Wojciech Kujawski, *M. Arch., MRAIC*

IMPACT OF BUILDINGS ON CONTEMPORARY URBAN INFRASTRUCTURE

Doctoral Thesis II.

Supporting Modules

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Cover photo: Bahrain WTC   Source: iiSBE

Thesis

Buildings are subjected to the life cycle processes that have direct impacts on the built environment including the urban infrastructure.
They are implicated in the process of design, construction, and operation of the infrastructure while contributing to it by using, disposing and producing energy, water, and waste.

Note: *Modules with their pagination are treated as separate entities but can be easily distinguished by their titles in the header*

Wojciech Kujawski, M.Arch, MRAIC

Impact of architectural design on buildings energy-efficiency and on potential renewable energy use

Module 1

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Introduction to the topic

The first module is the essential component of the dissertation being directly related to all aspects of the buildings either created or retrofitted/renovated, thus responsible for the size and requirements of the infrastructure for and around them. The idea was to approach the building from the design point of view and present, through the research findings, the design considerations, and results of the implementation of architectural features that can affect the municipal infrastructure. The answers in Module 1 are generated mainly by the studies of residential building type because the author conducted his research work at Canada Mortgage and Housing Corporation (CMHC), a Canadian Housing Agency, mainly on multi-unit residential buildings (MURBs). However, the research was coordinated with another federal department of Natural Resources Canada (NRCan) that works mostly on commercial, non-residential buildings. For usefulness of this dissertation and clarity and universality of some findings, that work is also included where indicated.

It is important to note that certain aspects of the residential housing in Canada are in a grey area because a “condominium” by definition is “commercial” as it is a private sector endeavor thus, in general, cannot be controlled or legislated by the government beyond the code and local by-law requirements. It automatically belongs to the non-residential construction while being entirely residential by the occupancy terms. The partial solution is to research as much as possible on both commercial and residential sides using the results where it is convenient at the given location. However, that does not make any of those results less reliable; they only belong to different pages in the studies, reports and building regulations.

Each research in this module (and in all other modules), was edited and abbreviated as much as it was possible, while keeping its goals, methodology, and the essential information intact in the conclusions followed by a brief description of primary results that is passed to the summary of the module and is also available in the primary document. Each publication is listed separately, and its shortened content is the base for the conclusions; however, in some instances, other research may be inserted or referenced in footnotes, to provide more clarity, or to create a better outcome for the thesis. Some projects have site-specific results; however, the idea is to see them in general terms of the building-related measures. Thus relevant comments are made towards the universal use of the knowledge.

1. Impact of Architectural Form on the Potential Energy Performance of Multi-Unit Residential Buildings,

CMHC, 2014, W.Kujawski as a Project Manager, with S. Kemp - MMM Group, former Enermodal Engineering);

To better understand all interrelationships contained in the title, the author initiated and managed a research project at CMHC conducted by S. Kemp at MMM Group to assess the relative impact of architectural form and envelope parameters on the energy performance and potential for solar energy collection of MURBs. Its conclusions were correlated with a similar study on commercial buildings conducted by S.Pope at Natural Resources Canada [Pope, 2015][1] and with Ryerson University in Toronto (T. Ferdous and M. Gorgolewski, 2014)[2].

The basic architectural form of buildings is defined by floor plate (or plan) geometry and building height. The building envelope (windows, walls, roof, and foundation) encloses the form and separates the interior environment from the exterior. Other features, such as balconies and shading may also contribute to the architectural form of a building that has an impact on space conditioning (heating and cooling) energy use but also determines the availability of roof and wall areas for solar energy collection.

When considered collectively, the impact of the elements above on energy consumption or solar energy potential is neither easy to anticipate nor apparent at all like, for example, the interrelationship between building height and floor plate geometry. While solar heat gains through window glazing can be beneficial during the heating season, they can be detrimental during the cooling season. The overall area ratio between walls and windows also has a significant effect on the "whole wall" thermal and solar heat gain performance and the availability of the facade area for solar collectors. Multi-unit residential buildings (MURBs) frequently have balconies that may cause thermal bridging effects lowering the effective thermal performance of the overall envelope. Nevertheless, during the summer months, balconies can provide shading to windows underneath, thus reducing solar heat gains and the resultant cooling loads.

[1] ISG Energy Seminar at Carleton University in Ottawa, 2015

[2] "Determining the effect of building geometry on energy use patterns of office buildings in Toronto" – T. Ferdous and M. Gorgolewski, 2014, http://www.journalofgreenbuilding.com/doi/abs/10.3992/1943-4618-9.2.124?code=copu-site&journalCode=jgrb – accessed Nov, 2017

Figures below [Fig.1] indicate the elements that have the direct influence on the energy performance in buildings and the further conclusions are directly related to them and evaluated in the form of help for future designers and planners with the assumption that building performance improvements lead directly to the creation of progressive infrastructure.

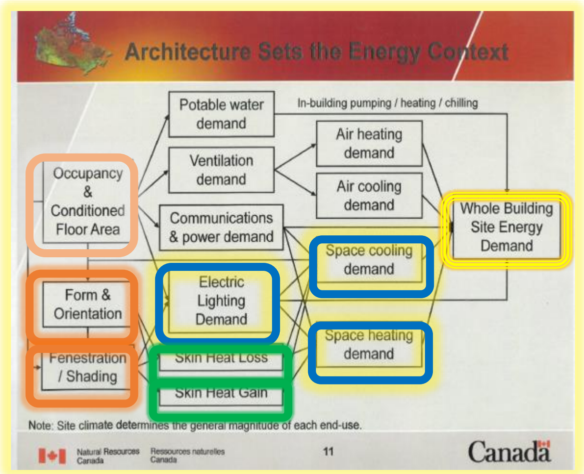

Figure 1. Energy and Form in Commercial Buildings. Source: NRCan, 2012

The presence of certain architectural features such as balconies in MURBs, potentially forming thermal bridges, is of much lesser importance than other features, thus the energy context is similar for both residential and commercial types and will be used here for general ideas how to design energy efficient buildings (Figure 1, 2).

It is important to underline that the main difference between commercial and residential buildings is associated with the occupancy factor related to the impossibility of a correct prediction of occupants' behavior. It is much easier, for example, to establish usage schedules in case of offices that run 9 a.m. to 5 p.m, than to predict the need to open the window or turn on the heating at 10 a.m. and at 7 p.m. by a member of the family and damaging all assumptions about the predicted energy performance.

There were no preferred combinations of architectural form (floor plate, orientation, and a number of floors) for any of the envelope parameters and the primary goal was to provide results that were HVAC[3] neutral and only attributable to the performance of the envelope and building form. Buildings were normalized by building area (energy load/area) allowing comparisons between parameters that affect the building size (e.g., number of floors).

The best-performing envelopes concerning the heating load had a low 30 % Windows-to-Wall-Ratio (WWR), well-insulated walls and triple-glazed windows with high solar heat gain coefficient (SHGC), low-e glazing. To minimize the summer cooling loads, triple-glazed low-SHGC and low-e windows could be used; however, this would sacrifice a significant amount of passive solar heat gains, leading to higher heating loads.

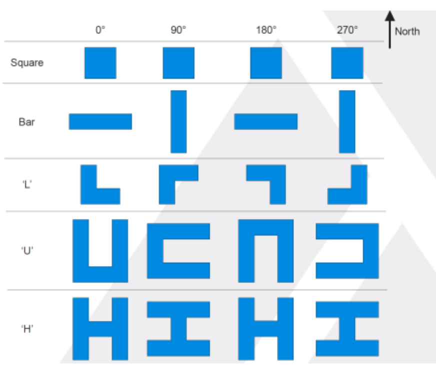

Figure 2. Shapes and orientation analysed. Source: MMM Group

[3] HVAC = Heating, Ventilation, and Air Conditioning- a general term for large building's temperature controlled air handling system.

Buildings shapes (Fig.2)**: 'U' and 'H' floor plates -** a "courtyard" floor plate experience slightly reduced heating loads and significantly reduced cooling loads compared to the more commonly built **'Bar'** and **'Square'** geometries. '**L'-shaped floor plates** were found to have the highest heating and cooling loads when normalized by floor area. The orientation had an only minor effect on the heating loads; however, it did have a significant reduction in cooling loads observed when orienting the 'U'- and 'H'-shaped buildings with the courtyards facing east or west [Fig.3].

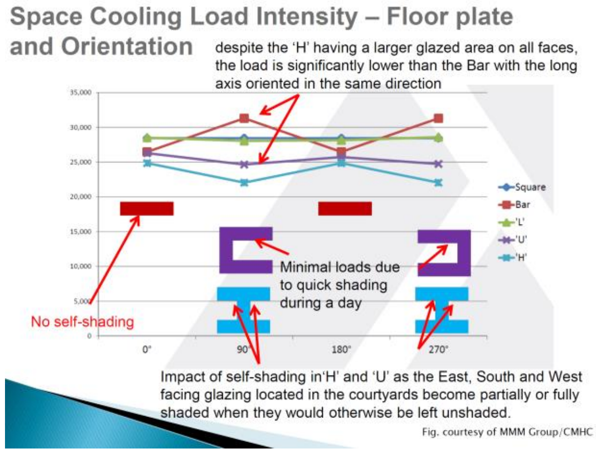

Figure 3. . Space Cooling Load Intensity. Edited and presented by W.Kujawski, ISG Seminar, 2015

The number of stories had a more significant impact on the annual heating load intensity than either the floor plate or orientation. Maximizing the number of stories (to 14 in the study) showed a reduction in total heating load intensity up to 20 %, outweighing the increase in the cooling load. It was because vertical envelope area (and thus heat loss) increases proportionally; however, the roof and floor slab areas (and heat loss) remain constant.

Balconies can act as a shading device thus decreasing cooling load; however, their (potential) thermal bridging can reduce the useful thermal value of the surrounding wall system. The overall relative impacts of the architectural features on the cooling loads and heating loads are depicted [Fig. 4 and 5], respectively. However, for summer cooling loads, low SHGC could be used sacrificing winter solar heat gains – a designer's choice.

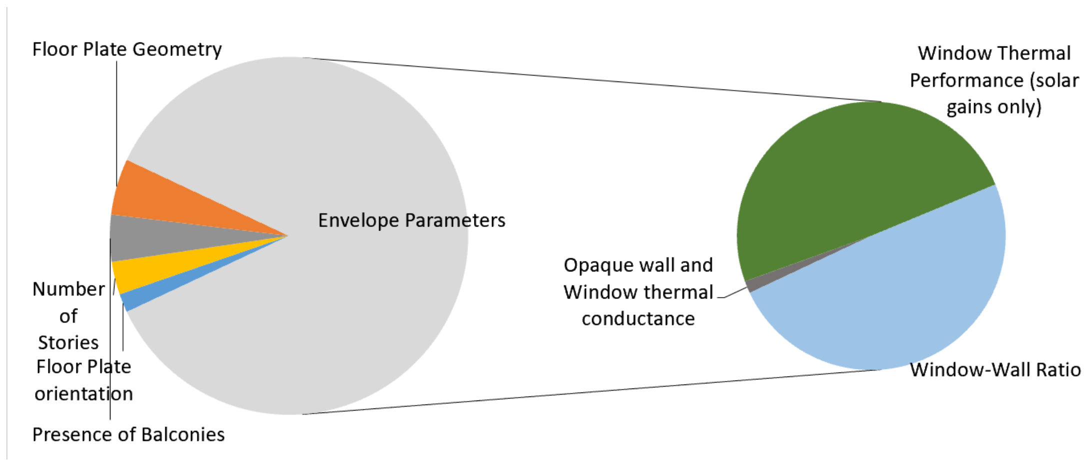

Figure 4. . Relative Impact of Architectural Features on Cooling Loads. Source: S.Kemp, MMM/CMHC

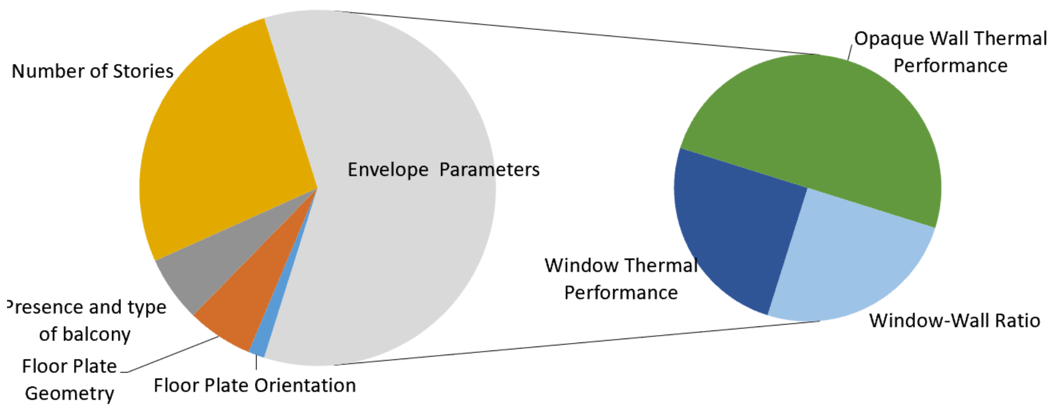

Figure 5. Relative Impact of Architectural Features on Heating Loads. Source: S. Kemp, MMM/CMHC

Regarding the **optimization of the renewable energy potential**, the study concluded that:

- overall building designs targeting "net zero" site energy should seek a balance between the height and a larger floor plate (such as the 'H' and 'U' floor plates).
- higher WWR results in higher heating loads and lower solar energy potential because of an increase in window area over wall area.

