INFO SHEET GRAPHIC

TURKSTRA CHAIR IN URBAN ENGINEERING

UNIVERSITY OF WATERLOO
FACULTY OF ENGINEERING
Department of Civil & Environmental Engineering

STATUS ON SUSTAINABILITY | BUILDING ADAPTATION

Adaptation of the existing buildings aims to improve its conditions to extend its useful life (Shahi, Esnaashary Esfahani, Bachmann, & Haas, 2020). Building adaptation has the potential to provide significant environmental advantages, making it a more sustainable option than demolition or new construction (Conejos, Langston, & Smith, 2011; Noorzalifah & Kartina, 2016). Some of the environmental benefits include reducing waste material and carbon emissions, preserving natural resources, improving energy efficiency, as well as preserving embodied carbon (Yung & Chan, 2012). The research by Shahi et al. (2020) proposes a definition framework to address the several terminologies used to describe the scope of building adaptation (Figure 1).

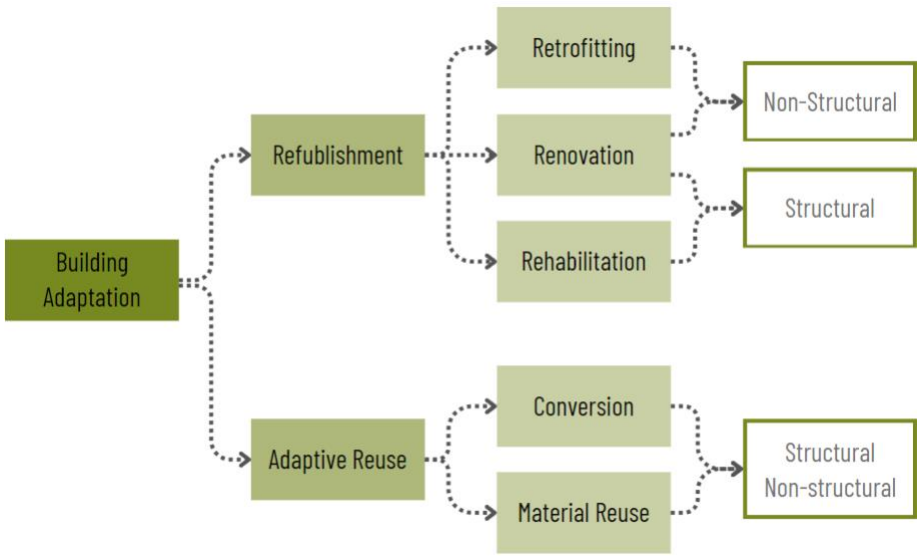

Figure 1. Building Adaptation Categorization (Shahi, Esnaashary Esfahani, Bachmann, & Haas, 2020)

Building refurbishment is the process of enhancing a building's current conditions and making modifications for its current use (Hassan, Ali, Chua, & Baharum, 2017). The sub-categories include retrofitting: improving energy efficiency and performance, renovation: repairing outdated components or remodeling the interior, and rehabilitation: structural improvements that make buildings livable and safe (Shahi, Esnaashary Esfahani, Bachmann, & Haas, 2020). Adaptive reuse includes the terms conversion, modifying existing buildings for a different use, and material reuse, the use of salvaged material for a new purpose (Shahi, Esnaashary Esfahani, Bachmann, & Haas, 2020).

TRENDS IN BUILDINGS ADAPTATION

GLOBAL TRENDS

- The global buildings stock - a measure to quantify the total area of buildings within a defined spatial unit - was 223.4 billion square meters in 2015. This number is expected to increase to 5.5 billion square meters per year to reach almost 415 billion square meters in 2050 (GABC, 2016).
- In 2018, the existing buildings and construction sector accounted for 36% of global energy usage and 39% of global CO_2 emissions (IEA, 2019).
- By 2030, the existing buildings in some countries are projected to represent up to 80% of the global building stock (IEA, 2020).
- Most existing buildings that require high energy demands were built before effective building codes were implemented, and the current energy retrofit rate is less than 1% (IEA, 2020).
- In the USA, new construction replaces around 93 million square meters that are demolished (National Trust for Historic Preservation, 2011).

