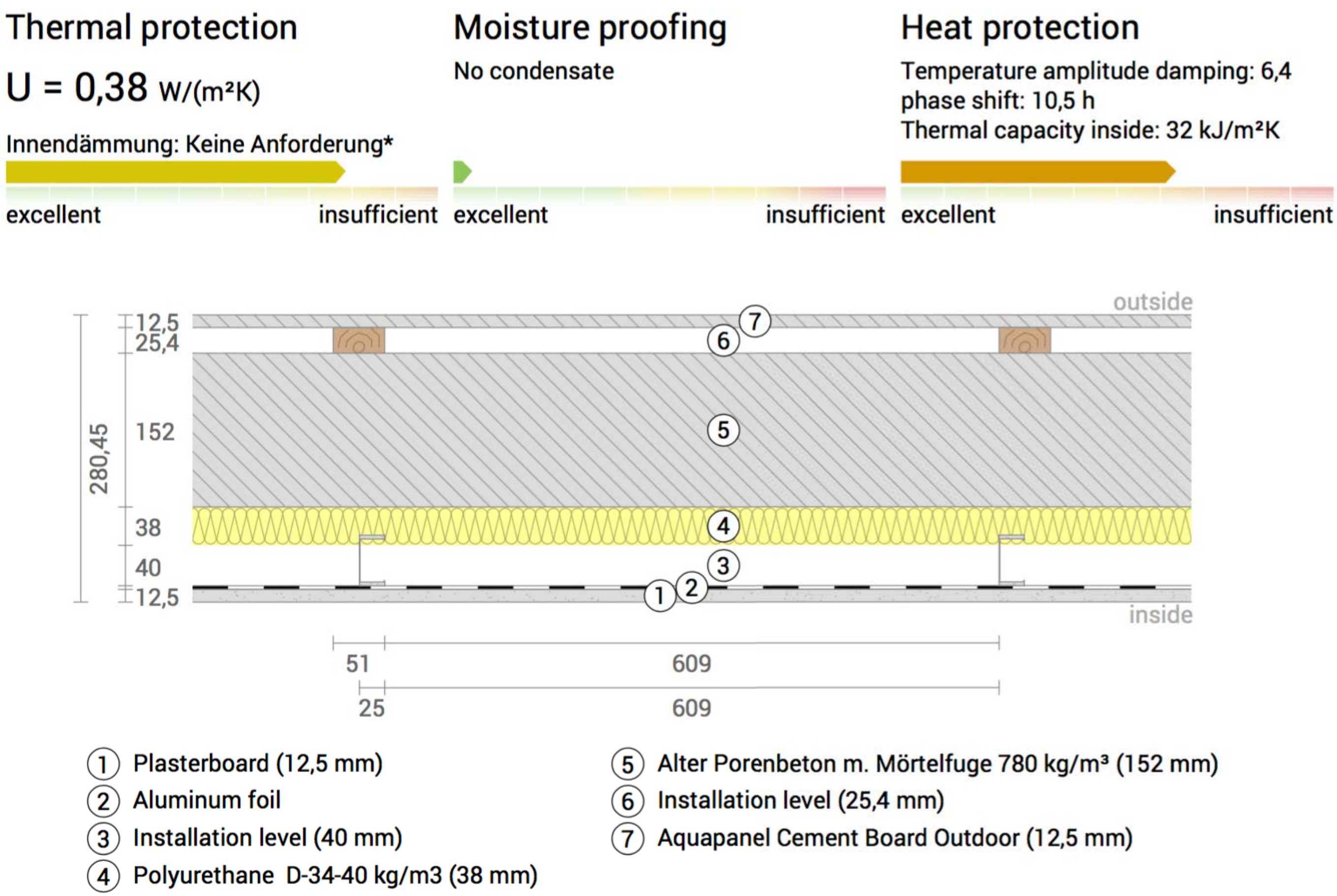


Figure 86: Contrast Balcony Wall. Source: U-wert.net.