Concerning **solar potential relative to building height**:

- shorter buildings are optimal for both solar thermal domestic hot water (DHW) and photovoltaics (PV)due to the higher ratios of roof area to the total conditioned floor area.

Some more detailed important conclusions:

- **Roof mounted solar thermal collector panels** will produce XX kWh of renewable energy per m² of gross floor area (GFA) **-** Canadian base: 2.88 m² PV unit for every suite.
- **The 'L' shaped archetype would use at ten stories nearly the entire roof** using a one collector per suite ratio, so any higher will not have enough roof area.
- **With the entire roof for solar thermal, PVs can go on the south facing walls** with 32% of the gross area taken by windows (prescriptive code); 20% by exhaust and supply grills, balcony areas; thus **only part of the wall (48%) is left for PVs**.
- **The 'H' floor plate building is capable of producing 95% more PV output** (by GFA) due to its larger south-facing surface compared to the size of the floor plate.
- **Shorter buildings are optimal** for both solar thermal domestic hot water (DHW) and photovoltaics (PV), regarding energy production in kWh per m^2, due to the higher ratios of roof area to the total conditioned floor area.
- **Higher buildings** have **reduced annual heating load intensity** in the heating season, and **increased annual cooling load intensity** in cooling season.

- **The right balance** between building height and a more significant floor plate (such as the 'H' and 'U' floor plate) is needed in buildings targeting "net zero" site energy to optimize the renewable energy potential.
- **Available opaque wall area for vertical solar collectors depends on the WWR.**

NOTE 1: In most MURBs **concrete roof decks typically have high enough load capacity** to accommodate collectors.
Metal and wood roof decks may require additional structure to accommodate the loading of solar collectors.

***NOTE 2*: Wall mounted collectors** are still rare in MURBs. The extra structural requirements for brise soleils / shading devices may often result in significant thermal bridging in the wall [Fig. 6].

Figure 6. Source: iiSBE -Transition to Sustainable Buildings IEA 2013

Conclusions 1

MURBs:

- **Envelope performance is essential.** When the envelope is poor, massing and orientation can improve energy performance.
- Good envelope performance allows freedom in massing/orientation
- The impacts on the heating and cooling loads from the envelope parameters were found to be relatively independent of the building geometry.
- The study indicated that there were no preferred combinations of architectural form (floor plate, orientation, and a number of floors) for any of the envelope parameters.
- The best-performing envelopes concerning the heating load used low WWR (30%), well-insulated walls and triple glazed windows with high solar heat gain low-e glazing;
- The insulation level in the wall has a minimal impact on the cooling load when compared to the heating load
- Number of stories has a more significant impact on heating load intensities than on cooling; however, the envelope parameters are affecting more the annual cooling load intensity impact

- However, for summer cooling loads, low SHGC could be used sacrificing winter solar heat gains – a designer's choice

Energy and Form in Commercial Buildings

- [S.Pope, 2015]

Commercial:

- **Surface Area to Volume ratio (SAVR)** is not a significant indicator of energy efficiency [Fig.7]
- Square may be the "most compact," but is not the most accommodating or less energy consuming;
- The square plan does not produce significantly different results than letter shaped plans;
- Standard energy efficiency measures can mitigate form's differences..

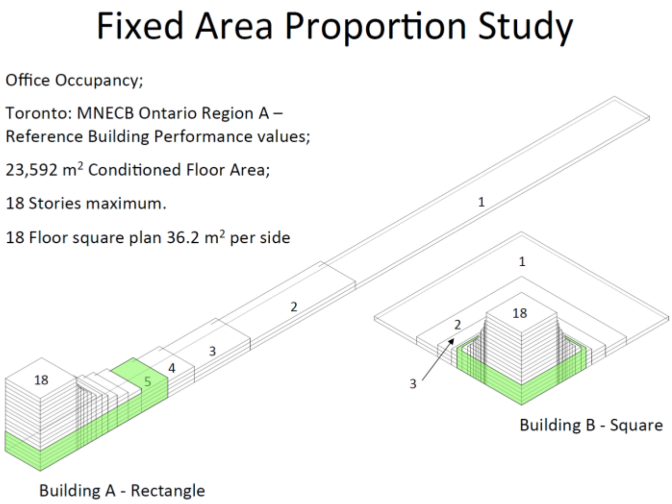

Figure 7. Fixed Area Study. Source: S.Pope, 2015

Significant energy penalties will not be incurred for increasing skin area for purposes of better access to air, light, or renewable energy.[S.Pope, 2015]

Corroborating Study by Ryerson University, Toronto

Commercial buildings (offices), [Gorgolewski, 2014].:

- Rectangular plans have a lower Volume to Surface (V2SA) ratio, and higher unit area energy intensity than square plans;
- V2SA ratio difference is inconsequential by floor 14;
- Energy intensity difference is inconsequential by floor 11.
- Maximum difference in V2SA ratio occurs at floors 3 and 4;
- Maximum difference in energy intensity between the square and rectangular plan occurs at ground floor

2. An Affordable, Low-rise, Energy-efficient Multi-unit Residential Building: The "Ateliers Rosemont, Montréal"[4]

CMHC, 2016 – (W.Kujawski as a Project Manager, with l'OEUF, Montreal);

Collectively known as "Ateliers Rosemont," the project comprizes the housing co-operative, *"Le Coteau Vert",* and the non-profit organization, *"Un toit pour tous"*, with 155 affordable housing units on a brownfield site in the Rosemont neighborhood in Montréal. It is an example of a holistic approach to the development that took into account the social, economic and environmental aspects of affordable housing and urban intensification – the sustainability. [Fig.8, 9]

The planned environmental measures were architectural, landscaping, electrical and mechanical- all of them help contribute to the infrastructure. They included, besides purely technical aspect of the low-energy design, the orientation of the buildings to optimize natural ventilation and daylight, the arrangement of balconies as shade screens, use of low pollutant-emitting finishes decreasing ventilation requirements. As for the elements related directly to the built infrastructure, they were as follows: production of renewable geothermal energy on site, smart management of surface water to reduce demand on the existing sewer system network, choice of local plant species for landscaping, and encouragement of sustainable transit through minimization of parking spaces and a proximity of public transit (Montreal's metro).

[4] https://www.cmhc-schl.gc.ca/odpub/pdf/68534.pdf accessed March 2018

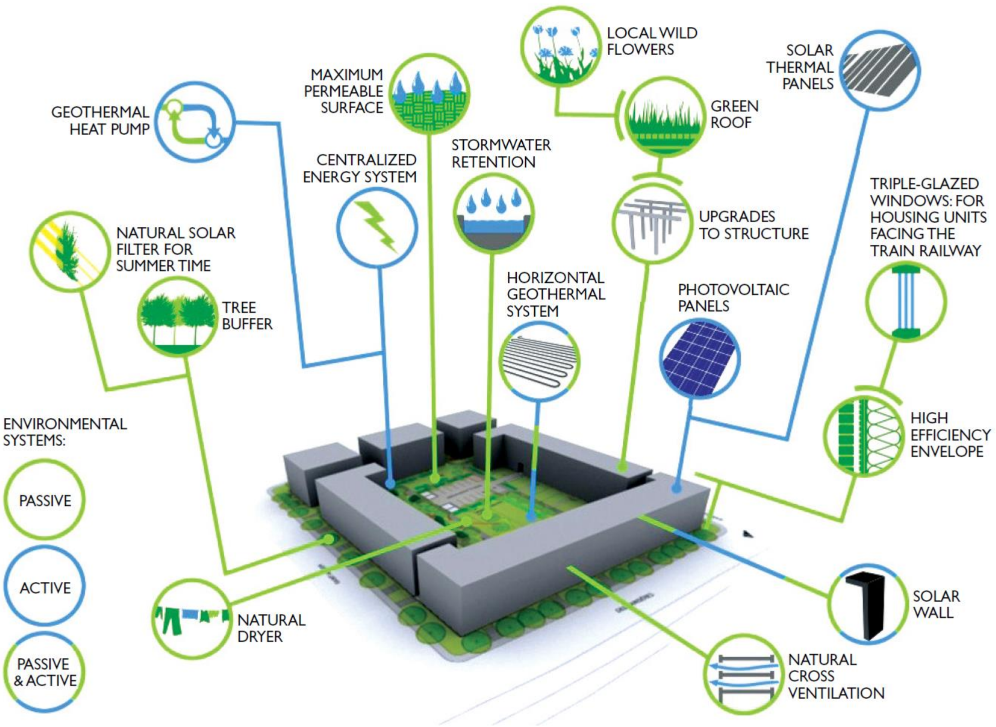

Figure 8. Consider all possible design features AT FIRST, and only then use the appropriate technology. Source: D. Pearl, l'OEUF

Passive Active strategies – a hybrid approach

One of the partners at l'OEUF, Mark Poddubiuk, says that many of the project goals were achieved through passive design:

"*The buildings are ten meters deep. Conventionally, we have 18- to 20-meter deep buildings with double-loaded corridors. A ten-meter building with southern orientation solves 80 percent of our environmental design. Such a design approach is low-hanging fruit – big gains at no cost through clever design. The degree of fenestration is also an issue. The standard limits solar gain to 30 percent maximum. Southern orientation is the easiest way to save 10 to 20 percent of the energy costs, so the project uses passive design, including careful control of orientation, fenestration, depth of the building, natural ventilation, and shading*." [after Pearl, Wentz, 2014]. Solar wall concept [Fig. 11, 12] was designed but, in the end, not needed due to the excellent performance of the envelope and the geothermal system.

The energy recovered from the outgoing drain water helps to offset water heating energy consumption and costs. The passive nature of the units (no moving parts) offers ongoing energy savings with little or no maintenance [Fig.10].

Figure 9. Bicycle parking is still there in January. Source: W.Kujawski

Figure 10. Drainwater heat recovery Source: l'OEUF

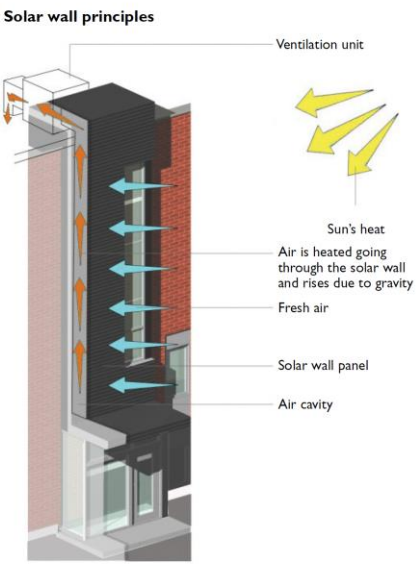

Figure 11. Proposed solar wall concept. Source: Solarwall

Figure 12. After first 2 years it was obvious that Solarwall was not even needed. Source: l'OEUF

Figure 13. Nowhere else one can see that today. Source: Holcim Foundation

Figure 14. Cloth lines add some character while saving energy. Source: W.Kujawski

Additionally to other spectacular features, there is one not fitting the XXI century by judging people's initial reaction: use or clothlines as natural dryer extended across the backyard (Fig.13, 14)

Conclusions 2

The development of the Rosemont project provides a useful example of how sustainable features can be embodied in an affordable housing project. It demonstrated that building envelope insulation and airtightness improvements could represent an important starting point for making significant reductions in energy use and operating costs also impacting the adjacent infrastructure.

Such improvements can also be cost-effective in comparison with the installation of renewable energy systems. Preliminary results from performance monitoring indicate a total project annual energy use of 80 to 100 kWh/m^2 of which space heating constitutes approximately 50 % or 50 kWh/m ^{2}. This performance compares favorably with other energy-efficient sustainable housing projects constructed elsewhere across Canada. Although the project required significant investments in time, effort and commitment from all stakeholders, consultants, local and regional authorities and municipal employees, the effort demonstrated that sustainable features could be cost-effectively implemented in affordable housing projects, which is a substantial point also because of budgetary restrictions that touch both buildings and infrastructure.

3. "Design Development of Low-Energy and Affordable Multi-Unit Residential Buildings"

CMHC, 2016 – Case study: Bois Ellen Co-operative Residence, Laval, Quebec W.Kujawski as a Project Manager with l'OEUF, Montreal

The Bois Ellen Cooperative Residence in Laval, Quebec, to the north of Montreal, is comprised of two wings: a six and a thirteen-story, totaling 166 residential units, with a common dining hall and meeting rooms in between the wings [Fig.15]. Two-thirds of the units are reserved for seniors and one third for families. The Cooperative includes significant innovations that are rarely if ever, seen in this depth and at this scale for affordable housing. Thus it is an excellent opportunity to provide a first-hand overview of the building's direct impacts on the infrastructure.

Project outcomes- the improvements to the skin- the building envelope are the most important part as mentioned earlier in the *Impact of Forms.* The strategic selection and installation of windows and doors, the careful placement of insulation in the exterior wall and roof assemblies, the mitigation of thermal bridging, the use of passive solar shading, and roofing systems selected to facilitate urban cooling and the retention of storm waters. The project intends to provide information and guidance for low-energy affordable housing projects from one side, and the information on the contribution to the infrastructure from the thesis side. It is important to note an issue of the difference between a nominal and effective thermal resistance (*what is the REAL thermal performance of a given assembly once installed and where physical adjacencies and thermal anomalies are factored in*).