TRENDS IN CANADA

- There are 9-10 million buildings in Canada. Its building stock is estimated to be 2 000 million square meters of residential and 750 million square meters of commercial and institutional building floor area (Efficiency Canada, 2021).
- Canada has ~2.9 billion square meters of inefficient construction (Natural Resources Canada, 2023a) which contributes to 17% of the GHG emissions (ECCC, 2016).
- Regarding commercial and institutional buildings in 2019, the total energy consumed was 948.2 million gigajoules (GJ) in a total of 709 million square meters of floor area with an energy use intensity (EUI) of 1.33 GJ/m^2. This is close to the average country's EUI of 1.31 GJ/m^2(Statistics Canada, 2022).
- In Canada, the retrofit rate remains at 0.7% for residential buildings and 1.4% for commercial buildings (Efficiency Canada, 2021).
- The construction and building operation sectors are the source of nearly half the GHG emissions (National Trust for Canada, 2020).
- The construction and demolition activities in Canada account for 35% of the landfill waste (National Trust for Canada, 2020).
- There is a large opportunity to reuse and retrofit a large portion of buildings in Canada (National Trust for Canada, 2020):
  - 33% (159 707) of commercial/industrial buildings were built before 1970.
  - 19% (2 581 000) of residential buildings are pre-1960.
  - 25 000 faith buildings.
  - 23 035 heritage buildings.
  - 30 000 buildings in regulated historic areas.
  - ~300 000 potential heritage properties.

TRENDS IN ONTARIO, CA

- In Ontario, the distribution in building construction time of commercial floorspace is 23% are pre-1960, 31% are 1960-1980, 30% are 1980-2000, and 16% are post-2000 (CAGBC, 2022).
- The Home Efficient Rebate Plus program delivered by the Natural Resources and Enbridge Gas in Ontario provides grants from $125 CAD to $5000 CAD to cover the partial cost of eligible home retrofits (Natural Resources Canada, 2023b).
- The Property Assessed Clean Energy (PACE) program of Ontario includes the Home Energy Loan Program (HELP) and the High-Rise Retrofit Improvement Support Program (HI-RIS) to finance energy efficient and resilient enhancements with interested rates between 2.05% to 5.26% at 5 to 20 years payment terms (AMO, 2021).

TRENDS IN WATERLOO, ON

- The development of the Waterloo Region Green Development Standards (GDS) aims to provide an integrated approach to reduce GHG emissions including future work to ensure that all renovation projects meet Passivhaus standards (GDS WR, 2023).
- In the Waterloo Region, the Home Reno Rebate program allowed homeowners to complete energy efficiency upgrades to 10 366 homes which reduced 58 533 tonnes of GHG emissions between 2017 and 2020 (Climate Action WR, 2023).
- Building demolition generated 2.572 Mt of material waste in total between the cities of Kitchener and Waterloo from 2003 to 2018 (Mollaei, Ibrahim, & Habib, 2021).

UNIVERSITY OF WATERLOO RESEARCH

- Climate Resilient and Intelligent Buildings (CRIB) - Intelligent and low carbon building and community design, construction, and operations.
- Heritage Resources Centre - Education related to heritage themes and work with all levels of government on heritage initiatives.
- Professor John Straube - Building science, building materials, and engineering design with a focus on high-performance low-energy sustainable buildings, and others.
- Professor Carl Haas – Circular economy and the built environment; fundamental methods and processes that influence and improve practices in construction.

SUSTAINABILITY DIMENSIONS

ENVIRONMENTAL IMPACT

- The global potential for the construction sector is 84 gigatons of CO_2 ($GtCO_2$) through measures in buildings (GABC, 2016) which could diminish the 50% expected increase in energy demand from the building sector by 2050 (IEA, 2016).
- The U.S. National Trust for Historic Preservation conducted a study that found that building reuse can present environmental savings from 4% to 46% over new buildings with the same energy performance level (National Trust for Historic Preservation, 2011).
- A new building with 30% more efficiency than the average performing existing building can take from 10 to 80 years to overcome the negative environmental impact associated with its construction (National Trust for Historic Preservation, 2011).
- The production of building materials produces ~3.6 $GtCO_2$ in global emissions. By 2050, it is estimated that over 80% of greenhouse gas emissions from the production of building materials can be reduced if implementing material efficiency strategies, including the use of recycled material (UNEP, 2022).

