ESC204 | Praxis III

Request for Proposals

Improving Sustainability and Energy Management in Buildings on the African Continent

This Request for Proposals (RFP) provides guidance towards the design and preliminary implementation of an engineering system to address challenges in sustainability and energy management in buildings on the African continent.

In the following sections, we provide additional information to support the Context, outline the desired Approaches teams should take to address the stated Value Proposition, and provide a preliminary set of Engineering Requirements for each approach, which any Design Concepts developed in response to this RFP must address.

Contents

1 Context: Sustainability Challenges and Opportunities for Buildings in Africa

This section provides key background and contextual information regarding sustainability challenges for buildings on the African Continent, organized into the following sections:

1.1: Energy Challenges of Building Operations
1.2: Energy Demand Dynamics in Africa
1.3: Potential and Challenges for Local Renewable Energy Generation
1.4: Alignment with United Nations Sustainable Development Goals

Finally, key stakeholders within the context are discussed, and the section concludes with a statement of the Value Propositions all Design Concepts must aim to fulfill.

1.1 Energy Challenges of Building Operations

Buildings provide shelter, support personal activities for individuals and families, and provide space for conducting various social and economic activities. They also represent a big challenge for sustainability due to the high energy demand from their operation, which includes lighting, heating, ventilation and air-conditioning (HVAC), water heating, and appliances. Of these, HVAC and water heating represent significant demand and have been identified as areas where more efforts are needed to improve sustainable energy use in building operations [1][2].

According to the International Energy Agency's (IEA) Tracking Clean Energy Progress Report 2023, in 2022, the operations of buildings accounted for 30% of global final energy consumption. Building operations also accounted for 26% of global energy-related emissions from energy combustion and industrial processes, with 8% coming from direct emissions in buildings and 18% coming from indirect emissions from the production of electricity and heat used in buildings [2].

These sustainability challenges must be addressed both for existing buildings, through retrofits, and for new buildings, during the design phase, while ensuring that buildings serve the goals of those who use them. To aid in these efforts, there is a need to understand how building operations (and user activities) affect energy demand [3][4], and to explore various ways to meet user needs at lower energy demand or through sustainable energy sources.

1.2 Energy Demand Dynamics in Africa

The African continent has a population of just over 1.4 billion [5][1]. About 56% of this population lives in informal housing. This population is expected to reach 2.4 billion in 2050 with 80% of this growth anticipated to occur in cities [6]. This growth comes with the need for new buildings both residential and commercial to provide safe housing and to support life activities.

The expected growth in Africa's population presents challenges as well as opportunities. Much of the current housing has low resilience to climate change; however, because a large amount of construction is yet to happen, there is an opportunity to design new buildings and retrofit existing ones to be more sustainable and resilient to climate change [7]. Though much of the growth in population is expected to occur in cities and urban settings, it is important to consider the case

[1] The reference provides only indivdual country numbers so the total was computed from these numbers.

of rural settings since these areas are often important for key economic activities such agriculture [8].

1.3 Potential and Challenges for Local Renewable Energy Generation

PricewaterhouseCoopers South Africa's 2021 Africa Energy Review report leverages data from the World Bank to show that, on average, about 42% of the African population live without electricity access. This is not evenly distributed as North Africa has some of the highest access (98% electrified) and Central Africa has the lowest (30% electrified) [9]. Increasing energy access is important for getting the most value out of building operations.

According to the World Banks' Global Solar Atlas project [10], Africa has one the highest potentials for solar energy production. Much of this potential remains untapped as almost 75% of electricity generation comes from fossil fuel sources (coal, oil, and natural gas), with less than 1% coming from solar [11]. In addition, electricity only accounts for about 9.37% of the energy mix in terms of consumption with the use of biofuels and fossil fuels accounting for the rest of energy consumption (with biofuels at 54.41%, oil at 26.27%, natural gas at 7.38%, and coal at 2.57%) [12]. A focus on solar and other renewable energies has the potential to increase energy access in a sustainable way and reduce dependence on fossil fuels. Despite the high potential for solar energy, tapping this potential comes with its challenges. Local weather and dust conditions can affect output of panels [13], [14]. Terrain and local policies on land use can affect location of installations [15]. Ease of maintenance is critical as well [16].