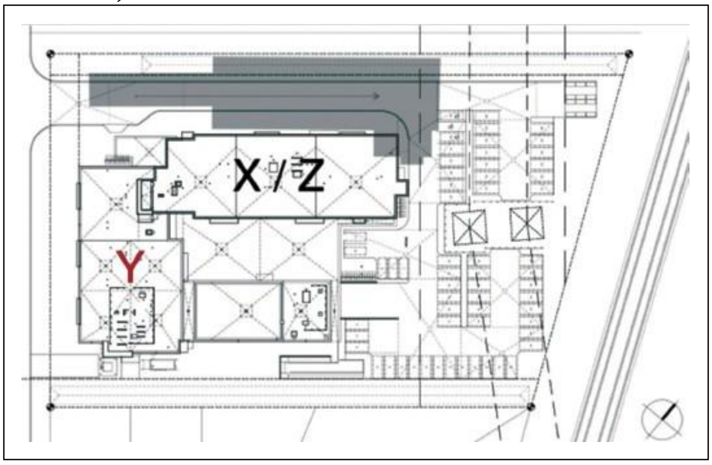

Figure 15. Site plan of the Bois Ellen Co-operative Residence. Source: L'OEUF

The objectives of the Bois Ellen design process were to combine the most strategic innovations with the financial limitations of the project as follows:

- **Energy efficiency:** the effectiveness and complementarity of building systems.
- **Comfort:** designing to increase thermal comfort and enhance indoor air quality.
- **Durability:** the selection and integration of durable, low- maintenance building elements, equipment, and systems that seriously reduce potential future risks, in the short and long term.
- **Resilience:** future adaptability or "future proofing"—the selection of resilient building systems that can be adapted over the long term with changing demands on the building including changes in energy sources, climate change, and severe weather events.

Improvements to the building envelope

- triple-glazed windows with a reasonable performance frame on north-facing facades
- Insulation –to be a cost-effective strategy for reducing heat loss in the winter and heat gain in the summer an exterior wall assembly with 125 mm of semi-rigid "outsulation" (insulation situated outside of the supporting steel stud wall) was proposed. Such configuration helps to reduce the risk of condensation and moisture damage within the wall assembly and protects the integrity of the air barrier that is placed over the exterior surface of the exterior wall sheathing. This solution results in a better performing, durable building envelope assembly and reduces the complexity of labor and costs, helping reduce long-term repair and maintenance costs.
- Passive solar shading - brise-soleil installed on the southwest-facing building facade to permit solar heat gains in the winter, but to mitigate them (by about 80 percent) in the summer. A combination of high-performance windows with high solar gain and fixed, minimal and straightforward maintenance-wise brise-soleil assemblies can selectively reduce solar heat gain to help reduce air conditioning loads.

Other measures that affect both building and infrastructure performance such as:

Implementation of effective measures for coordination, commissioning and monitoring such as:

- Establishing the commissioning agent to ensure a coordinated and successful installation of all building systems, including the administration of warranties and maintenance programs.
- Making sure that durability, maintenance, and varied life cycles requirements between mechanical systems and fixed assemblies were taken into account in the analysis of the building's lifecycle and the planning of its operation and maintenance programs.
- Testing for airtightness the integrity of the exterior envelope targeting 0.9 air changes per hour (at 50 pascals), the airtightness between adjacent units,

Testing units and corridors twice:

- after envelope construction but before services and interior finishes installation; and
- after building services installation, but before substantial completion.

The implementation is one side of the performance equation. The other is **the verification of the predicted versus actual performance through monitoring and evaluation protocols.**

Monitoring and post-occupancy evaluations of window and door operation is planned at initial occupancy, at three months, six months and one year. The operation of doors and windows can greatly affect the heating, cooling, ventilation and air quality of a building. There is, therefore, a need to better understand occupant's behavior.

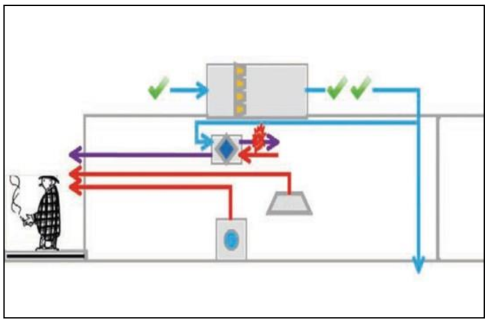

Figure 16. The ventilation concept. Source: F.Genest, Pageau Morel)

The outside air intake is located at the roof, away from common smoking areas and boasts high-efficiency filtration that improves air quality by removing fine particulates [Fig.16].

Air is preconditioned by a large solar duct system before being supplied to the individual unit HRVs.

Conclusions 3

The combined effects of the energy conservation measures resulted in a projected reduced total energy demand of about 135 kWh/m2/year (approx. 42 % reduction) including a heating demand of about 43 kWh/m2/year (approx.70 % reduction).

An integrated design process (IDP) and a whole building analysis have been valuable design tools facilitating the integration of environmental and sustainable measures for low- to mid-rise MURBs. Because of the composition of residents of the Bois Ellen Co-operative, durable, easy-to-use and low-maintenance building systems were included in this project.

The engagement and education of the residents in operation and maintenance of their building may also play a key role in determining the future overall energy use and energy savings thus impact on the overall infrastructure. Other important goals, such as improved thermal comfort, high indoor air quality, and long-term envelope durability have all been integrated into the final design while respecting the constraints of affordability. An issue of the difference between a nominal and effective thermal resistance is raised as crucial in real performance assessment.

Combination of the benefits related to the occupants through the performance of the building and thus their contribution to the infrastructure only underlines the importance of it for the simple reason of an easy acceptance due to the reduced operating costs and quality of a building.

2. Energy Simulations of Strategies to Achieve Low-Energy, Multi-unit Residential Building Designs in Different Regions of Canada

CMHC, 2015, W.Kujawski as a Project Manager with EnerSys Analytics

Improvements in the multi-unit residential building (MURB) sector have not advanced as far in Canada over the years, as single-family, detached housing. In contrast, low-energy MURB projects are becoming more prevalent in Europe, mostly thanks to regulations and high costs of energy. Passive House, a voluntary energy efficiency certification, and labeling system is one program that helps designers, developers and property owners to construct buildings that consume very little energy. Its stringent energy targets limit the overall energy consumption of certified buildings to 120 kWh/m² per year, with space heating not exceeding 15 kWh/m².

Notwithstanding all already existing studies, design guidelines and well-documented case studies, a need to respond to the request for a unified approach in the construction of MURBs has obtained a green light to proceed after years of unnecessary confusion among the professionals.

The author initiated a study that used energy simulations in MURBs based on Passive House requirements to examine how similar levels of energy performance could be achieved across Canada given its significantly different climate zones (spanning 5,514 km east to west and 4,634 north to south), design practices, building codes, and the availability of technologies. Most Canadians live in the much narrower area along the border with the U.S., and the study was applied there.

Methodology

Conceptual energy models of MURBs were developed for six regions in Canada: British Columbia West Coast (Vancouver), British Columbia Interior (Kelowna), Alberta (Edmonton), Southern Ontario (Toronto), Southern Quebec (Montréal), Atlantic Canada (Halifax).

The initial "base" model had the envelope, electrical, and heating, ventilation and air conditioning (HVAC) characteristics set to meet or exceed the 2011 National Energy Code for Buildings (NECB 2011) requirements for each region. Different energy efficiency technologies were then applied to reduce the annual space heating load to Passive House design levels (less than or equal to 15 kWh/m²). This led to the development of strategies that illustrate the extent to which the design of MURBs would have to change to achieve the required efficiency close to the Passive House standards.

Envelope strategies

Exterior walls

- **Superinsulation** of buildings is one of the tactics that were developed with consideration of the market availability, practicality, and cost-effectiveness - one that could hold a significant amount of insulation, minimized both linear losses and thermal bridging and was airtight. The developed low-energy wall assembly included 125–150 mm semi-rigid exterior insulation secured with non-conductive clips and interior spray foam insulation *(confirmation of the earlier studies of Rosemont and Bois Ellen - author)*. Reduced balcony thermal bridging, no spandrel panels, non-conductive window frames and connections increased the performance as well. When fully accounting for thermal bridging and linear losses, the wall system had thermal resistance of at least 25% -50% better than the code with the higher end applied to the walls of the buildings in the colder climates. Such a wall system, with the overall thermal resistance nearly the same as the nominal value of the insulation, is very high-performing compared to typical market practices.

- Including interior spray foam insulation also permitted adjustments to the energy model to reflect the improved airtightness that both reduced the infiltration and improved the overall performance of the heat recovery systems.

Roof

- The roof construction assumed for all regions was a typical concrete or metal deck roof with continuous rigid insulation and no significant thermal bridging.
- For the colder climates, however, the roof insulation value was increased to as high as RSI-9.1 (R-52). The lowest roof thermal resistance was maintained at RSI-5.6 (R-32).
- Cost-effectiveness of the most measures depends on the type of heating system (i.e., gas, electric, oil etc) and the location of the building.

Floor

- The baseline construction for the floors above the parkade (parking garage) consisted of spray foam insulation below the concrete slab, with no significant thermal bridging.
- The floor insulation was increased only slightly since extra insulation saved very little energy and a different construction might be required (for example, a deeper soffit to house the insulation).

Windows

- Windows are a prime source of heat loss accounting for approximately one-quarter of the overall exposed building envelope area. Thus, any reduction of the impact of window area on the heating load would be beneficial. For the baseline, reducing the window area made a noticeable difference. However, the difference decreased with higher-performing (lower U-value) windows, especially if they still allowed in relatively high levels of beneficial solar energy offsetting space heating loads. Therefore, the window-wall ratio of 30 to 35%, was retained for the low-energy case, even though lowering the amount of glazing usually is an effective energy conservation strategy. [Torok, 2013]
- The windows modeled for the low-energy buildings included fiberglass frames, which improve the window USI-value by roughly 30% or more over aluminum frames.
- The analysis also evaluated replacing the double-pane units with high-performance, triple-pane units with a relatively high solar heat gain coefficient. The quadruple-pane windows with fiberglass frames were not cost-effective in comparison to triple pane units; however, they reduced the heating

load noticeably in the colder locations. Therefore, such glazing was included in the final low-energy case for all regions except Vancouver with its milder climate.

Other

Ventilation strategies

- The baseline model included in-suite heat recovery ventilation (HRVs) even if this approach to ventilation is not standard in MURBs. It is needed to meet the energy code requirements in some zones in Canada, and it represents a good practice. Therefore, this approach was maintained for other locations for consistency.

Space heating strategies

- In many locations heating with electricity is much more expensive than with natural gas; however, the capital cost to install, maintain and replace electrical systems can be much lower than for any other

Table 1 Regional characteristics for low-energy MURBs

Table 1. Regional Characteristics for low-energy MURBs. Source: EnerSys

Component	Vancouver	Kelowna	Edmonton	Toronto	Montréal	Halifax
Additional linear losses through walls	17%	15%	14%	14%	14%	14%
Roof thermal resistance	RSI-5.6	RSI-6.9	RSI-9.1	RSI-7.4	RSI-9.1	RSI-8.3
Floor thermal resistance	RSI-4.6	RSI-4.6	RSI-4.6	RSI-4.6	RSI-4.6	RSI-4.6
Window percent	35%	30%	30%	30%	30%	30%
Window conductance	USI-0.91	USI-0.91	USI-0.68	USI-0.68	USI-0.68	USI-0.68
Window SHGC	0.55	0.55	0.39	0.39	0.39	0.39
Natural infiltration (ACH)	0.1	0.1	0.1	0.1	0.1	0.1
Heat recovery effectiveness	0.70	0.80	0.80	0.80	0.80	0.80

Source: EnerSys Analytics Inc.

systems. The Passive House approach is based on such reduction of space heating loads that very little heating energy is needed and that makes electric baseboard a viable option with its very low capital and life-cycle costs. The cost savings can then be applied to significantly improve the performance of the building envelope and the efficiency of the mechanical system and such measure was proven for locations with lower heating requirements and electricity prices closer to that of natural gas. Table 1 summarizes the building characteristics needed to achieve the targeted performance for each region.

Figure 17 shows a comparison of the space heating loads calculated for each region for the base and low-energy designs. All of the low-energy designs saved a significant amount of heating energy compared to the base NECB 2011 designs—with savings from 76% to 84%. However, only the buildings located in Vancouver and Kelowna in B.C. (with their moderate climates) were able to meet the targeted Passive House 15 kWh/m² threshold, which is shown as the green line in Figure 19.

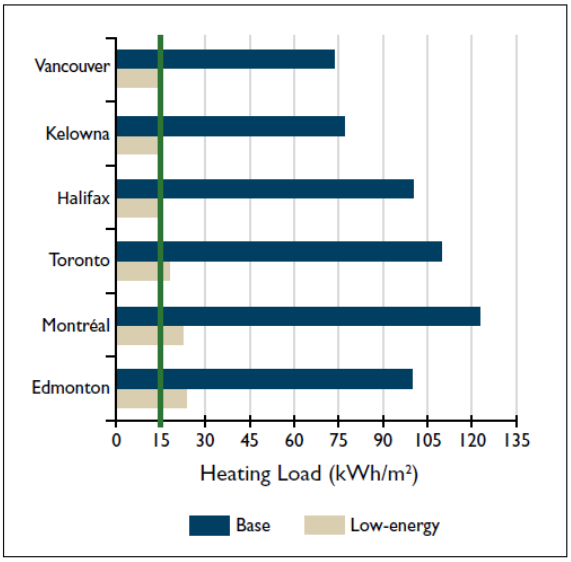

Figure 17. Space heating loads by region. Source: Enersys Analytics.