ECONOMIC IMPACT

- The federal government's plan to grow the low carbon economy includes investing $3.6 billion CAD to finance energy efficiency and low carbon upgrades to large existing buildings (CAGBC, 2022).
- The Canada Green Building Council reports that the green building industry in Canada generates around $47.9 billion in GDP and directly employs 462 000 full-time workers (CAGBC, 2022).
- Over the last two decades, the Green Municipal Fund (GMF) has provided $15.1 million in funds and $55.7 million in loans to implement energy efficiency and renewable energy projects in existing buildings (ECCC, 2020).
- According to the Climate Forward Scenario of the Canada Green Building Council's Market Impact and Opportunities Report, meeting Canada's 2030 GHG emissions reduction target (50 Mt CO2e) has the potential to generate $150 billion CAD in GDP, 1.47 million jobs, and long-term community resilience (CAGBC, 2020).
- The government's economic measures for existing building adaptation include (ECCC, 2020):
  - Investing $247 million CAD to assist 21 energy retrofit programs (Low Carbon Economic Fund).
  - Providing $1.01 billion CAD to increase energy efficiency in buildings through the Green Municipal Fund.
  - Devoting $2 billion CAD to the Canada Infrastructure Bank to support large-scale building retrofits.
  - Financing 12 RD&D programs that include deep energy retrofit projects.

SOCIAL IMPACT

- The benefits of thermal comfort from building retrofits have the potential to lower interior temperatures and lessen the negative health effects of excessive heat (CHASE, 2021).
- The Canadian Association of Physicians for the Environment states that building adaptations that enhance interior comfort and quality can enhance mental, respiratory, and general health, especially in those with pre-existing respiratory disorders (CAPE, 2019).

- There is the potential to create 3 million jobs and save $12.5 billion (CAD) in residential energy costs by implementing an investment of $21 billion (CAD) until 2030 (Torrie, Bak, & Heaps, 2020).

RELEVANCE TO UNITED NATIONS SUSTAINABLE DEVELOPMENT GOAL (UN SDG)

(United Nations, 2023)

9 INDUSTRY, INNOVATION, AND INFRASTRUCTURE

9.4: Upgrade the retrofit industries to reach sustainable goals.

11 SUSTAINABLE CITIES AND COMMUNITIES

11.4: Protect the world's cultural heritage (existing buildings).

11.b: Increase the number of cities that implement integrated policies and plans towards adaptation to climate change, resilience to disasters, and holistic disaster risk management.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

12.5: Reduce waste generation through material reuse.

13 CLIMATE ACTION

13.2 Integrating climate change into policies, strategies, and planning for building adaptation to reduce GHG emissions.

17 PARTNERSHIPS WITH THE GOALS

17.16: Enhance multi-stakeholder partnerships to include the construction industry to support the Sustainable Development Goals.

TOWARDS SUSTAINABILITY

INNOVATIONS IN PRACTICE

Technology Types:

- Building retrofitting technologies can be categorized into supply side management, demand side management, and change of energy consumption patterns (Ma, Cooper, Daly, & Ledo, 2012).

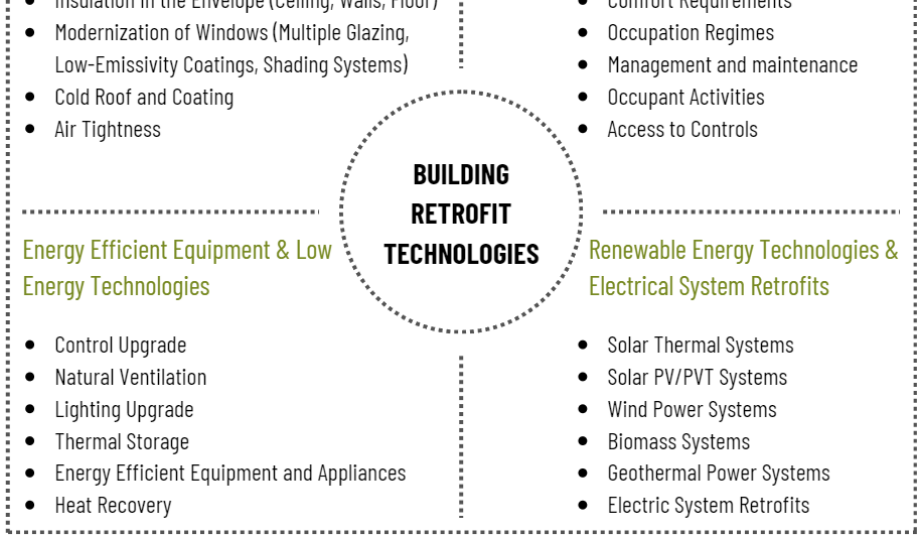

Figure 2. Building Retrofit Technologies Categories (Ma, Cooper, Daly, & Ledo, 2012)

Various Innovations in Practice:

- Digital Technologies: 3D scanning and Building information modelling (BIM) systems could allow to assess diverse retrofit solutions and monitoring of energy usage for future adaptations (Efficiency Canada, 2021).
- Prefabrication: Off-site manufacturing of building envelopes and HVAC systems (e.g., CanmetENERGY) to improve quality and reduce time, waste, and cost during construction (Efficiency Canada, 2021).
- Off-the-shelf Solutions: over-cladding envelope developments provide easiness in construction at lower costs than other enclosure enhancement alternatives (CUG+R, 2020).