1.4 Alignment with United Nations Sustainable Development Goals

Innovations focused on enabling activities in buildings that promote sustainability or addressing energy management in buildings on the African continent (and beyond) align with the following United Nations Sustainable Development Goals (UNSDGs):

- UNSDG #7 Affordable and Clean Energy [17]
- UNSDG #11 Sustainable Cities and Communities [18]
- UNSDG #13 Climate Action [19]

1.5 Stakeholders Summary

1.5.1 Building Occupants

For this design challenge, we will focus on residential buildings, office spaces, event and entertainment spaces, and other similar non-industrial buildings. In a residential setting, an individual or small group of people living together use various appliances that have different energy demands for various activities and to be comfortable in the space. In all settings occupants have to balance energy-saving behaviors with comfort and activities they want to engage in while using the building.

1.5.2 Building Operators

Non-residential spaces and communal residential spaces such apartment buildings often have building managers. These people make decisions about resources required to operate the building and how to provide a space that is most conducive to the goals of the use of the building. Building managers have to balance any building management decisions that lead to reduced energy demand (or increased local renewable energy generation) with the needs and preferences of building occupants.

1.5.3 Government and Policy makers

Policies play an important role in shaping the behavior of the various stakeholders as relates to energy dynamics of buildings. Development of policies and programs happens at multiple levels from local communities, to municipalities to regional and local governments. In addition, governments often collaborate with non-governmental organizations on policy development. The higher (more national) levels of government can constrain the policy options the lower (more local) levels have.

While an understanding of energy dynamics is important for policy makers, they also have to understand the lived experience and cultural and social norms of the communities that policies may affect to ensure better policy adoption. Furthermore, governments may have to contend with special interests and influence from those external to their communities (e.g., policy mandates that are attached to investments from foreign governments [20] or global organizations such as the International Monetary Fund (IMF) [21]). Often, especially at the local level, policy makers are themselves also members of the communities they serve.

1.5.4 Technology Developers

Technology developers support other stakeholders by providing a number of different solutions to meet various needs. They are guided by policy incentives that shape technology development and adoption, as well as early feasibility explorations of researchers or early concept ideas from design challenges. Data on the dynamics of energy use is especially important to technology developers as it allows to them to understand how new technologies can impact various stakeholders. Technology developers also need an understanding of building design and development to know what can be feasibly incorporated into new buildings or as retrofits to existing buildings. Our locations of interest tend to have more developing economies where goods need to have reasonable price points in order to be more widely accessible to various stakeholders. There may also be limitations on access to certain materials and resources for technology development.

1.5.5 Building Designers and Developers

Buidling designers and developers play a role in providing new buildings or renovating existing ones to meet the needs of building occupants and operators in ways that are aligned with policy. They also play a key role in incorporating new technologies that help with energy demand reduction or energy generation to give occupants and operators options for managing energy use.

1.6 Value Proposition

Buildings support essential activities which create energy demands. Enabling and/or empowering communities to lower these energy demands, or to offset energy use by leveraging local renewable generation will help with improving sustainability as it relates to building use.

2 Preferred Approaches: Mechatronics and IoT

This section outlines three preferred approaches which address the Value Proposition provided in Section 1.6:

2.1: Mechatronic Approach: Reduced Energy Use to Support Various Activities
2.2: Mechatronic Approach: Mitigating Environmental Effects on the Performance of Renewables
2.3: IoT Approach: Monitoring Factors That Affect Energy Demand

More details regarding these preferred approaches as well as a preliminary table of Engineering Requirements tailored to each approach are provided in the following sections.

2.1 Mechatronic Approach: Reduced Energy Use to Support Various Activities

Recommendations to tackle energy use for various activities in buildings include addressing lighting, heating and hot water, and cooling [2](see "Lighting", "Heating", and "Space Cooling" under "In this Sector"). To support building occupants in going about their activities while reducing energy use, we solicit designs that leverage natural processes (*e.g.*, natural light, heat sources, or heat sinks) and/or adapt to environmental conditions to ensure that energy from the grid is only used when necessary (*i.e.*, when other natural processes are not available) to provide these amenities that support occupants' activities.

2.1.1 Engineering Requirements

Any Design Concepts developed in response to this RFP should address the Value Proposition given in Section 1.6, and in particular should support building occupants in reducing energy (or leveraging renewable sources) use while going about their activities. Based on this approach (described in more detail in Section 2.1), the following Goals provide guidance towards designs which appropriately address the opportunity.