Table 2 expands upon the results shown in [Fig.17] and provides the total metered kWh/m² for the buildings in each region, as well as the cost-effectiveness of the low-energy designs regarding life-cycle cost payback period and internal rate of return (IRR[5]).

While the modeling showed that the low-energy designs had high life-cycle cost payback periods for Edmonton and Toronto, these designs proved more cost-effective for the other regions.

Table 2. Regional energy and economic indicators for low-energy MURBs

Location	Heating load (kWh/m²)		Total energy (kWh/m²)		Economic results*	
	Base	Low-energy	Base	Low-energy	Payback Period	Internal rate of return
Edmonton	99.8	23.8	234.9	141.1	>30 yrs	N/A
Montréal	122.7	22.5	263.4	140.2	6.7 yrs	20.3%
Toronto	109.9	17.9	239.1	127.0	>30 yrs	5.5%
Halifax	100.4	15.7	223.0	120.4	8.2 yrs	17.1%
Kelowna	76.9	14.4	185.3	110.8	10.4 yrs	13.2%
Vancouver	73.7	13.9	176.7	106.4	11.7 yrs	8.1%

*30-year analysis based on 5% discount rate, 2% inflation and 3% energy cost escalation.
Source: EnerSys Analytics Inc.

For Edmonton and Toronto, the reason for "poor" performance was mainly due to their relative electricity rates being respectively 6.4 and 4.4 times higher than the equivalent gas rates. Hence,

[5] Assuming the costs of investment are equal among the various projects, the project with the highest IRR would probably be considered the best and be undertaken first. IRR is sometimes referred to as "economic rate of return" or "discounted cash flow rate of return." The use of "internal" refers to the omission of external factors, such as the cost of capital or inflation, from the calculation.
https://www.investopedia.com/terms/i/irr.asp

switching to a cheaper electric resistance heating system and slashing the heating requirements largely appeared cost-effective depending on the relative utility rates (not the absolute rates).

Conclusions 4

It could be inferred from this study, that the low-energy cases became cost-effective when the marginal electricity prices fell below roughly four times the respective natural gas prices (inconsistent units of measurement).

In Canada, targeting reductions in the space heating load is a key to achieving low-energy-use buildings. Based on the results of the building energy simulations and analysis, it appears possible to significantly reduce the space heating requirements of newly constructed MURBs through the application of available technologies and design practices.

One of the developed tactics is the use of a significant amount of insulation, minimized both linear losses through the non-conductive window frames and thermal bridging through reduced balcony connection-related thermal conductivity, and the airtightness. When fully accounting for thermal bridging and linear losses, the wall system had thermal resistance of at least 25% -50% better than the code with the higher end applied to the walls of the buildings in the colder climates. The overall thermal resistance nearly the same as the nominal value of the insulation, creates a better, high-performing wall system, compared to typical market practices.

The results also tend to support the financial viability of making higher capital investments in energy-saving features to reduce longer-term life-cycle costs. As in other parts, it is evident that the buildings built to the best standards will minimize the expansion of infrastructure to the minimum required and every step towards the efficiency of buildings contributes to the optimization of the infrastructure as well.

4. "Manitoba Hydro – An office building that breathes"

W.Kujawski, Zawód: Architekt #33, 2013 (Budynek, który oddycha)

"The architectural concept had to clearly indicate how the form of the building, its size, and shape can react smoothly to the climate while creating a healthy, perfectly connected work environment while enriching the public space."
Bruce Kuwabara, KPMB ARCHITECTS

The motto perfectly reflects the ideas behind the design of this building. In light of the main topic, it is interesting to follow the design process of the office building when the finances are not the biggest problem of the owner/developer, but the lack of a tradition of energy efficiency is. For that reason, all design aspects should be carefully assessed because it is not only the building itself but its impact on the surrounding urban area and its infrastructure. It is worth noting that already in May 2012, the Manitoba Hydro building received the Platinum LEED® Certificate, and was previously named the best office building in North America, despite being built in the so-called "middle of nowhere," in other words, the Canadian prairies.

The 64,800 m² headquarters of the Manitoba Hydro, a monopoly giant in energy supply in Manitoba and the fourth largest in Canada, is located in the center of Winnipeg, the coldest city in the world with a population of over 500,000 inhabitants. It is also the sunniest location in Canada with the hottest, humid summer and the most-used air conditioning. Average temperature differences exceed 70° C (!) during the year, dropping below -35° C in winter, and rising above 35° C in the summertime.

The used strategies of sustainable design that contribute, in a short and long term, to the infrastructure are as follows:

- maximum "harnessing" of solar, wind and geothermal energy
- operation of the solar chimney (air draft) to ensure ventilation of the entire building with minimal energy consumption
- double façade with openable windows
- waste heat recovery
- narrow office spaces with high ceilings
- full use of natural lighting.

The final concept is the result of a long and rigorous integrated design process (IDP) [Fig.18]

To achieve the goal of 60% of the Building Code energy consumption requirements, passive systems had to be optimized through simulations ensuring a uniform and consistent comparison of energy indicators of different strategies [Fig.19].

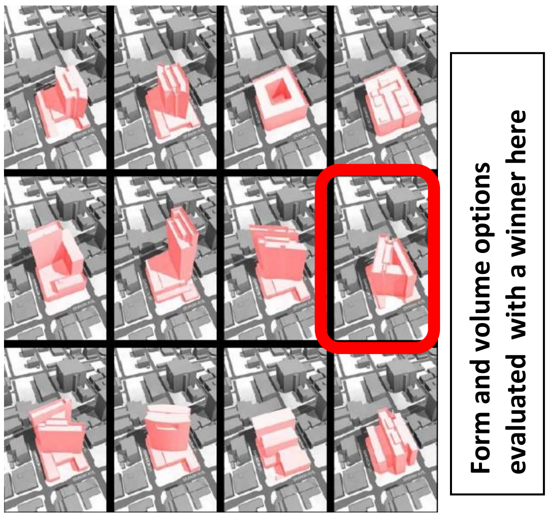

Figure 18. Design charrette options. Source: Manitoba Hydro

Actual building performance depends on but is not limited to, current weather conditions, quality of assembly, proper operation and maintenance of the equipment, and user behavior and building management.

The MH project shows the importance and necessity of using IDP for the implementation of environmental and ecological goals that are otherwise difficult to achieve. However, in the eyes of employees, its highest value is the improvement of the working environment.

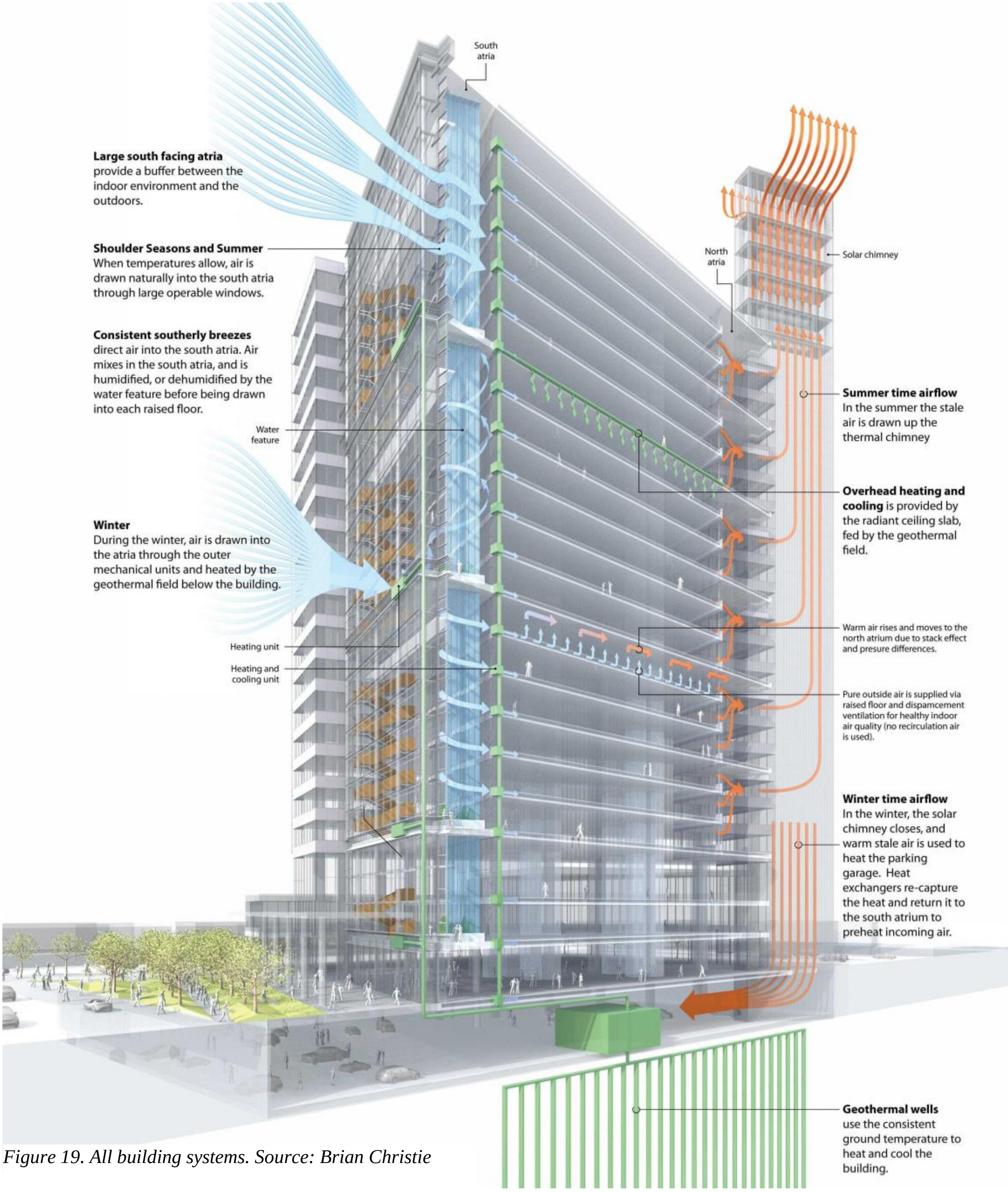

Figure 19. All building systems. Source: Brian Christie

The MH building complex contains two 18-story glazed office buildings set on a three-story podium, divided in half by the Public Gallery / Passage finished in brick referring to the city's tradition [Fig.20]. The towers converge on the north side of the building (Fig.24) to minimize the area affected by cold northern winds, and the southern divergence (Fig.25) captures the sun's rays and the strong southern winds typical of the region. The solar chimney located at the end of the north façade helps to ventilate the building in the summer, and direct the warm, used air from the offices to the garage in the cold season.

In winter, external air is drawn into three six-story atria on the southern side where it is heated by geothermal field heat and moisturized in each of the three atria by a unique 24-meter high water curtain that effectively regulates the humidity and simultaneously enriches the space. The curtain consists of 280 Mylar tapes, followed by flowing purified ice water drying the air in the summer (at 10° C), or warm water moisturizing them in the winter. Fan coils placed on each floor additionally push the air in the atria under pressure, and then, if necessary, into office rooms through devices located on the perimeter of the building.

Atria, acting as solar collectors, create, in conjunction with the solar chimney, the "lungs" of the building providing the initial "treatment" of the air before it is delivered to the office space – they introduce 100% of fresh air 365 days a year. In winter, the air introduced into the atria is pre-heated up to 5^{o} C, abundant insolation from the south provides the rest of the heat. In the summer, when the fan coil units are turned off, the air is supplied via controlled intake openings. The chimney effect in each of the atria causes the influx of the prepared air to the ducts in each of the raised floors, from where it is directed to the rooms with floor inlets. In summer, the exhaust air is expelled due to the draft from the solar chimney, while in the winter the air is sucked into the underground parking lot for ventilation and heat recovery.

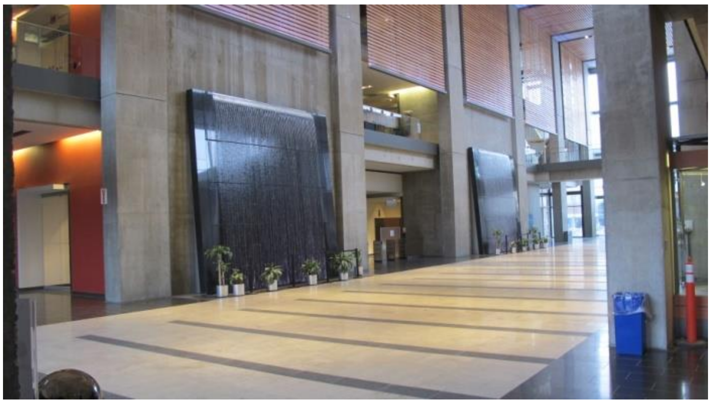

Figure 20. Water curtains in the hall. Source: W. Kujawski

Figure 21. Solar chimney on the roof. Source: W. Kujawski

Figure 23. Machine room. Source: W.Kujawski

Figure 22. Double wall and controlled blinds. Source: W.Kujawski

High performance of the envelope is ensured by triple glazing with atria (vestibules) from the north and south acting as double façades. On the eastern and western walls, the inner layer of glazing consists of a single pane with low-e coating and is shaded by automatic blinds depending on the angle of incidence of sunlight [Fig.23]. It is separated from the double glazed outer layer, one meter wide, with a buffer zone.