POLICY AND REGULATIONS

- According to the United Nations Environment Program, the industry has increasingly adopted a life cycle analysis that focuses on "avoid", "shift", and "improve" as strategies for "adaptability" and involves all stakeholders to take responsibility for the environmental impact of materials over its life cycle (UNEP, 2022).

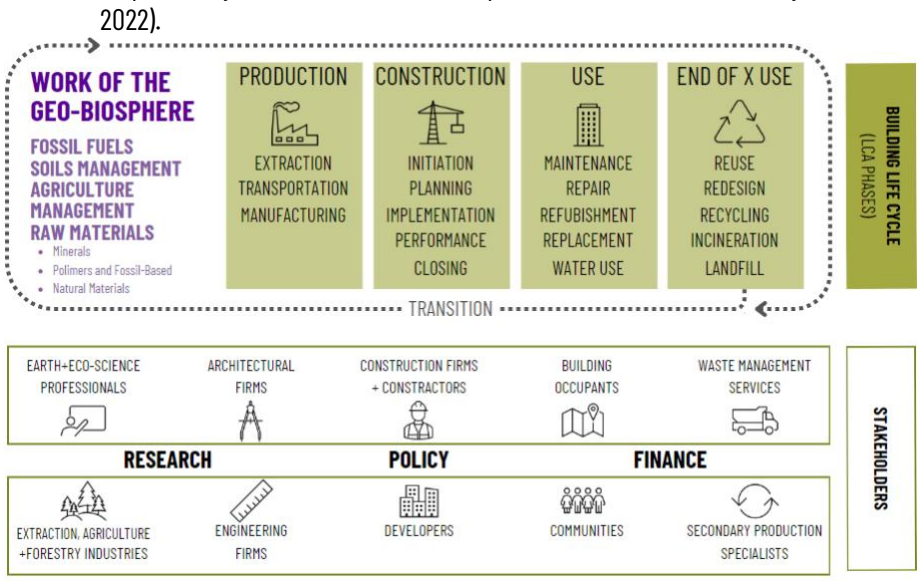

Figure 3. Building Life Cycle & Stakeholders (UNEP, 2022)

- The Energy Technology Perspectives 2016 report from the International Energy Agency recommends policy areas to meet short-term and long-term objectives for existing buildings.

Table 1. IEA Recommendations on Global Building Technology Policy (IEA, 2016)

Policy Area	Near Term (Present – 2025)	Long Term (2025 – 2050)
Building System	Deep energy strategies to renovate existing structures.	Create codes with low-energy targets for existing structures.
Building Envelope	Mandatory energy codes for high performance envelopes.	Minimum performance for building envelope through energy-efficient codes.
Heating and Cooling	Performance of 350% for cooling and 120% for heating equipment. Heat-pump and sun thermal technology.	Performance of 400% for cooling and 150% for heating equipment. Net zero heating and cooling technology, and solar cooling techniques.
Water Heating	Use of instantaneous systems or heat-pump water heaters. R&D on solar thermal systems.	Electrical equipment with 150% efficiency. Solar thermal systems that can handle ≥75% annual water heating load.
Lighting	Forbid all halogen and conventional incandescent lights. R&D of solid-state lighting (SSL), and other cutting-edge designs	Energy performance standards for lights over 100 lumens per watt

FUTURE PROJECTIONS

- A scenario from the report Canada's Climate Canada Retrofit Mission estimates that up to 21.2 million tonnes of CO_2 (51%) could be reduced by implementing large building retrofits (Efficiency Canada, 2021).
- In Canada, at the current retrofitting rates (0.7% for residential buildings and 1.4% for commercial buildings), it will take 142 years and 71 years to retrofit all low-rise residential buildings and commercial buildings respectively (Efficiency Canada, 2021).
- According to a 2022 forecast, Canada would require 3.5 million more housing units by 2030 to restore affordability, emphasizing the need to reduce the housing supply gaps in Ontario and British Columbia (CMHC, 2023), in which building adaptability can play a role.