Designs which take the Reduced Energy Use to Support Various Activities approach to the opportunity should:

G–1 Leverage natural processes (e.g., light, heat sources, heat sinks) to provide amenities and/or to support regular activities of building occupants.
G–2 Reduce grid energy use for building operations.
G–3 Enable convenient and long-term operation to ensure opportunity for energy savings.

Based on these Goals, the Objectives provided in Tables 1-3 describe the key functions and performance elements necessary for any Design Concepts.

Table 1: Objectives for Designs which take the Reduced Energy Use to Support Various Activities Approach, Part 1.

	Objectives	Metrics
G-1: Leverage natural processes to support activities of building occupants.		
O–1.1	Provide for at least one occupant need (i.e., lighting, heating, cooling, hot water) leveraging a natural process.	Use of methods in the ENERGY STAR checklist linked to natural process (e.g. lighting, heat flow into and out of the building, etc.) [22]
O–1.2	Provide occupant needs to a sufficient level, i.e., keep heat index not more than 27C for cooling [23], keep temperature no less than 18C for heating [24], keep temperature no less than 60C for hot water [25] or provide at least 300 lux for lighting [26].	Metric associated with particular need, e.g. Heat Index (C) for cooling [23][27]; Temperature (C) for heating; Temperature (C) for hot water; Illuminance (lux) for lighting [26].

Table 2: Objectives for designs which take the Reduced Energy Use to Support Various Activities Approach, Part 2.

	Objectives	Metrics
G-2: Reduce grid energy use for building operations.		
O–2.1	Reduce grid energy consumption of the building, at worst maintaining grid energy use levels when there was no intervention.	Energy [kWh] consumed by building.

Table 3: Objectives for designs which take the Reduced Energy Use to Support Various Activities Approach, Part 3.

	Objectives	Metrics
G-3: Enable convenient and long-term operation to ensure opportunity for energy savings.		
O–3.1	Reduce maintenance within the operational context, with longer Mean Time to Repair (MTTR) preferred [28].	Consideration of characteristics of maintainability such as Mean Time To Repair (MTTR), Health Status Monitoring (HSM), etc. [28].
O–3.2	Operate quietly, generating not more than 40 dBA at the nearest listener during operation [29].	Sound Pressure level (dBA) observed by the nearest listener while the design is in operation.

2.2 Mechatronic Approach: Mitigating Environmental Effects on the Performance of Renewables

While Africa has high potential for solar energy production because of its geographic location, various factors make extensive deployment challenging. Local weather and dust conditions can affect effective output of panels [13], and many parts of Africa that have the highest solar production potential have high level of dust and other aerosols in the atmosphere that reduce sunlight contact with panels and hence, panel output[13] [14]. Terrain and local policies on land use can also affect location of installations [13][15]. Ease of maintenance is critical as well [16]. Therefore, we solicit designs which reduce the impact of environmental effects on either existing or newly installed solar power systems, to improve feasibility and promote adoption of these technologies[2].

2.2.1 Engineering Requirements

Any Design Concepts developed in response to this RFP should address the Value Proposition given in Section 1.6, and in particular should mitigate the effects of local environmental conditions on performance of solar panels. Based on this approach (described in more detail in Section 2.2), the following Goals provide guidance towards designs which appropriately address the opportunity.

Designs which take the Mitigating Environmental Effects on the Performance of Renewables approach to the opportunity should:

G–1 Remove dust particles from solar panels to increase solar panel performance, without compromising overall energy output.

G–2 Improve solar panel reliability without adding significant maintenance or other impacts to users (especially residential users).

Based on these Goals, the Objectives provided in Table 4-5 describe the key functions and performance elements necessary for any Design Concepts.

Table 4: Objectives for designs which take the Mitigating Environmental Effects on the Performance of Renewables Approach, Part 1.

	Objectives	Metrics
G-1: Increase solar panel performance, without compromising overall energy output.		
O–1.1	Remove dust particles that obstruct sunlight from a solar panel surface, achieving a dust density of at most 2 mg/cm.sq. after cleaning [14].	Dust density after cleaning [mg/cm2] [14].
O–1.2	Allow sunlight to contact as much of the solar panel's surface as possible, with a maximum reduction in sunlight coverage of 5% during operation.	Reduction in sunlight coverage area during operation [%].
O–1.3	Enhance the overall available solar energy for a user, at worst achieving the same energy output as making no intervention.	Mean available solar energy [J] produced per day.

[2]This approach was inspired by work done by previous teams in the course!