Figure 24. Narrow North facade. Source: W.Kujawski

Figure 25. Large South facade to capture the sun. Source: W.Kujawski

Conclusions 5

Thanks to the advantage of being enormously rich, Manitoba Hydro (utility of province of Manitoba based on water (hydro) resources) achieved previously unknown goals in building performance. The building constructed downtown Winnipeg creates the space others can only dream about. The city benefits of almost every design aspect starting with colossal energy consumption cut through a nearly perfect design using form, advanced double skin envelope, passive features, ground source heat pump, environmental features providing comfort while at the same time mitigating the potentially huge size of an infrastructure which would be required otherwise.

The green roofs of the podium at the base of the towers are planted with vegetation typical of the region, including native prairie grasses, which reduce the size of urban infrastructure, e.g., storm installations and minimizes the effects of the heat island. Gardens are irrigated with rainwater and condensate from fan coils, saving on, otherwise used, potable water with its infrastructure.

Comfort related aspects of both occupants and passers-by are no less critical than purely technical ones, as the building is merely alive- it breaths. By creating its new quality together with active and attractive public spaces, investments were made in the future health of the society, thanks to which the contribution of the MH building to the public sphere of Winnipeg is priceless.

Such simple requirement as making ground floor commercially available to “others” led to the creation of livable streets around the building thus introducing a new meaning to the “optimized” urban infrastructure that also includes landscaping features [refer to Mangone, 2015 in the Buildings and their Operational Partners at work” section]. It is important to add that the City required the commercial spaces on the ground floor accessible only from the outside to animate the streets despite both heat and cold during all seasons.

The design and construction of the MH building were unprecedented in the world, constituting a real model, setting new standards for sustainable design, energy savings, building performance and the comfort of employees in the workplace. At the same time, it can be a model for optimizing the use of passive energy in similar buildings erected any climatic conditions. MH building has only 152 parking places on one underground level the building has a perfect connection to public transport. Before opening, 95% of employees commuted to work by cars from the old buildings; less than half a year of work in a new building, 50% used a different form of transport than a car. In all, the building contributes enormously to the municipal infrastructure through all its features and long-term strategies.

Basic construction facts of Manitoba Hydro building

Construction: 2006-2008 Area of the building: 64,590 m^2, Height: 88.6 meters at the top of the building, 115 meters to the top of the solar chimney, Number of users: approx. 2000; Number of floors: 22 with the technical storey and so-called podium. Storey height: 3.1 m; Typical floor area of 1850 m^2; Actual values of airtightness of the building envelope: 0.02 m^3 / h / m (at 150 Pa); U-values for elevation: 0.227 W / m^2K; For green roofs and inverted roof assemblies, the thermal coefficients have been additionally increased to provide maximum values: U = 0.162 W / m^2K

5. "Condé Nast Building"[6]

W.Kujawski, Advanced Buildings Newsletter "# 25" (Canada), 2000,

Designed before the LEED Certification, the tower is a pioneer in sustainable design; saving close to 50% of the energy of comparable buildings when it was built[7].

How environmentally sustainable can a 48-story urban high-rise office building be? It is a difficult question to answer. Such "monsters" have traditionally been considered anything but "green." On the other hand, this high-rise building can be justified by its consolidation of space and energy services, mass transit access, minimum envelope area, material distribution, ease of communication, self-contained amenities, and its efficient use of precious and extremely expensive land. All these measures contribute significantly to the New York's infrastructure.

Architects can agree that urban high-rise architecture is having an ever-increasing impact on the built and natural environments. The vertical nature of this building and economic constraints, particularly those coming from the developer/tenant dynamics, had the most considerable influence on the application of "green" design. They required all parties to work together with challenges when applied to modern speculative buildings, but it is exactly the reason of presenting

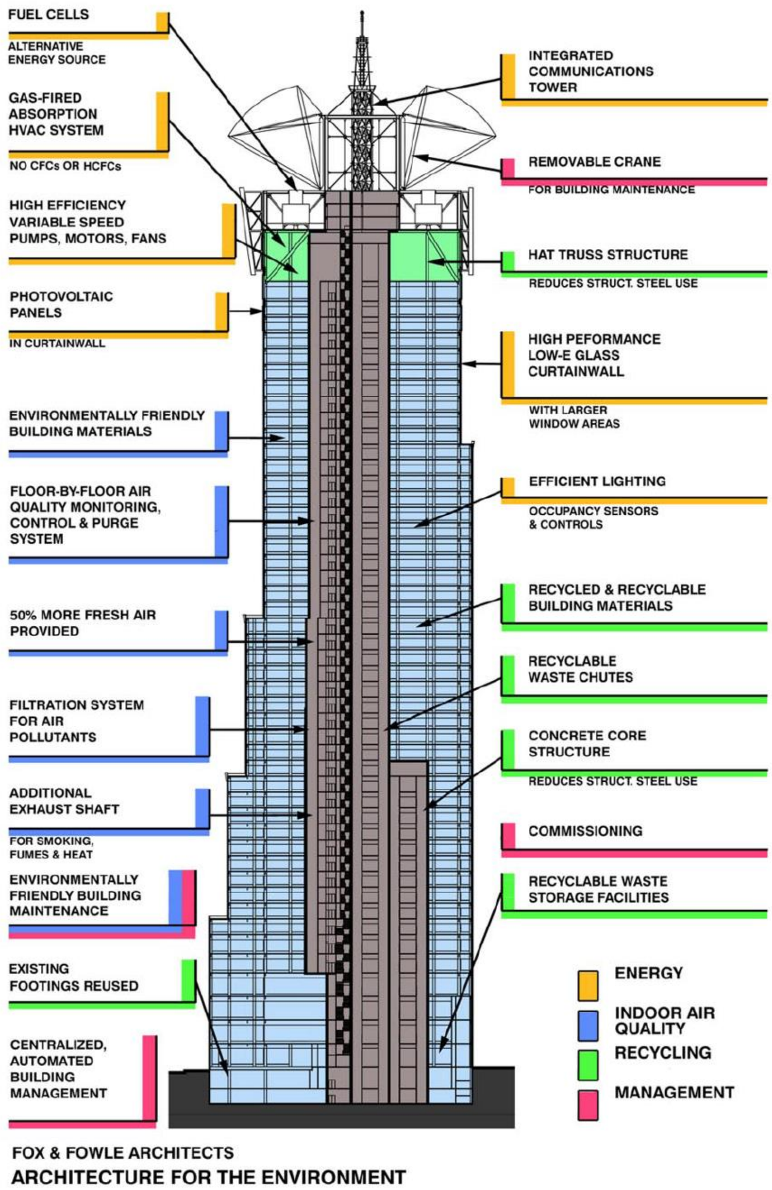

Figure 26. 4TS with all systems as planned. Source: F&F Architects

[6] http://iisbe.org/abn/down/4TS.pdf

[7] Source: http://www.fxcollaborative.com/projects/46/3-times-square/ accessed May 2018

the "lessons learned" to others so the benefits could be shared by all, including the municipalities taking care of the infrastructure issues.

In case of 4TS (its address: 4 Times Square), the integrated design approach, as in the Manitoba Hydro building almost 20 years later, required extremely close coordination and extensive communication among all design team members, clients, contractors, various consultants, suppliers, and technicians from related industries.

Robert Fox from Fox & Fowle Architects (today: fxcollaborative) - based in New York, talked about the process and said, "Our group was working together in an unprecedented way. Never before, have I felt this sense of teamwork and pulling together on a project. We were not wasting time in different directions we had one purpose, one goal - the ' environmentally responsible building."

Lessons learned [after Kaplan, 1999]

Some examples, by Dan Kaplan of Fox& Fowle Architects of the "design and build" process are edited and complemented with additional information gathered by the author in F&F and Cosentini (engineers) offices in New York in 1999/2000 [Fig.26].

Glass selection – daylighting

Architects had little influence over the tenants' selection of daylighting strategy and no control over their interior layout. Since light shelves were discarded as an option (a significant projection beyond the building line would have violated NYC's code), very large windows were chosen (2.1 m high out of a 2.7 m ceiling height) with a high visible light transmittance glass (0.4 and 0.66) and a good shading coefficient of 0.30.

Central cooling plant

Natural gas-fired, low-emission absorption chiller/heaters were chosen and located on the roof.
Such equipment is closely related to emissions-based legislation or incentives which would ensure that future installations take into account their impact on the environment [Fig.27].

On-site electrical generation

With the objective of generating energy on-site without losses during transmission and by utilizing alternative energy sources, two solutions were provided: fuel cells and photovoltaics.

Fuel cells

Fuel cells generate electrical power through the combination of hydrogen and oxygen under controlled conditions. The process produces power without the byproducts of combustion, and the only emission is water. In the case of 4 TS, the source of hydrogen is natural gas [Fig.28].

Photovoltaics

Only integrated solutions like PVs embedded in part of the building's skin and not rooftop will offer a reasonable payback (*author's note: it was done in late 90-ties, well before PVs started to be seen as economically viable*). In this case, the cost of the "replaced" area of the curtain wall is credited to the cost of the PV panels placed in an 18.2 m wide area at the center of the southern and eastern sides of the building on the upper 14 floors. The peak output of the installation is about 15 kW, roughly equaling the electricity required to run five or six suburban homes.

Waste

The approach to the segregated waste was one of the first in New York [Fig.29].

Figure 27. Technical 49th Floor. Source: W.Kujawski

Figure 28. Fuell Cells. Source:W.Kujawski

Figure 29. Waste segregation. Source:W.Kujawski

Conclusions 6

Even building located “in the middle of the world” and built by developers who were never green before, can become a symbol of green. Early aspects of a very conscious environmental design can be seen and then followed while the infrastructure aspects can also be very evidently observed starting from energy and water efficiency, waste treatment through to transportation ease and renewable energy on site. An additional aspect is reserved for human factors such as occupants satisfaction from most of the measures providing stable occupancy thus limiting vacancies and unused urban spaces contributing indirectly to the infrastructure loads.

7. EQuilibrium Housing Initiative, Urban Ecology Home[8], Winnipeg, Manitoba

CMHC Project Officer: W.Kujawski, 2007-2012

The EQuilibrium™ Housing Initiative was launched in 2006 to demonstrate ways of achieving more sustainable housing in Canada bringing together the private and public sectors to design, build and demonstrate market-ready and cost-effective sustainable housing solutions in most climates across Canada. The design and the construction of the EQuilibrium™ Housing projects included strategies to create a healthy home and to reduce the impact of housing construction and occupancy on the environment. The Initiative presented a holistic and integrated approach to sustainable housing based on five sustainability performance themes and twenty-six indicators to address occupant health and comfort, energy conservation and renewable energy production, resource conservation, reduced environmental impact, and affordability.

The author was the leading force in the creation of the technical guidelines for the initial NetZero Energy Healthy Housing renamed later into the EQuilibrium™ Sustainable Housing Initiative. He took part in the entire process becoming later the CMHC project officer for the Urban Ecology in Winnipeg, Manitoba, presented below with thesis related features, and the Annex Project in Toronto, which was later canceled due to the 2008 market crash in North America. The Urban Ecology project became one of the best examples of affordable housing significantly cutting energy and environmental impacts on surrounding urban infrastructure. The description takes into consideration only high-level aspects of a design with no details; however, with the results of monitoring, the contribution to the infrastructure can easily be seen, proving that the similar concept of so-called NetZeroReady can be used almost anywhere.

Figure 30. EQ Urban Ecology on the left, R-2000 on the right, just before the opening day, Winnipeg, Manitoba. Source: W.Kujawski

Urban Ecology is a new, two-story, semi-detached 103 m^2 home [Fig.30] with a full basement. It is located on an infill site [Fig.32] Downtown Winnipeg in the area that is currently undergoing revitalization and is within walking distance of a wide variety of amenities including shops, public

[8] ftp://ftp.cmhc-schl.gc.ca/chic-ccdh/Research_Reports-Rapports_de_recherche/eng_unilingual/Ca1_MH_14U62_w.pdf

transit, and parks in the center of Winnipeg. The other semi-detached part is built to the R-2000 standard, for years a symbol of high performance in Canadian housing industry.

The well insulated, air-tight building envelope, and the other energy-efficiency [Fig.31]features of the Urban Ecology home were designed to reduce the household energy requirements to be much less than the annual energy requirements of a typical Canadian home with the balance of it to be met, in part, by renewable energy sources. They include passive solar space heating, active solar space and domestic water heating and photovoltaic (PV) electricity generation, minimal for the initial stage, but with the building ready for the full installation at any time.

The calculated EnerGuide for Houses (EGH) rating for Urban Ecology with renewable energy features (EGH) was 96[9]. The home achieved a final measured air change rate of 0.82 air changes per hour (ACH) at 50 Pascals. Urban Ecology also includes features that provide a healthy and comfortable indoor environment, and environmental considerations (e.g., land use planning, landscaping, solid waste management). Over the year of performance monitoring, Urban Ecology consumed approximately

Figure 31. Mechanical equipment in UE. . Source: CMHC

Figure 32. Urban context of the project. Source: W.Kujawski

70% less energy than a typical Canadian home of similar size, and renewable energy production met 62% of these reduced needs. Water consumption on a per capita basis was 43% lower than the Canadian average. Regarding indoor environmental quality, temperature, relative humidity, radon, and total volatile organic compounds (TVOCs) were well within published acceptable limits.

Conclusions 7

The main idea of this project is to present an unlimited possibility of a construction of so-called Net Zero Ready buildings that are resilient and with little or no maintenance itself and have a huge impact, if built in numbers, on every aspect of the surrounding infrastructure including energy, potable, grey and black water, stormwater and waste.