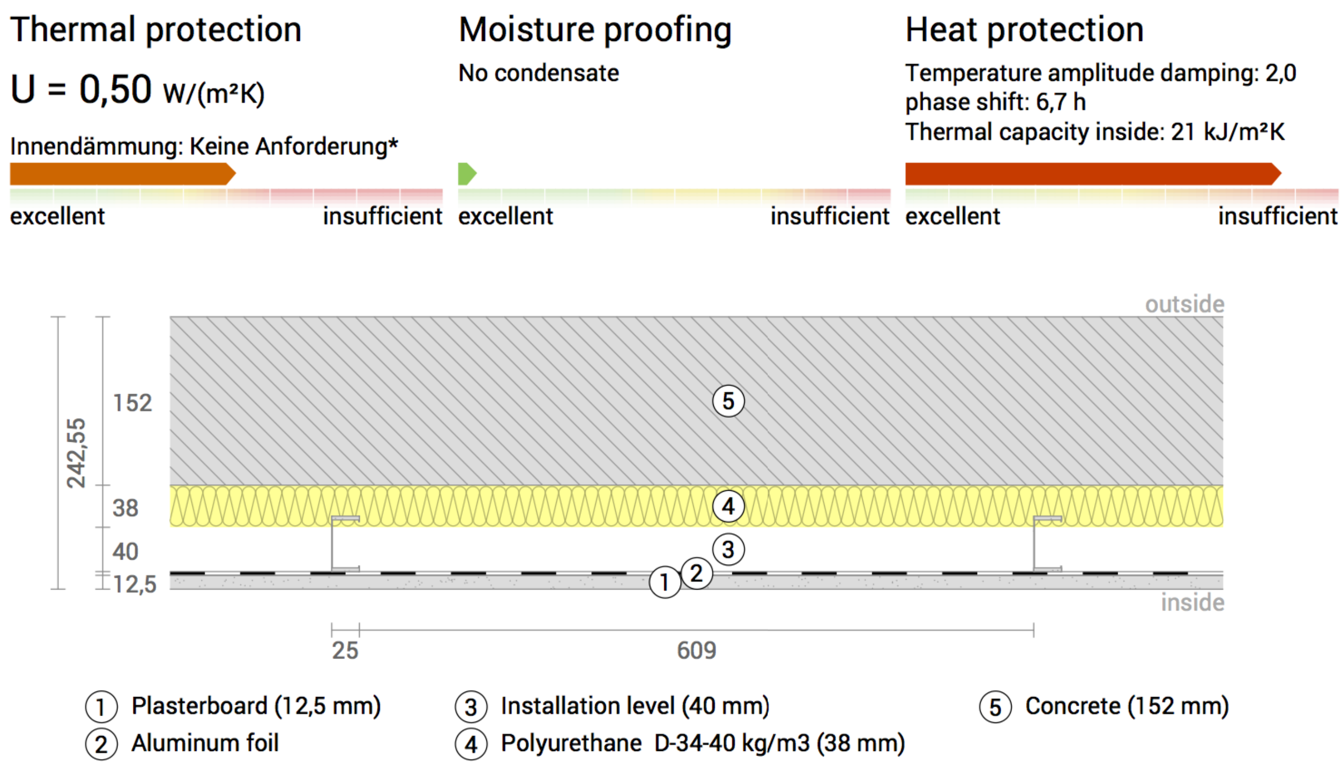


Figure 87: concrete shear wall. Source: U-wert.net.