Table 5: Objectives for designs which take the Mitigating Environmental Effects on the Performance of Renewables Approach, Part 2.

	Objectives	Metrics
G-2: Improve solar panel reliability without adding significant maintenance.		
O–2.1	Minimize use of materials consumed (e.g., fuel, water, disposable parts, etc.) during operation, with no consumables preferred.	Consumption per square meter of surface from which dust is removed [kg/m2].
O–2.2	Reduce maintenance within the operational context, with longer Mean Time to Repair (MTTR) preferred [28].	Consideration of characteristics of maintainability such as Mean Time To Repair (MTTR), Health Status Monitoring (HSM), etc. [28].
O–2.3	Operate quietly, generating not more than 60 dBA at the nearest listener during operation [29].	Sound Pressure level (dBA) observed by the nearest listener while the design is in operation.

2.3 IoT Approach: Monitoring Factors That Affect Energy Demand

Any changes to buildings and their operations to achieve sustainability goals must ensure that buildings serve the purpose for those who use them. To aid in these efforts, there is a need to understand how building operations (and user activities) affect energy demand [3][4]. This information can be useful for helping operators plan energy management as part of building operations or to manage energy in real-time; for educating building users about behaviors and effects on energy use to to support behavior change; or to help policy makers enact policies that encourage improved energy demand from building use while adequately supporting users' activities [2] (See "Recommendations"). We solicit designs that provide information that help understand the relationships between environmental factors, building occupants needs and activities, and resulting energy demand.

2.3.1 Engineering Requirements

Any Design Concepts developed in response to this RFP should address the Value Proposition given in Section 1.6, and in particular empower building operators and/or users to make better operations decisions and policy that improves sustainable energy use through providing actionable data. Based on this approach (described in more detail in Section 2.3), the following Goals provide guidance towards designs which appropriately address the opportunity.

Designs which take the Monitoring Factors That Affect Energy Demand approach to the opportunity should:

G–1 Collect time-series data on energy use in buildings, alongside factors which affect energy use (i.e., building operations, environmental factors, etc.).

G–2 Support users in leveraging energy use data to improve sustainability of building operations.

G–3 Enable convenient and long-term operation.

Based on these Goals, the Objectives provided in Tables 6-8 describe the key functions and performance elements necessary for any Design Concepts.

Table 6: Objectives for designs which take the Monitoring Factors That Affect Energy Demand Approach, Part 1.

	Objectives	Metrics
G-1: Collect time-series data on energy use and factors which affect it.		
O–1.1	Collect data related to both energy use and at least one factor which affects it (e.g., occupancy, occupant behavior, environmental factors, etc.), with more relevant factors preferred.	Types of data collected [3][4].
O–1.2	Collect data at a sufficient rate to understand energy use trends, and not less frequently than hourly.	Sampling frequency [1/hours].

Table 7: Objectives for designs which take the Monitoring Factors That Affect Energy Demand Approach, Part 2.

	Objectives	Metrics
G-2: Support users in leveraging energy use data to improve sustainability.		
O–2.1	Communicate data to relevant users (building occupants, building operators, policy makers) with on-demand communications preferred.	Availability of data to the user [uptime for communication].
O–2.2	Store data for later retrieval and analysis for a minimum of 12 months [30].	Data history length [months].
O–2.3	Promote understanding of energy use and options to improve sustainability, with designs incorporating principles of Universal Design for Learning (UDL) preferred [31].	Consideration of principles of Universal Design for Learning (e.g. see [31]) to promote understanding.

Table 8: Objectives for designs which take the Monitoring Factors That Affect Energy Demand Approach, Part 3.

	Objectives	Metrics
G-3: Enable convenient and long-term operation.		
O–3.1	Reduce maintenance within the operational context, with longer Mean Time to Repair (MTTR) preferred [28].	Consideration of characteristics of maintainability such as Mean Time To Repair (MTTR), Health Status Monitoring (HSM), etc. [28].

3 Opportunity Champions

Mona Mohammed: Mona is a Programme Management Officer at the United Nations Environment Programme (UNEP) based in Paris, France. Through the Life Cycle Initiative, Mona works on increasing access to Life Cylce Analysis (LCA) data, life cycle knowledge, and harmonized methodology for public and private stakeholders, including within UNEP, to implement sustainable consumption and production (SCP) strategies. In her role, she works closely with the Building and Construction, and the Mining and Extractives high impact sectors. Mona's background is in Environmental Engineering and Women and Gender Studies. Before joining the UN, Mona worked as a water, sanitation, and hygiene (WASH) Advisor supporting the Humanitarian response in Yemen and Sudan. Mona provided the initial resources and input that were the basis of the first version of the RFP for this design space.