[9] On a scale 0 to 100, 0 is a very inefficient home, 80 is a standard for R-2000 energy level, 100 means net zero

8. Residential Solar Mass Wall Analysis for Canada[10]

CMHC, 2007 - (W.Kujawski, CMHC Project Manager with Habitat Design + Consulting Ltd.

https://www.cmhc-schl.gc.ca/odpub/pdf/65861.pdf**How to optimally use the potential of the sun depending on the location?**

That was one of the most important questions posed by all housing stakeholders. Some answers came from two following projects; however, they only signal the beginning of a long process of analyzing all aspects of such problems. The analysis for Canada is, as usual, quite complicated due to many very different climatic zones. For that reason, the application of specific technologies might be simple in one zone, but entirely impossible in another.

Passive solar heating offers great promise for reducing the use of conventional heating fuels in Canadian houses. Direct gain is the most common form of passive solar heating. Sunlight enters through south-facing windows, where it heats the room interior and the heat is stored in the building's fabric to be released later.

This study explores the performance of another type of passive solar heating system—the mass wall that holds the promise of being able to provide passive solar heating in situations in which direct gain is not suitable. A mass-wall solar heating system places a 200 to 300 mm thick concrete wall behind southward-facing glazing.

The wall surface behind the glazing is painted a dark color, usually black, or covered with a selectively coated metal foil. Sunlight passing through the glazing falls on the outside face of the wall, heating it up. Then the heat is conducted through the concrete wall and transferred to the room behind the wall by radiation and convection [Fig.33]

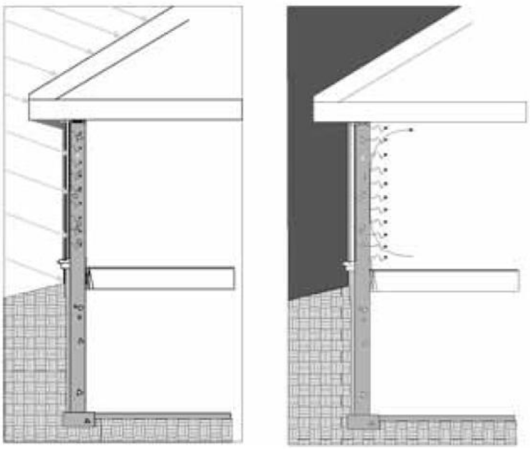

Figure 33 Mass wall day and night. Source: CMHC

A variation of this type of passive solar system, in which high and low vents are located through the concrete wall, is referred to as a Trombe wall [Fig.34] after the French architect who introduced it. In such a wall, heat is transferred both

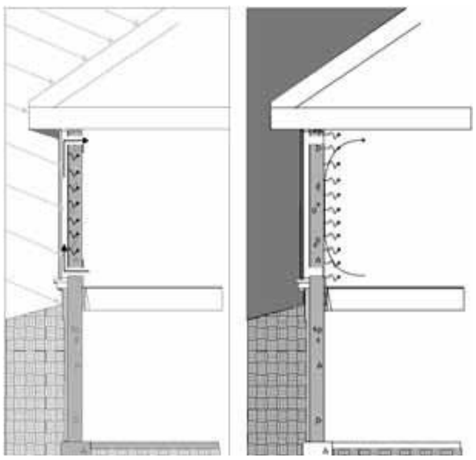

Figure 34. Trombe wall day and night. Source: CMHC

10 https://www.cmhc-schl.gc.ca/odpub/pdf/65861.pdf?lang=en

through the wall by conduction and by the movement of air due to natural convection. Air located between the glazing and the outer face of the concrete wall is heated and rises, entering the room through the upper vent to be replaced by cooler room air that enters the Trombe wall through the lower vent at the base of the wall. The vents are closed at night to prevent cooling.

This research investigated mass walls as an alternative to direct-gain passive solar heating and the study consisted of three tasks:

- To develop representative sample homes that could be used in computer modeling
- the input of archetype data into Suncode, a PC version of SERI-RES or SUNREL software with the capability to model mass wall and Trombe wall passive solar heating systems
- Running hourly mass wall performance simulations in Suncode

Sensitivity runs were performed in which a portion of the south wall area of each of the archetypes was replaced with a mass wall of varying characteristics. The objectives of these runs were to determine the predicted hourly temperatures on the inside surface of the mass wall for a typical clear winter day.

Conclusions 8

Mass or Trombe (vented) walls replacing well-insulated south walls yield relatively small reductions in space heating loads even with selective surfaced walls and high-performance glazings. The most significant reduction is achieved in the milder Canadian West Coast climate.

Venting the mass wall has a minimal effect on space heating load reduction (three to five percent more) relative to an unvented mass wall. More daytime load is offset, but less evening load. Air temperatures in front of the mass wall are reduced with venting. If combined with direct gain there is a greater potential for overheating of the room behind the mass wall.

A higher conductivity wall affects similar to reducing its thickness. Energy performance suffers slightly with decreased thickness and higher conductivity. Black-surfaced walls with double-glazed, low-e glazings are net energy losers in better-insulated houses in the colder parts of the country. In most cases, room air temperatures were similar or lower with the mass walls than for the base cases.

Based on the best current solar energy absorber and glazing technology, mass walls do not appear to be a good feasible option for space heating in Canada; however, the analysis itself is beneficial for future attempts to justify such design in cases where the financial aspects will play a decisive role.

9. "Selection of Low-e Coated Glass for Older Residential High-Rise Apartment Buildings in Canada"[11]

CMHC, 2013, W.Kujawski as a Project Manager with G. Torok, GRG

This research provides a basic view of often neglected or simply misunderstood issue of a selection of glazing with high solar gain (HSG) and low solar gain (LSG) coatings. There exists a general assumption that there is one, ***a low-e coating*** but, unfortunately for some designs, that is not the case. The analysis adds to the combined knowledge of the building envelope assembly and its impact on energy efficiency and comfort. Both are closely related, impacting the infrastructure directly through the use of energy to heat and cool also providing, or not, occupant's satisfaction.

In older multi-unit residential buildings (MURBs), residents often report discomfort in apartments with sunny exposures, arising from solar heat gain through windows. Apartment buildings typically lack features to control solar gain (such as exterior shades, shutters) and space heating systems often don't have the flexibility to adapt to high solar heat gain (overheating) on sunny elevations and at the same time, to heat loss on non-sunlit elevations. Residents may seek relief by opening exterior windows and doors, wasting both solar heat gain as well as space heating energy. Since glazing is part of the problem, can it be part of the solution?

Figure 35. Test building in Otawa, Ontario. Source: CMHC

A research study was carried out in three apartments in an occupied building in Ottawa, Ontario (Figures 35 and 36). Three southeast-facing one-bedroom apartments in the building were fitted with equipment to monitor indoor air temperature, relative humidity, and solar radiation at the exterior of the building and received through window glazings. One Control apartment was left as-is with the existing, uncoated glazing; one was refitted with high solar gain (HSG) low-e glazing, and one was refitted with low solar gain (LSG) low-e glazing. Monthly visits were made to download

Figure 36. Test apartments facing east of south by 31 deg. Source: CMHC

[11] ftp://ftp.cmhc-schl.gc.ca/chic-ccdh/RHT-PenRT/67829.pdf

data, review apartment space heating and cooling operation and survey the residents of the test units on their perceptions of thermal comfort. At the end of the monitoring period, data and observations in the HSG and LSG apartments were compared to the control apartment to determine what effects, if any, of HSG and LSG low-e glazing, had on resident thermal comfort.

Decreased solar radiation received through HSG, and LSG low-e glazing corresponded to observed and reported increased use of space heating (higher thermostat settings and for a longer time) indicating that solar radiation can contribute to the heating of the space. However, a higher level of solar radiation can cause discomfort, such as experienced in the Control and HSG apartments in the fall and spring.

Factors contributing to the reduction of SHGC include transmission, reflection and absorption characteristics of glass, HSG and LSG low-e coatings applied to glazing and duration of sun exposure modified by building shape and orientation.

Conclusions 9

In apartments with sunny exposures, the use of LSG low-e glazing can be beneficial to improve resident’s thermal comfort in the spring and fall (the effect of overheating),. However, the inclusion of heat-loss reducing features would be advisable (triple glazing, argon gas fill, and warm-edge spacers) to address discomfort experienced by the resident of the HSG apartment by offsetting increased space heating usage. In buildings where entire windows and doors are to be replaced, thermally-efficient frame materials would further help reduce heat loss.

Residents reported discomfort in the summer, especially in the Control and LSG apartments even if the solar radiation received in the apartments is lowest in the summer, generally less than half of winter values. Direct solar radiation likely contributes to discomfort, but in the context of MURBs, LSG low-e glazing is of little benefit. Care should be taken in applying the results from this study to other buildings of different typology, size, and location.

Summary of Module 1

Presented and analyzed buildings constitute models for optimizing almost every aspect of the design that impacts on the infrastructure in its urban, or suburban environments. Buildings that use less energy overall reduce their dependence on fossil fuels and cut GHG emissions that contribute to smog, air pollution and on a global scale, climate change. Such reductions have direct or indirect impacts on municipal infrastructure which, with its usual deficits, offers opportunities to buildings to lessen their impact on or add to the capacity of its systems if only architects and engineers apply the appropriate design practices complementing them with appropriate technologies.

The critical aspects of buildings that can have an impact on infrastructure:

Net-positive energy buildings designed to produce more energy than they consume can free up capacity within established energy systems and provide safe, secure and reliable sources of energy. Buildings that include all water treatment systems and also manage stormwater can reduce the impact on, or eliminate the need to be connected to municipal water systems. The buildings built to the best standards will minimize the expansion of infrastructure to the minimum required and every step towards the efficiency of buildings contributes to the optimization of the infrastructure as well.

Most significant recommended measures for MURBs and commercial buildings through the corroboration of research for both:

The studies for MURBs and commercial buildings show that several architectural form parameters can significantly impact the annual heating and cooling load intensities. The most critical factor, relatively independent of the building geometry, was the combined building envelope performance considering wall insulation value, window U-value and window solar heat gain coefficient (SHGC), and the window-to-wall ratio (WWR). Floor plate geometry and building orientation typically have minor impacts on heating loads and slightly more significant impacts on cooling loads (being always within close range of one another). Good envelope performance is essential, and it allows freedom in massing/orientation and the building geometry.

One of the developed tactics is the use of a significant amount of insulation, minimized losses through the window frames (with location and orientation relevant glazing), use of thermal breaks, and the application of necessary airtightness. However, the amount of embodied energy in massive amounts of certain types of insulation and the impact of materials would bypass most of the energy savings from the increased performance.

By following the rules of an energy efficient design, the use of technologies can be either significantly mitigated or avoided entirely. Almost all roofs, being part of the envelope, can mitigate rainwater impact and heat losses and gains, can affect air quality, potential food production as well as the installation of solar collection/energy production systems.

As shown in the examples, net zero and net positive buildings and neighborhoods are becoming more and more commonplace—either as new construction or retrofits of existing buildings and building developments/ neighborhoods. Relatively easy construction of Net Zero Ready buildings that are resilient and with little or no special maintenance itself will have a huge impact, if built in numbers, on every aspect of the surrounding infrastructure including energy, potable, grey and black water, stormwater and waste.

In determining the environmental impact of the buildings, it is essential to take into account the perspective of buildings' life cycle through the approach called Life Cycle Assessment (LCA). It depends on used materials, the impact of the design itself, construction process, operation and maintenance during the period of use and the demolition. Such an assessment can provide useful insights into both durability[12] and resilience[13] of all relevant elements. The development of both the building and the infrastructure is influenced by the balance of benefits and losses and require a detailed study with all considered conditions.

The use of the low impact materials can significantly reduce the environmental burden of buildings. Durable materials and the buildings constructed with them can provide a better outcome and allow optimization of the resources required to maintain and repair buildings such as energy with its emissions, waste, and transportation therefore directly impacting the size and quality of the infrastructure.

The results from the study on Net Zero Energy home designs indicated that they were considerably more materially, technologically and hence energy-intensive if compared to the conventional building code requirements or more advanced Canadian R-2000[14] design baselines. However, the operating energy demand of the NetZero designs was found to be between three to five times lower than their comparable versions. The results also demonstrate that the energy embodied in the projects targeting net-zero energy consumption or better makes up a much more significant proportion of the overall life-cycle energy.

Designs and construction practices allowing for long useful lifetimes represent efficiency in resource use. The principle belongs to both the buildings and the infrastructure interchangeably affecting the direct energy consumption and the embodied energy related to the used materials in cradle-to-gate (extraction to operation) principle. It is necessary to understand better the implications of

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[12] the selection and integration of durable, low- maintenance building elements, equipment and systems that greatly reduce potential future risks, in the short and long term.

[13] future adaptability or "future proofing"—the selection of resilient building systems that can be adapted over the long term with changing demands on thebuilding including changes in energy sources, climate change and severe weather events.

[14] R-2000 is a voluntary standard developed by Natural Resources Canada (NRCan) in collaboration with Canada's residential construction industry.
R-2000 promotes the use of affordable, energy-efficient building practices and techniques, clean air features and other measures to help protect the environment. Certified R-2000 homes are on average 50 percent more energy-efficient than typical new homes. (source: https://www.nrcan.gc.ca/energy/efficiency/homes/20564 - accessed in May, 2018

material choices to ensure that operating energy objectives do not come at the expense of increased embodied energy use and environmental impacts.