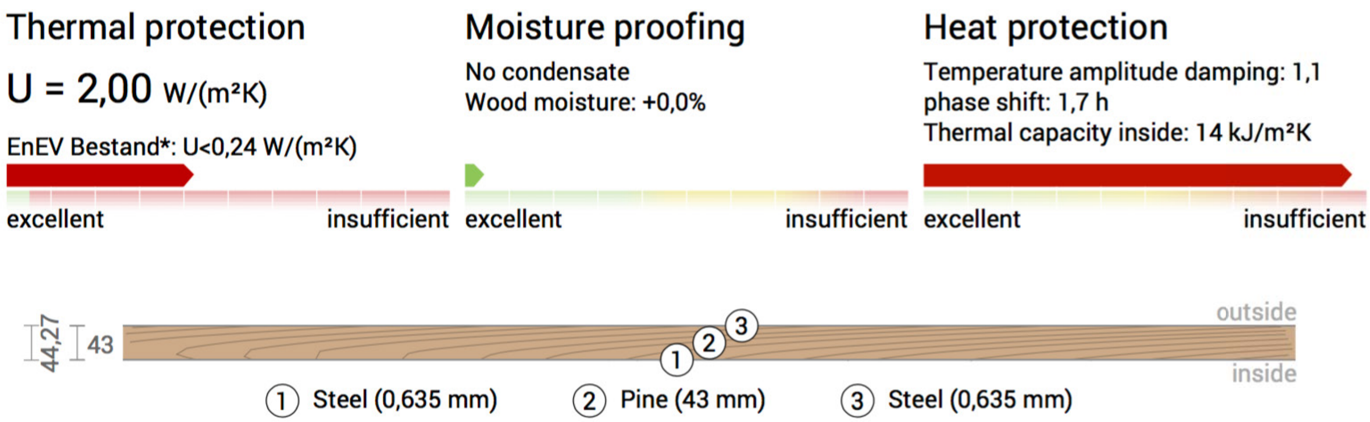


Figure 88: exterior door. The U-value for the original exterior non-balcony Kalamein doors could not be found, and it was subsequently difficult to find a U-value for steel-clad solid wood core door, so this was modeled in U-wert. The balcony doors were modeled as windows in designPH due to their frames and amount of glazing. Source: U-wert.net.

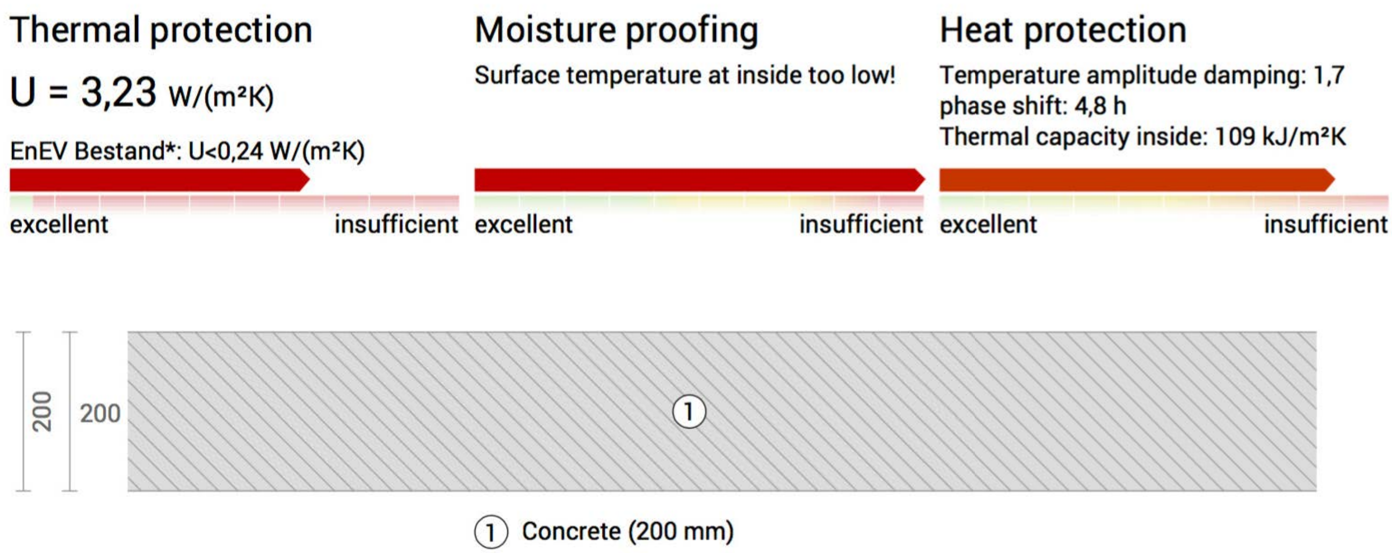


Figure 89: test slab. Source: U-wert.net.