Amma Oforiwaa Ampomah Asiedu: Amma is an engineer in training in the IP network planning division of MTN Ghana, the Ghanaian subsidiary of the multinational telecommunication company MTN Group. Amma has a background in Electrical and Electronic Engineering and a keen interest in wireless communication and home automation, where she has explored entrepreneurial projects in smart home innovations that enable sustainable living solutions. Amma provided input into the development of the revised version of the RFP.

Nigel Derby: Nigel is the Founder of Capsule Africa, a dedicated contracting firm specializing in the design and construction of modern container homes in Ghana, blending creativity with sustainability. Committed to innovation, he is interested in integrating cutting-edge sustainable practices in buildings, including cladding with vertical garden systems, rainwater harvesting, and energy-efficient insulation, to reduce environmental impact without compromising comfort or quality. Nigel provided input into the development of the revised version of the RFP.

References

[1] UNEP, "2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector," United Nations Environment Programme, Nairobi, Tech. Rep., 2022. [Online]. Available: https://globalabc.org/resources/publications/2022-global-status-report-buildings-and-construction.

[2] International Energy Agency, *Energy System: Buildings*. [Online]. Available: https://www.iea.org/energy-system/buildings.

[3] A. G. Dagnachew, S.-M. Choi, and G. Falchetta, "Energy planning in Sub-Saharan African countries needs to explicitly consider productive uses of electricity," *Scientific Reports*, vol. 13, no. 1, p. 13 007, Aug. 2023, ISSN: 2045-2322. DOI: 10.1038/s41598-023-40021-y.

[4] V. Daioglou, B. J. van Ruijven, and D. P. van Vuuren, "Model projections for household energy use in developing countries," *Energy*, vol. 37, no. 1, pp. 601–615, Jan. 2012, ISSN: 03605442. DOI: 10.1016/j.energy.2011.10.044.

[5] Economic Commission for Africa, African Development Bank Group, and African Union Commission, "The African Statistical Yearbook 2021," Tech. Rep., 2022. [Online]. Available: https://www.afdb.org/en/documents/african-statistical-yearbook-2021.

[6] African Development Bank Group, "Tracking Africa's Progress in Figures," Statistics Department, African Development Bank Group, Tunis, Tech. Rep., 2014. [Online]. Available: https://www.afdb.org/en/knowledge/publications/tracking-africa%E2%80%99s-progress-in-figures.

[7] M. M. Gambo, *Enhancing climate adaptation: The role of climate resilient housing in Africa's cities*, 2023. [Online]. Available: https://www.brookings.edu/articles/enhancing-climate-adaptation-the-role-of-climate-resilient-housing-in-africas-cities/.

[8] African Development Bank Group, "Annual Report 2023," African Development Bank Group, Tech. Rep., May 2024.

[9] PwC, "Africa energy review," PricewaterhouseCoopers Services South Africa Proprietary Limited, Tech. Rep., 2021. [Online]. Available: https://www.pwc.com/ng/en/assets/pdf/africa-energy-review-2021.pdf.

[10] Solargis s.r.o and World Bank Group, *Global Solar Atlas 2.0*. [Online]. Available: https://globalsolaratlas.info/.

[11] International Energy Agency, *Energy system of Africa*. [Online]. Available: https://www.iea.org/regions/africa/electricity.

[12] African Energy Commission, "Key Africa Energy Statistics," Department of Infrastructure and Energy, African Union, Algiers, Tech. Rep., 2023.

[13] O. Bamisile, C. Acen, D. Cai, Q. Huang, and I. Staffell, "The environmental factors affecting solar photovoltaic output," *Renewable and Sustainable Energy Reviews*, vol. 208, p. 115 073, Feb. 2025, ISSN: 1364-0321. DOI: 10.1016/J.RSER.2024.115073.

[14] S. Z. Said, S. Z. Islam, N. H. Radzi, C. W. Wekesa, M. Altimania, and J. Uddin, "Dust impact on solar PV performance: A critical review of optimal cleaning techniques for yield enhancement across varied environmental conditions," *Energy Reports*, vol. 12, pp. 1121–1141, Dec. 2024, ISSN: 2352-4847. DOI: 10.1016/J.EGYR.2024.06.024.