Design of more durable building reduces the exposure of the building envelope to moisture, the primary building deterioration factor, through improved drainage around foundation walls, improved air tightness of the envelope and better weather protection of the facade. Use of slightly more, or of a higher quality, materials can significantly improve the durability of the building or its infrastructure. Designs must also take into account ease of maintenance and repair of the critical components in the building and should be forgiving — ensuring that a failure of any component of the building does not cause long-lasting, irrevocable damage. The typical financial problem is that shorter payback periods valuing ’the quicker, the better’ (not necessarily, the cheaper) usually disregards what the best for occupants and the environment is.

The research findings illustrate the benefits and trade-offs associated with the pursuit of high-performance design, namely, low operating energy consumption versus increased material usage and higher related embodied energy. The study shows that residential energy efficiency measures and renewable energy generation systems are effective means to lower overall life-cycle energy use and many environmental impacts—though not all.

The presented characteristics support the thesis: the use of specific materials in buildings, even if environmentally wrong, can contribute to the decrease of the energy consumption and, as proven, is a leading factor contributing to the size of the required infrastructure in both utilities and transportation services area.

However, it is imperative to look at all aspects of such contribution. High performance and resilient buildings and by default types of the neighborhood (always related to buildings) with their equally resilient infrastructure may stay in shape against the adverse weather or other events but can also contribute very quickly to the damage of the environment, and that is where and when the balance must be found.

Table of figures

Wojciech Kujawski, M.Arch, MRAIC

Impact of residential buildings life cycle on infrastructure

Module 2

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Introduction to the topic

The building industry uses vast quantities of raw materials that also involve high energy consumption. Choosing materials with high content in embodied energy entails an initial high level of energy consumption in the building production stage but also determines future energy consumption to fulfill heating, ventilation and air conditioning demands. [I. Bribrian, A. Capilla, A. Uson, 2011]

In determining the environmental impact of the buildings, it is essential to take into account the perspective of buildings' life cycle, depending on used materials, the impact of the design itself, construction process, operation and maintenance during the period of use and the demolition. This approach is called Life Cycle Assessment (LCA) and is used to quantify the impact on the environment: however, as with any complex model, assumptions and a degree of uncertainty are inherent to LCA. It is a misconception to expect LCA to deliver precise predictions of environmental impacts. LCA is an outstanding tool for estimating potential environmental impacts and comparing the relative performance of alternatives [O'Connor, Meil, 2012].

An LCA study can compare the most commonly used building materials with some eco-materials using different impact categories to deepen the knowledge of energy and environmental specifications of building materials, to analyze their possibilities for improvement and to provide guidelines for materials selection in the eco-design of new buildings and renovation of existing buildings. Such studies can prove that the impact of construction products can be significantly reduced by promoting the use of the best techniques available and eco-innovation in production plants. [I. Bribrian, A.Capilla, A.Uson, 2011]. That is precisely why the LCA is used to support the thesis in regards to the way we construct the buildings and neighborhoods with interconnecting infrastructure systems that create the "quality" of the built environment.

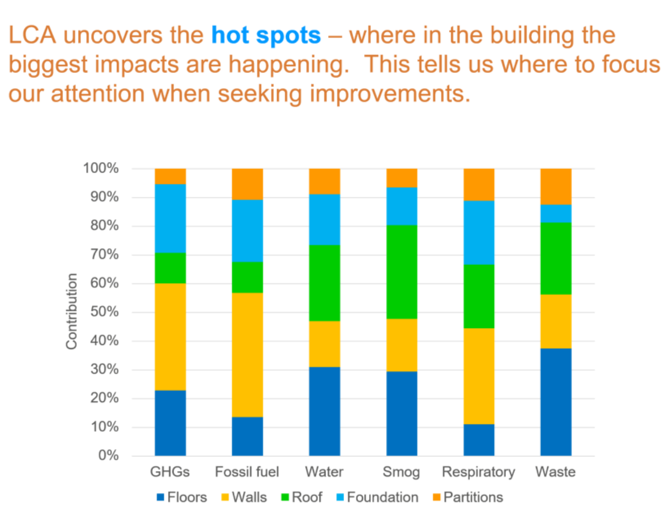


Figure 1. LCA hot spots. Source: Athena SMI

The LCA can provide useful insights into both durability[1] and resilience[2] of all elements of such an environment. The results of LCA research show that certain aspects of the high-performance buildings are suitable for specific reasons like, for example, energy efficiency, but at the same time such performance may be achieved by very "environmentally unfriendly" means such as production of a super energy efficient insulation that requires more energy than it would be saved later during the operational phase, even in a long term. The development of the infrastructure is influenced by the balance of benefits and losses and require a balanced study with considered conditions.

1 the selection and integration of durable, low- maintenance building elements, equipment and systems that greatly reduce potential future risks, in the short and long term.
2 future adaptability or "future proofing"—the selection of resilient building systems that can be adapted over the long term with changing demands on the building including changes in energy sources, climate change and severe weather events.

1. A Life-Cycle Environmental Assessment Benchmark Study of Six CMHC EquilibriumTM Housing Initiative Projects,

W.Kujawski, CMHC Project Manager, 2012 -with J.Meil - Athena Sustainable Materials Institute

Introduction

In 2006, CMHC launched a "Net-Zero Energy Healthy Housing" demonstration project that came to be known as the EQuilibrium™ (EQ™) Sustainable Housing Demonstration Initiative. The net-zero annual energy consumption target was relatively well understood regarding impact on annual operating energy use. However, what was not immediately apparent was how much more energy would have to be embodied in each of the houses over a given life- cycle period to meet such a high-performance objective and what the related environmental impacts would be [Meil, 2012]. Such a study appeared to be vital for balancing pro and cons of the newly coined expression of a Net Zero Building and its impacts on the environment. While the benefits of much smaller energy consumption are directly linked to the size of related infrastructure, the "cost" of them may sometimes be prohibitive, and that fact had to be evaluated properly. The author, working on the EQ™ housing, proposed the evaluation of all projects; however, not all of them were ready at that time.

Methodology

The Athena Sustainable Materials Institute undertook a 20-year life-cycle assessment (LCA) of the designs of six out of thirteen built EQuilibrium™ houses to evaluate the environmental performance and inherent trade-offs associated with achieving net-zero annual energy consumption. The LCA was compared to the energy and environmental impacts of more conventional and advanced housing methods that would be expected to have less embodied energy and lower environmental impacts associated with their delivery to construction.

The LCA study can best be characterized as a "cradle-to-gate" assessment, where the "cradle" is the earth (all material and energy systems are followed back to the earth) and the "gate" is the completed dwelling and its operation at the end of a predetermined period—in this case, 20 years up to the first point of the significant material replacements. The study quantified the energy and environmental impacts associated with the resource extraction, processing, product manufacturing, delivery, construction, operation and maintenance of the six projects to assess the relative benefits of achieving low operating energy performance given the higher anticipated energy inputs and environmental impacts over the selected 20-year life-cycle. Five projects were new builds, and one was a retrofit.

The manufacturing, construction, and maintenance stages are together the cradle-to-gate embodied effects of the structure and envelope materials. While not precisely a life-cycle stage, the "building service systems" effects were segregated from those associated with the manufacturing, construction, and maintenance activity stages. The segregation was done to specifically highlight findings regarding the mechanical and electrical services since they do not typically appear in dwelling assessments given the lack of publicly available data and these components are of particular importance regarding their influence on EQuilibrium^{TM} house baseline performance.

The life-cycle impact indicators selected and used in the study were those supported by the Athena Institute's Impact Estimator for Buildings software and based on the United States Environmental Protection Agency's (EPA's) Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) methodology, thus providing a North American context for the supported measures. The indicators were as follows:

- **Primary energy –** The sum of non-renewable energy sources that are drawn directly from the earth such as natural gas, oil, coal, or mineral fuels (for example, uranium). It included fuels combusted (to create and transmit) and used as fuel energy and is expressed in megajoules (MJ).
- **Global warming potential (GWP) –** TRACI uses global warming potential for the calculation of the potency of greenhouse gases relative to CO_2. GWP can be considered one of the most accepted life-cycle impact assessment categories.
- **Acidification –** Processes that increase the acidity (hydrogen ion concentration, [H+]) of water and soil systems (as per TRACI). Acidification is a more regional rather than global impact, affecting freshwater and forests as well as human health.
- **Human health (HH) respiratory effects –** The TRACI midpoint based on exposure to elevated particulate matter (PM) found in the air, including dust, dirt, soot, smoke, and liquid droplets less than 2.5 micrometres in diameter (PM2.5) that are referred to as "fine" particles and pose the greatest health risks. Particles less than 10 micrometers (PM10) can be inhaled and accumulated posing also a health risk.
- **Eutrophication –** Fertilization of surface waters by nutrients that were scarce (as per TRACI). It encompasses the release of mineral salts and their nutrient enrichment effects on waters. The result is expressed on an equivalent mass of nitrogen (N) basis.
- **Ozone depletion –** This is the reduction of the protective ozone within the stratosphere caused by emissions of ozone-depleting substances.
- **Smog –** Caused by air emissions from industry and transportation that, under certain climatic conditions, can be trapped at ground level. In the presence of sunlight, the emissions produce photochemical smog, a symptom of photochemical ozone creation potential (POCP). The "smog" indicator is expressed on a mass of equivalent ethylene basis.

- **Solid waste –** Summarizes the life-cycle impact of solid waste flows and is expressed in kg. It does not include occupant-related household waste.
- **Water use –** Summarizes the life-cycle impact of water usage flows associated with the production of materials and energy and is expressed in m^3. **It does not include occupant-related household water consumption.**

The study was based on design information received for each dwelling, which included construction drawings, technical submission materials, and a HOT2000 operating energy simulation file. All were used to calculate the materials used for each dwelling as well as those that would be used for the building code and R-2000 baseline cases. The conventional and advanced versions of the EQ™ projects were modeled in HOT2000 (v10.5) to determine annual operating energy use. The resulting material quantities and energy use were then entered into the Athena Institute's Impact Estimator for Buildings (v4.1) software and proprietary LCA software SimaPro (v7.18) to provide a complete life- cycle analysis of each dwelling scenario.

Results

The six dwelling units that were assessed varied regarding housing type, size (a significant factor as it directly relates to the conditioned space volume) and location. All six are located in one of three provinces—Alberta, Ontario or Quebec and faced a unique number of heating degree-days (HDD), varying between 3,650 and 5,700. All the dwellings were very airtight, thus making mechanical ventilation a necessity.

Predicted annual on-site energy use for the six EQuilibrium™ projects was calculated to be between 41 and 99 kWh/m2 and the annual total predicted on-site renewable energy production was estimated to vary between 29 and 82 kWh/m2 across the six dwellings, with two of them (Inspiration and Riverdale) producing more energy than they annually consumed.

The results of the analysis indicated that the EQuilibrium™ houses are considerably more materially and technologically intensive relative to the conventional or advanced housing. However, the energy demand of the EQ™ dwellings was estimated to be between three to five times lower. The environmental impact of the renewable energy and energy recovery systems used in the EQ™ dwellings were estimated to be significant and accounted for up to 30% of the total embodied effect of the dwellings over the first 20 years of operation.

As the dwellings are estimated to attain or approach a net-zero operating energy result, the materials embodied in each dwelling become more significant. For example, the material-related primary energy percentage is considerably lower for the renovation project, because the original materials costs were ignored in the assessment. As is evident, almost all of the environmental indicator results are primarily a function of the materials embodied in the dwellings.

The manufacturing of the materials required to construct each dwelling dominates consumption. The building service systems portion of the figure includes the embodied effects of heating, cooling and ventilation equipment, plumbing and electrical, and renewable energy systems. These systems are responsible for 11% to 32% of primary energy and 10% to 30% of the overall GWP impact.

Although the EQ™ baselines may be more energy-intensive to build, over the longer term, the lower operating energy associated with net-zero, or near net-zero, annual energy consumption results in overall reduced energy use.

Conclusions 1

The results indicated that the EQ™ designs were considerably more materially, technologically and hence energy-intensive relative to their conventional OBC or R-2000 design baselines. However, the operating energy demand of the EQ™ designs was found to be between three to five times lower than their comparable conventional and R-2000 versions. The results also demonstrate that the energy embodied in the projects targeting net-zero energy consumption makes up a much larger proportion of the overall life-cycle energy.

The embodied effects of the materials and technologies employed accounted for 84% to 100% of the dwelling's overall impact during the 20-year life-cycle period. The environmental impact of the renewable energy and energy recovery systems used in the EQ™ designs were also found to be significant and were estimated to account for up to 30% of total the embodied effect of the dwellings over the first 20 years.

Relative to the OBC and R-2000 benchmarks analyzed, over the 20-year, cradle-to-gate study period, the EQ™ baseline designs showed a reduction in primary energy consumption, global warming, acidification, and human health respiratory effects; an increase in ozone depletion, water use and smog (except for one project); a reduction in solid waste for 50% of the projects; and generally about the same performance in terms of eutrophication.

The results show that designers can significantly reduce the environmental burden of housing by selecting materials of the lower impact that perform the same function and by being aware of the local electricity generation mix. For example, some locations rely on coal-based generation, other on electrically powered systems that are responsible for much higher environmental impacts than natural gas-fueled systems or where lower-impact hydroelectric dams dominate electricity generation.