9.5 Appendix 5: 1365 Bank Street

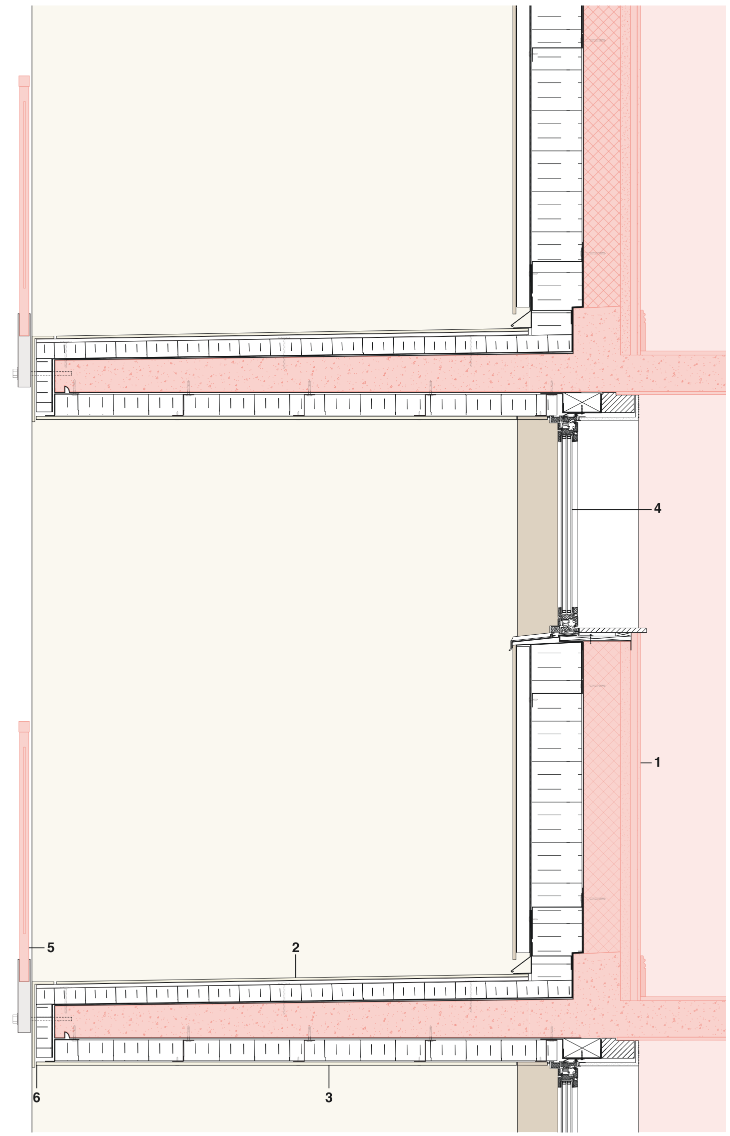
The example assembly was influenced by the Tower Renewal Guidelines as well as the EuroPHit EnerPHit handbook. It consists of a panel system overcladding with a pressure-moderated drainscreen approach for moisture management. This was chosen over an exterior insulation and finish system (EIFS; a face seal system) for its ability to accommodate a wider range of finishes, ease of disassembly for future replacement, and superior ability to be repaired in an aesthetically acceptable way.

The overcladding design tested in PHPP was a wall assembly with a U-value of 0.116 and this value was also used for the development of the example assembly. The wall section focused on in the design example is the overcladding of the balconies; the original assembly had a U-value of 0.38, though because the model did not take into account all thermal bridging, it is likely that heat loss is higher. In contrast, the new assembly has a U-value of 0.112 and thermal bridges are eliminated in this design.

The air barrier is located directly against the existing exterior wall surface, and this would be achieved using a spray on air barrier due to the potential difficulty of applying a textile membrane to the deep relief of the fluted concrete block. It is possible that the fluted concrete blocks require filing in order to apply the barrier, and this would add to demolition costs. It is assumed the entire assembly should be vapour permeable due the existing foil-backed gypsum and urethane foam on the interior.

The cladding chosen for the facade is a cement fibre board with fluting; smooth cement fibre board is used for the contrasting balcony facades. According to the marketing, these panels are resistant to fire, frost, impact, and extreme temperatures, they have a lifespan in excess of 50 years and are low maintenance. These characteristics alone make them a worthy choice, but the textured boards are particularly worthwhile as a cladding for this project since they provide interesting relief on the large blank expanses of the facade. This would seem to be the original intention for the fluted concrete block (see figures 90 and 91).