[15] J. Carrilho, G. Dgedge, P. M. P. d. Santos, and J. Trindade, "Sustainable land use: Policy implications of systematic land regularization in Mozambique," *Land Use Policy*, vol. 138, p. 107 046, Mar. 2024, ISSN: 0264-8377. DOI: 10.1016/J.LANDUSEPOL.2023.107046.

[16] R. Chidembo, J. Francis, and S. Kativhu, "Underlying beliefs that influence solar home system adoption in Vhembe district Municipality, South Africa," *Social Sciences & Humanities Open*, vol. 9, p. 100 754, Jan. 2024, ISSN: 2590-2911. DOI: 10.1016/J.SSAHO.2023.100754.

[17] United Nations Department of Economic and Social Affairs, *United Nations Sustainable Development Goals 7: Affordable and Clean Energy*. [Online]. Available: https://sdgs.un.org/goals/goal7.

[18] United Nations Department of Economic and Social Affairs, *United Nations Sustainable Development Goal 11: Sustainable Cities and Communities*. [Online]. Available: https://sdgs.un.org/goals/goal11.

[19] United Nations Department of Economic and Social Affairs, *United Nations Sustainable Development Goal 13: Climate Action*. [Online]. Available: https://sdgs.un.org/goals/goal13.

[20] V. Collingwood, "Assistance with Fewer Strings Attached," *Ethics & International Affairs*, vol. 17, no. 1, pp. 55–67, 2003, ISSN: 1747-7093. DOI: 10.1111/J.1747-7093.2003.TB00418.X. [Online]. Available: https://www.cambridge.org/core/journals/ethics-and-international-affairs/article/abs/assistance-with-fewer-strings-attached/3761F53A5EEAD173BD1B3D6DEAF511C8.

[21] International Monetary Fund, *Economic Surveillance*. [Online]. Available: https://www.imf.org/external/pubs/ft/ar/2022/what-we-do/economic-surveillance/.

[22] "Checklists of energy-saving measures," ENERGY STAR Program, United States Environmental Protection Agency, Tech. Rep., 2021. [Online]. Available: https://www.energystar.gov/buildings/save-energy-commercial-buildings/ways-save/checklists.

[23] J. Teare et al., "Dwelling characteristics influence indoor temperature and may pose health threats in LMICs," *Annals of Global Health*, vol. 86, no. 1, pp. 1–13, 2020, ISSN: 22149996. DOI: 10.5334/AOGH.2938.

[24] H. Janssen et al., "Cold indoor temperatures and their association with health and well-being: a systematic literature review," *Public Health*, vol. 224, pp. 185–194, Nov. 2023, ISSN: 0033-3506. DOI: 10.1016/J.PUHE.2023.09.006.

[25] *WHO Housing and health guidelines*. Geneva: World Health Organization, 2018, p. 149, ISBN: 978 92 4 155037 6. [Online]. Available: Available%20at%20https://www.who.int/publications/i/item/9789241550376.

[26] I. Konstantzos, S. A. Sadeghi, M. Kim, J. Xiong, and A. Tzempelikos, "The effect of lighting environment on task performance in buildings – A review," *Energy and Buildings*, vol. 226, p. 110 394, Nov. 2020, ISSN: 0378-7788. DOI: 10.1016/J.ENBUILD.2020.110394.

[27] National Weather Service, *Heat Forecast Tools*. [Online]. Available: https://www.weather.gov/safety/heat-index.

[28] R. F. Stapelberg, *Handbook of Reliability, Availability, Maintainability and Safety in Engineering Design*. Springer London, 2009.

[29] Government of Ontario, Environment & Energy. "Noise in our environment: Learn what you can do about noise in your neighbourhood. "[Online]. Available: https://www.ontario.ca/page/noise-our-environment. (accessed: 01.25.2026).

[30] U. S. E. P. A. ENERGY STAR Program, *ENERGY STAR Portfolio Manager Portfolio Manager: What data is required to benchmark your property?* [Online]. Available: https://portfoliomanager.energystar.gov/pm/dataCollectionWorksheet.

[31] Government of Canada. "Universal Design for Learning (UDL). "[Online]. Available: https://a11y.canada.ca/en/universal-design-for-learning-udl/. (accessed: 01.27.2025).