ACKNOWLEDGEMENTS

The project is funded in part by the Sustainability Action Fund (SAF) at the University of Waterloo. The project proposal "Status on Sustainability Infosheets and Infographics" was awarded funding by the University of Waterloo Sustainability Office in 2023 and selected by the President's Advisory Committee on Environmental Sustainability (PACES).

REFERENCES

Association of Municipalities Ontario, AMO. (2021). *Retrofitting Building for GHG Reduction and Deeper Energy Savings.* Retrieved from https://www.amo.on.ca/sites/default/files/assets/DOCUMEzNTS/Reports/2021/RetrofittingBuildingsforGHGReductionDeeperEnergySavings20210430.pdf

Canadian Green Building Council, CAGBC. (2020). *Canada's Green Building Engine: Market Impact and Opportunities in a Critical Decade.* Retrieved from https://delphi.ca/wp-content/uploads/2021/01/canadas-green-building-engine.pdf

Canadian Green Building Council, CAGBC. (2022). *Green Retrofit Economy Study.* Ottawa: The Delphi Group. Retrieved from https://www.cagbc.org/wp-content/uploads/2022/06/Green-Retrofit-Economy-Study.pdf

Canadian Association of Physicians for the Environment, CAPE. (2019). *Climate Change Toolkit for Health Professionals: Module 5 – Climate Change Solutions with Immediate Health Benefits.* Retrieved from https://cape.ca/wp-content/uploads/2019/04/Module-5-Ready-to-upload-SOLO-UDATED.pdf?fbclid=IwAR3nJ7XLcDP1ZWODaicAyGnjLKi2sWYqM-Lk-kp3gdT4pU6s_6bnsFjw__4

Canadian Health Association for Sustainability & Equity, CHASE. (2021). *Building Retrofits: Good for People and the Planet.* Retrieved from Canadian Health Association for Sustainability and Equity: https://chasecanada.org/2021/12/20/building-retrofits-good-for-people-and-the-planet/

Climate Action WR. (2023). *Our Progress, Our Path 202: Community Greenhouse Gas Re-Inventory.* Retrieved from https://climateactionwr.ca/wp-content/uploads/2023/04/Our-Progress-Our-Path-2020-Community-Greenhouse-Gas-Re-inventory.pdf

Canada Mortgage and Housing Corporations, CMHC. (2023). *Housing shortages in Canada: Updating how much housing we need by 2030.* Canada Mortgage and Housing Corporation. Retrieved from https://assets.cmhc-schl.gc.ca/sites/cmhc/professional/housing-markets-data-and-research/housing-research/research-reports/2023/housing-shortages-canada-updating-how-much-we-need-by-2030-en.pdf?rev=3b66f87d-0bec-44d6-aa54-f8af71f9b2c4&_gl=1*1c6fqyd*_ga*MT

Conejos, S., Langston, C. A., & Smith, J. (2011). Improving the implementation of adaptive reuse strategies for historic buildings. *International Forum of Studies titled S.A.V.E. Heritage* (pp. 1-10). Aversa, Capri, Italy: Institute of Sustainable Development and Architecture. doi:http://www.leviedeimercanti.it/httpdocs/2011/index.html

Centre for Urban Growth and Renewal, CUG+R. (2020). *Advancing Building Retrofits.* Retrieved from https://eppdscrmssa01.blob.core.windows.net/cmhcprodcontainer/sf/project/archive/publications/nhs/research_and_planning_fund_program/cugr_advancing-building-retrofits_jan-21.pdf

Environment and Climate Change Canada, ECCC. (2016). *"Pan-Canadian Framework on Clean Growth and Climate Change: Canada's Plan to Address Climate Change and Grow the Economy.* Retrieved from https://www.canada.ca/content/dam/themes/environment/documents/weather1/20161209-1-en.pdf

Environmental and Climate Change Canada, ECCC. (2020). *A Healthy Environment and a Healthy Economy.* Retrieved from Government of Canada: https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy.html

Efficiency Canada. (2021). *Canada's Climate Retrofit Mission.* Retrieved from https://www.efficiencycanada.org/wp-content/uploads/2021/06/Retrofit-Mission-FINAL-2021-06-16.pdf

Global Alliance for Buildings and Construction, GABC. (2016). *GLOBAL STATUS REPORT 2016: Towards zero-emission, efficient, and resilient buildings.* Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/10618/GABC-Report_Updated.pdf?sequence=1&amp%3BisAllowed=

GDS WR. (2023, October 25). *GreenWR.* Retrieved from https://greenwr.org/

Hassan, Z. F., Ali, A. S., Chua, S. L., & Baharum, M. R. (2017). Building pathology, maintenance and refurbishment. In *Building Design, Construction and Performance in Tropical Climates* (pp. 188-217). Routledge.