In this example, window overhangs are provided wherever sun shading is necessary instead of exterior blinds. This is because overhangs are a more reliable form of sunshading: they are non-mechanical so it's unlikely they will break or need to be replaced. The original railings, with some modifications to their height and positioning, are reused as well (see figures 92 and 93).



1. Exterior Wall Assembly
Existing wall assembly
Spray on air barrier (vapour permeable)
Mineral wool insulation (between metal z-girts)
Water resistant vapour-permeable barrier (drainage plane)
Vertical metal hat channels with gasket
Fibre cement panel cladding

2. Balcony Floor Assembly
Exterior grade tile and grout
Drainage membrane set in mortar
Tile backer board (mechanically fastened)
Insulation board
Moisture barrier membrane
Existing concrete slab

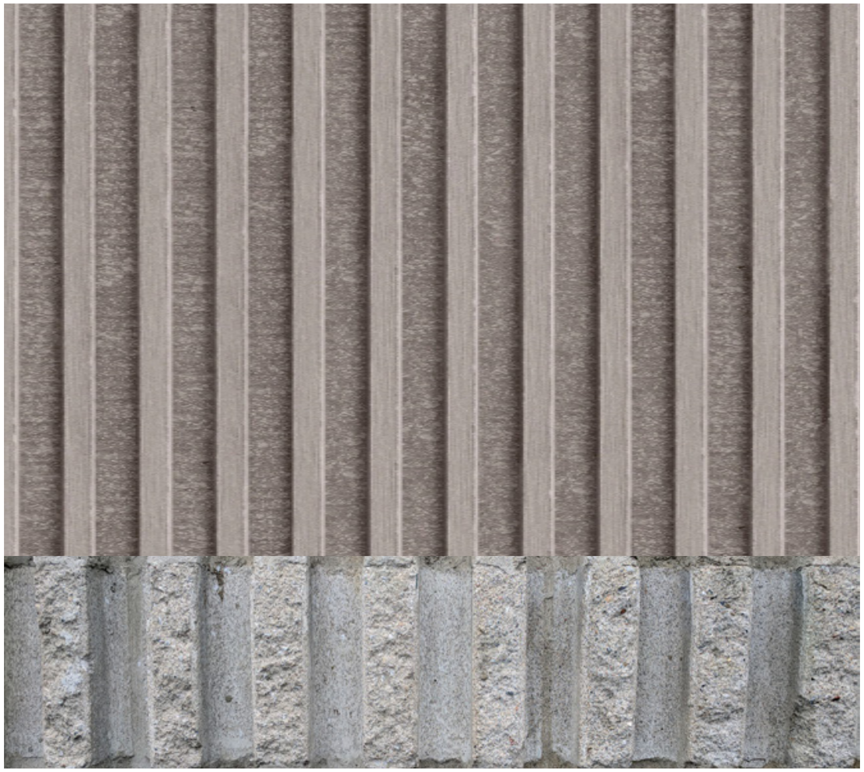
3. Balcony Soffit Assembly
Fibre cement panel cladding
Mineral insulation between metal z-girts
Spray on air barrier (vapour permeable)

4. Triple glazing (glass and frame PHI-certified)
5. Existing Balcony guard with exterior connection and extension
6. Gap for drainage

All fasteners as per structural engineer/manufacturer specifications.

1:10 Section Detail at Balcony Overcladding

Adapted from Tower Renewal Guidelines.



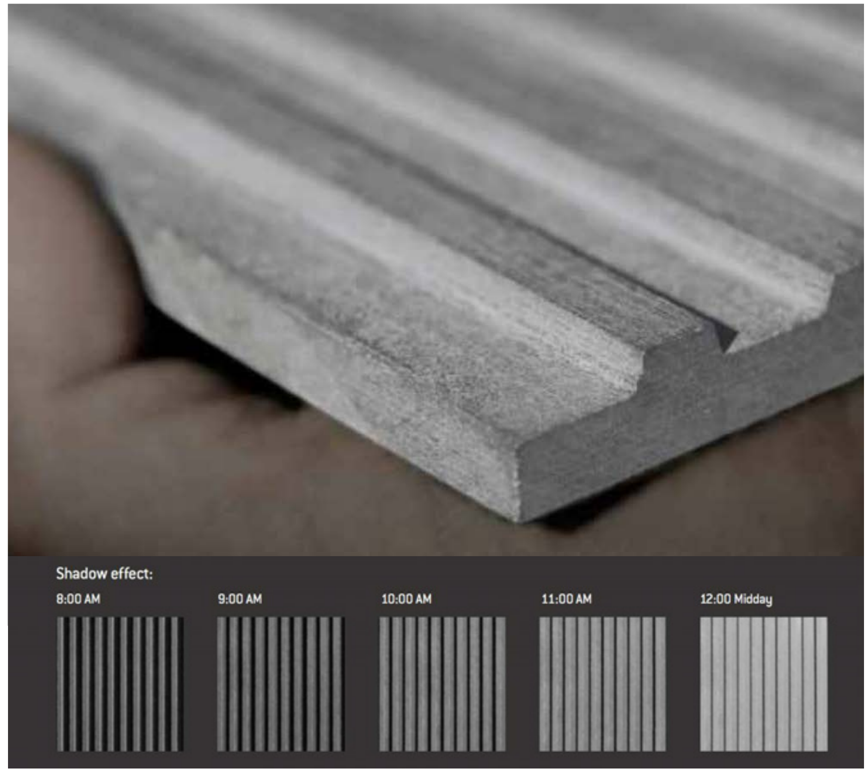


Figure 90 & 91: comparison of original concrete block with fibre cement panel; texture and shadow effects of fibre cement panel. Source: Equitone.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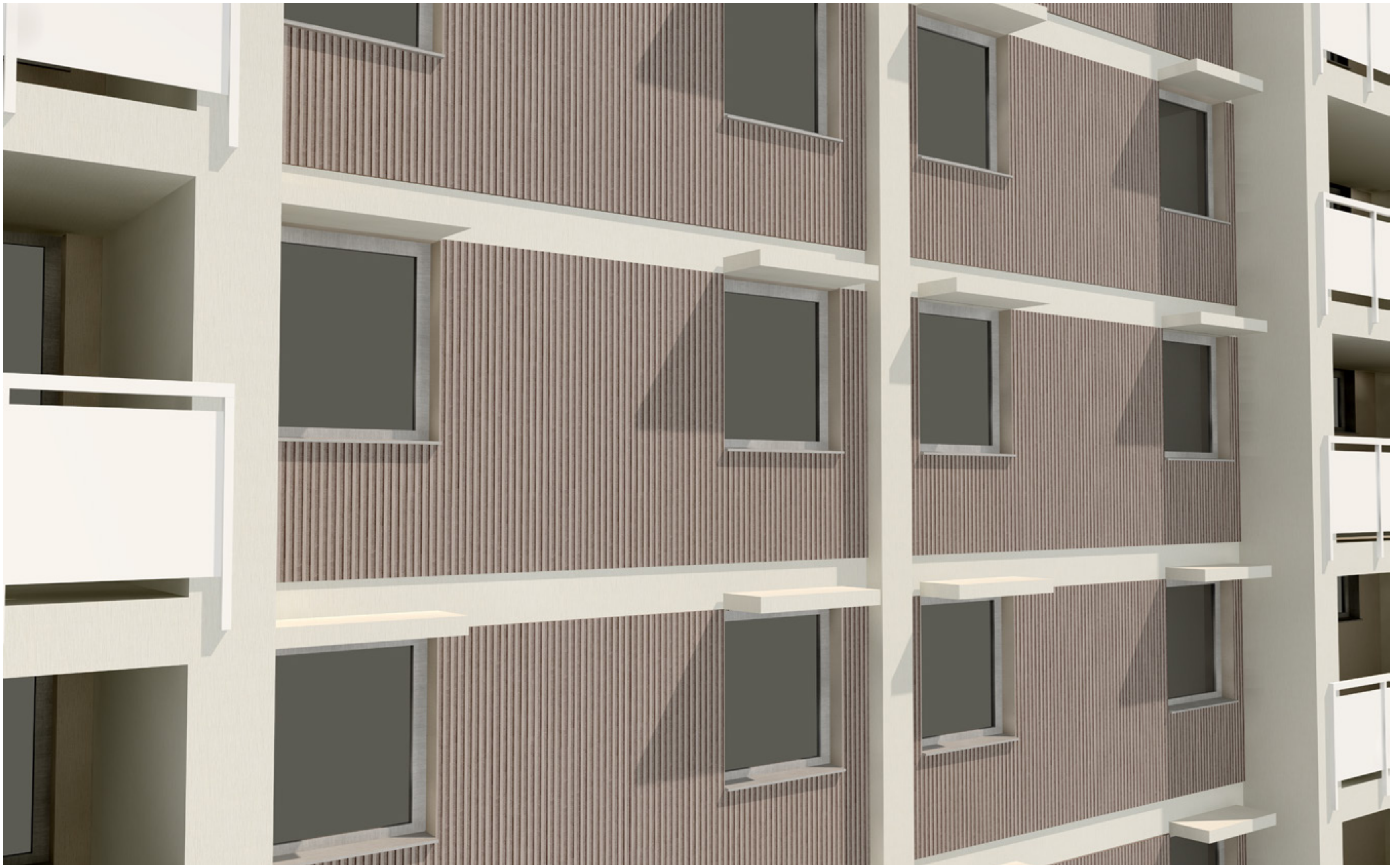