International Energy Agency, IEA. (2016). *Energy Technology Perspectives 2016: Towards Sustainable Urban Energy Systems.* Paris, France. Retrieved from https://iea.blob.core.windows.net/assets/37fe1db9-5943-4288-82bf-13a0a0d74568/Energy_Technology_Perspectives_2016.pdf

International Energy Agency, IEA. (2019). *Global Status Report for Buildings and Construction 2019.* Retrieved from https://iea.blob.core.windows.net/assets/3da9daf9-ef75-4a37-b3da-a09224e299dc/2019_Global_Status_Report_for_Buildings_and_Construction.pdf

International Energy Agency, IEA. (2020). *Sustainable Recovery Plan.* Retrieved from https://iea.blob.core.windows.net/assets/c3de5e13-26e8-4e52-8a67-b97aba17f0a2/Sustainable_Recovery.pdf

Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings, 55*, 889-902. doi:https://doi-org.proxy.lib.uwaterloo.ca/10.1016/j.enbuild.2012.08.018

Mollaei, A., Ibrahim, N., & Habib, K. (2021). Estimating the construction material stocks in two Canadian cities: A case study of Kitchener and Waterloo. *Journal of Cleaner Production, 280*. Retrieved from https://doi.org/10.1016/j.jclepro.2020.124501

National Trust for Canada. (2020). *Making Reuse the New Normal – Accelerating the Reuse and Retrofit of Canada's Built Environment.* Retrieved from https://regenerationworks.ca/wp-content/uploads/2020/12/E_Making-Reuse-the-New-Normal-Report-FINALV2.pdf

National Trust for Historic Preservation. (2011). *The Greenest Building: Quantifying the Environmental Value of Building Reuse.* Retrieved from https://living-future.org/wp-content/uploads/2022/05/The_Greenest_Building.pdf

Natural Resources Canada. (2023a). "Residential Housing Stock and Floor Space. Retrieved from https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB&sector=com&juris=00&rn=7&page=0#sources

Natural Resources Canada. (2023b). *Canadas Greener Homes Grant.* Retrieved from Government of Canada: https://natural-resources.canada.ca/energy-efficiency/homes/canada-greener-homes-initiative/canada-greener-homes-grant/greener-homes-grant-ontario/24835

Noorzalifah, M., & Kartina, A. (2016). The Criteria For Decision Making In Adaptive Reuse Towards Sustainable Development. *MATEC Web of Conferences, 6*, 92. doi:10.1051/matecconf/20166600092

Shahi, S., Esnaashary Esfahani, M., Bachmann, C., & Haas, C. (2020). A definition framework for building adaptation projects. *Sustainable Cities and Society, 63*. doi:10.1016/j.scs.2020.102345

Statistics Canada. (2022, August 5). *Survey of Commercial and Institutional Energy Use: Commercial and institutional buildings 2019.* Retrieved from https://www150.statcan.gc.ca/n1/en/daily-quotidien/220805/dq220805c-eng.pdf?st=qbh8tLBk

Torrie, R., Bak, C., & Heaps, T. (2020, June 29). *Report: Building Back Better with a Bold Green Recovery.* Retrieved from Corporate Knights: https://www.corporateknights.com/wp-content/uploads/2021/02/2020-09-14-Building-Back-Better-with-a-Bold-Green-Recovery_FINAL_enfr.pdf

United Nations Environment Programme, UNEP. (2022). *2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.* Nairoby. Retrieved from https://globalabc.org/sites/default/files/2022-11/FULL%20REPORT_2022%20Buildings-GSR_1.pdf

United Nations. (2023). *Sustainable Development - The 17 Goals.* Retrieved from https://sdgs.un.org/goals

Yung, E. H., & Chan, E. H. (2012). Implementation challenges to the adaptive reuse of heritage buildings: Towards the goals of sustainable, low carbon cities. *Habitat International, 36*(3), 352-361. doi:10.1016/j.habitatint.2011.11.001

AUTHORS Javier Fierro

GRAPHIC DESIGNER Javier Fierro

CONTRIBUTORS Tyler Hull

PEER REVIEWERS Brandon Schupp, Dr. Carl Haas

PROJECT OWNERS Dr. Nadine Ibrahim, Dr. Dwarak Ravikumar