Figure 92 (on previous page): example overcladding design with new exterior garbage enclosure and safe park.
Figure 93: external solar shading.

10 Glossary

Affordable housing: in Canada, if shelter costs account for less than 30 percent of before-tax household income

Air layer coefficient: also known as air film thermal resistance, this coefficient measures the additional insulation provided to surfaces

Carbon performance: a metric that measures a building's carbon emissions per unit built area

designPH: a Passivhaus plugin for SketchUp

DOCOMOMO: International committee for documentation and conservation of buildings, sites and neighbourhoods of the modern movement

Energy performance: also known as Energy Use Intensity (EUI), the total amount of energy a building requires; the energy consumed divided by the built area

EnerPHit: the Passivhaus standard that caters to retrofit projects

Exterior absorptivity: in PHPP, a coefficient which measures how much solar radiation a surface will absorb

Exterior emissivity: in PHPP, a coefficient which measures heat radiation of a surface to the environment or sky

Form factor: the ratio of external surface area to internal treated floor area

Greenhouse gas (GHG): an atmospheric gas that absorbs and emits thermal energy; the increase of which is the cause of the greenhouse effect, an effect that increases the surface temperature of the Earth and detrimentally affects its ecosystems.

OCH: Ottawa Community Housing Corporation, the largest social housing provider in Ottawa, and the second largest in Ontario

Passivhaus: the German translation of passive house

Passive house: a building approach that uses superinsulation, heat recovery, passive solar gain, and electrical efficiency to minimize energy use and maximize comfort

PHPP: Passive House Planning Package, a software that provides an accurate steady-state building energy analysis and allows designers to iterate for the appropriate combination of interventions to achieve the Passivhaus criteria efficiently and cost effectively

SCAR: the “Shelter Consumption Affordability Ratio”, a measure of affordability that divides shelter consumption costs by discretionary income

Shading factor: in PHPP, a factor applied to glazed surfaces to account for various types of shading

Social housing: see Subsidized Housing

Solar heat gain coefficient (SHGC): also know as g-value, it is the fraction of incident solar radiation admitted through a window or door

Specific capacity: in PHPP, a measure for storage of heat in building components

Specific space heating demand: kilowatt hours per square metre per annum needed to provide space heating or cooling between 20-25 degrees Celsius

Subsidized housing: housing where the rent is geared to income and is calculated to be 30 percent of total household income

Total carbon footprint: the total amount of greenhouse gas emissions of a specific activity, population, or system

Treated floor area (TFA): the living space, or useful area

U-Wert: an online composite assembly U-value calculator

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