Implications for the infrastructure

These findings illustrate the benefits and trade-offs associated with the pursuit of net-zero energy design, namely, low operating energy consumption versus increased material usage and higher related embodied energy. The study shows that residential energy efficiency measures and renewable energy generation systems are effective means to lower overall life-cycle energy use and many environmental impacts—though not all. As housing design becomes even more energy-efficient in the future, the embodied contribution will become a greater share of total life-cycle effects. It will become necessary to understand better the implications of material choices to ensure operating energy objectives do not come at the expense of increased embodied energy use and environmental impacts.

All aspects presented above play a role in support of the thesis: the use of specific materials, even if wrong environmentally, can contribute to the mitigation of the energy consumption and neighborhood types, relevant to the urban issues, is a leading factor in the size of the infrastructure in both transportation and services area.

When considering buildings as contributors to the infrastructure, it is imperative to look at all aspects of such contribution. High performance and resilient buildings and, by default, its resilient infrastructure will stay in shape against the adverse weather or other events, but can also contribute very quickly to the damage of the environment, and that is where and when the balance must be found.

2. CMHC, 2008-Environmental Impact of Housing in Canada

Authors: Marbek Resource Consultants: B. Kynoch, M.Adelaar, M.Trudeau, J.Cuddihy Athena Sustainable Materials Institute: J.Meil, JaneThompson Architect: J.Thompson. Canada Mortgage and Housing Corporation: Project Manager - M. Ogden, Reviewer- W. Kujawski

This research presents the impact of the housing developments, the most environmentally damaging factor in the construction industry not because of its intensity, but the scale of it. Such developments even with highly used sustainability principles consist of more and more sophisticated infrastructure, and in a much larger macro-view of a vast country like Canada, it may be a warning to those developing multiple neighborhoods or communities of the energy and water efficient buildings without a holistic look at all pieces of the puzzle. Any environmental consideration given to the housing as a whole is passed automatically to all its components including infrastructure that is holding a prominent place in the entity of housing. When buildings contribute to the infrastructure they affect the environment; however, it is not a naturally positive or a negative role they play, so the results of this research related to the subject of the dissertation require a careful, balanced approach which is shown in the Final Synthesis supporting the thesis.

The author was an official reviewer during the duration of the contract and contributed to the final report and also presented the finding at SB08 conference in Melbourne, Australia under the title: *"How the results of the EQuilibrium^{TM} Housing Initiative could affect the future of Canadian housing."* The whole idea of such research was well timed when the environmental issues and warning about the lack of herewith, were coming from all parts of the globe. To correctly understand and assess the matter and the conclusions that follow, the methodology and partial, mostly thesis related, results, are presented. The study assumes the basic knowledge of the life-cycle analysis (LCA).

Introduction

Where we live, what we build, and where we build, have tremendous implications for environmental impacts during all life-cycle stages of development. Approximately 80% of almost 38 million Canadians live in urbanized areas (in about 13 million dwelling units) where urban development patterns currently include both continued low-density development and increased densification. This study attempted to quantify and describe the life-cycle resource use, environmental outputs, and resulting environmental impacts of Canada's residential sector. [Marbek, 2008].

Main aspects of environmental impact associated with past and current housing developments in Canada (up to the year 2025) and methodology of the approach

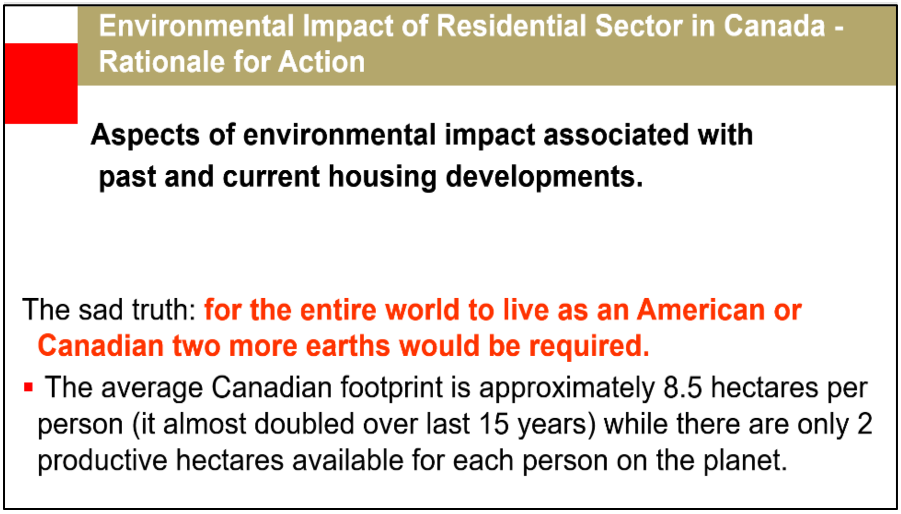


Figure 2. Environmental Impact. Source: W. Kujawski, SB08, Melbourne

A study for CMHC *(by Marbek et al.)* was based on two aspects. Firstly: on regional and global environmental outputs (emissions) of residential sector contributing to broader environmental impacts such as acid rain, smog, climate change, biodiversity decline, and Arctic contamination.

Secondly: on the evaluation of different scenarios for dwellings, neighborhoods, and infrastructure to develop the future mechanisms for establishing long-term policy goals and objectives.

The rationale for action through the relevant Housing Data Findings *(Marbek et al. 2007)*

Figure 3. The Challenge. Source: N.Larsson

- single detached houses account for about 57% of 12 million dwelling units in Canada and continue as the dominant dwelling type until at least 2025.
- only 25% of the estimated 16 mln dwellings projected for 2025 will be built after 2004.
- reductions in environmental impacts would be limited unless the condition of existing dwelling stock is upgraded (retrofits).
- there are significant opportunities in new housing regarding “getting it right the first time”.

Residential sector - overall resource use and environmental outputs:

- the operating stage dominates overall environmental outputs with 75%–95% of the total life-cycle environmental outputs during 2004–25.
- operation of dwellings and residential transportation dominate life-cycle energy use (almost 50% and 45% respectively) of the total life-cycle primary energy use during 2004–25.
- choices such as neighborhood and dwelling, dwelling conditions (e.g., envelope, equipment), and daily behaviors (e.g., heating/cooling, hot water use) have a considerable influence over how much life-cycle energy is needed.

Each life-cycle stage for residential structures and activities (e.g., dwellings, neighbourhood infrastructure, residential transportation) requires *resource use* (e.g., energy, water, land, and solids) and creates *environmental outputs* (e.g., emissions to air, water, and soil), which both result in local, regional, and global *environmental impacts* (e.g., climate change, loss of habitat).

Life-Cycle Stages

This study includes analysis of:

- Residential sector structures and activities such as**:**
  - **by dwelling type -** Existing, renovated, and new dwellings;
  - **by infrastructure type -** Existing and new neighborhood infrastructure
  - and by private vehicle and urban public transit **- Residential transportation**,;
- **Life-cycle stages** such as ***Operating*** (direct and indirect); and ***Non-operating*** (extraction, manufacturing, transportation, construction, maintenance and replacement);
- **Environmental impacts** such as: ***Resource use*** (energy, water, land, and solids); ***Environmental outputs*** (air, water, and soil emissions); and ***Resulting environmental impacts*** (local, regional, and global impacts on air, water, soil/land, and biota), attributed to the residential sector, where possible;
- **Estimated impacts in 2004 and potential impacts by 2025** through a business-as-usual (BAU) scenario[3], assuming no significant paradigm shift in dwelling construction and

[3] A *scenario* is a plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (e.g., technology changes, energy prices). A scenario is neither a prediction nor a forecast. (Source: Natural Resources Canada. 2006. *Climate Change Impacts and Adaptation: A Canadian Perspective* — Scenarios section.)

neighborhood infrastructure needs, except for the densification and land development practices;

- End-use categories for energy and water; and
- Neighborhood types.

Results & Implications

Based on the study scope, approach, and methodology described in the research report and its findings related to the thesis relevant to the infrastructure, some answers to the following high-level questions are provided:

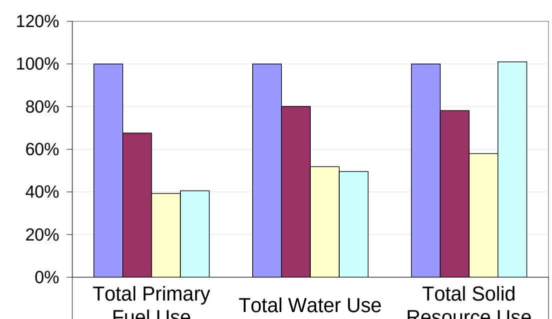
- Which residential sector life-cycle stages have the highest environmental impact?
- How are housing and neighborhood development patterns expected to evolve?
- How do choices of the neighborhood, dwelling, and dwelling operation affect the environment?

Overall Impacts

The two most important findings are that **the operating life-cycle stage (direct and indirect) has a much bigger environmental impact than other life-cycle stages**; and that the **reductions in these impacts are limited unless existing dwelling stock is addressed.** Factors such as neighborhood and dwelling choices, dwelling condition (e.g., envelope, equipment), and daily behavior (e.g., heating/cooling, hot water use) would have a considerable influence over how much life-cycle operational energy is needed by the residential sector.

Among *dwelling types*, single detached houses would have the highest environmental outputs(…) requiring significantly more life-cycle resources and producing significantly more life-cycle air, water, and soil pollutants.

Among *neighborhood types*, outer suburbs would have the highest environmental outputs per dwelling. They would require roughly 50% more life-cycle resources than dwellings in inner suburbs and roughly double that of dwellings in inner-city neighborhoods.



	Total Primary Fuel Use	Total Water Use	Total Solid Resource Use
Single	100%	100%	100%
Row/Town	68%	80%	78%
Low-rise MURB	39%	52%	58%
High-rise MURB	41%	50%	101%

Figure 4 : Life-cycle Resource Use per Dwelling during 2004–25, by Dwelling Type, Normalized to Single Detached. Source: Marbek

Similarly, dwellings in outer suburbs would produce roughly 30% more life-cycle emissions and pollutants than dwellings in inner suburbs, and roughly 25-100% more than that of dwellings in inner-city neighborhoods.

Residential transportation

Environmental outputs would be second only to dwelling impacts and would be driven mostly by choice of neighborhood type. Where one lives and how one moves results in almost as much air, water and soil emissions and pollutants as the home one lives in and how one operates it. Regardless of dwelling type, neighborhood type contributes to the transportation pattern of residents.

Water impacts

Dwelling (household) water use would continue to dominate life-cycle water use. This study assessed water use for material extraction, manufacturing, and transportation; fuel extraction, refining, and distribution; electricity generation; and dwelling operation. The water use from dwelling operation would account for over 80% of the total life-cycle water use of the residential sector over the study period. Annual water use in existing dwellings would decline, but total water use would still increase due to the growth of the residential sector. The aquatic environment would be significantly impacted by the residential sector**.** The intensity of water use and how it is managed has two major dimensions: the depletion of the water resource; and the effects on water quality. Water quality is only partially addressed by urban treatment infrastructure; while most of the metropolitan population on sewer systems in Canada is serviced by secondary wastewater treatment - a biological process that is not designed to remove **all** of the contaminants in wastewater. At the same time, about 30% to 50% of storm-water and snowmelt in urban areas is converted to surface runoff and, if treatment systems are in place, these typically are designed to address only a few pollutants.

Land & Soil Impacts

Changing land use patterns requires careful targeting of activities to reduce environmental impacts. Given expected neighborhood development patterns, one challenge would be how to mitigate the effects of housing development and use in existing neighborhoods. Land use patterns can be characterized regarding amount, density, mix and location of housing, and these patterns, directly and indirectly, affect infrastructure requirements, transportation mode choice and the building stock which, in turn, impacts energy and other resource use. Studies have identified land conversion for human uses, resulting in habitat loss and fragmentation, as the main driver of reductions in ecosystem services (e.g., life support) and biodiversity. However, suburban expansion and associated consumption of land would decline significantly compared with the patterns in the past 30 years or so, and urban intensification policies and initiatives would result in existing neighborhoods absorbing most of the new dwelling stock to 2025. These changes would mean environmental mitigation actions would need to address urbanization with its infrastructure within existing boundaries. Urban planning to reduce stormwater runoff and to protect aquatic ecosystems would be needed, as there is evidence that urbanization degrades ecosystem services to a higher degree than conversion to agriculture.

Land impermeability would increase, with implications for air and water quality.

This study assessed land consumption (regarding quantity and type), the amount of green space and impervious surface areas, infrastructure requirements (road, piping), and stormwater runoff quality and quantity. As a result of development, roughly 45% of urban land in 2025 would be classified as *impermeable* (i.e., cannot absorb water), meaning that fundamental changes to the water cycle would occur unless management measures are taken, for example, to allow groundwater recharge. Also, the increased impermeable area would intensify the "heat island" effect which, in turn, could produce secondary effects on local wind patterns, the development of clouds and fog, the number of lightning strikes, rates of precipitation, and smog.

Conclusions 2

Land use patterns can be characterized in terms of amount, density, mix and location of housing, and these patterns, directly and indirectly, affect infrastructure requirements, transportation mode choice and the building stock which, in turn, impacts energy and other resource use. Regardless of dwelling type, neighborhood type contributes to the transportation pattern of residents.

Even if the annual water use in existing dwellings would decline, total water use would still increase due to the growth of residential sector which would significantly impact the aquatic environment. The water use and its management have two major dimensions: the depletion of the water resource and the effects on water quality which is only partially addressed by urban treatment infrastructure.

The two most important findings are that the operating life-cycle stage (direct and indirect) has a much bigger environmental impact than other life-cycle stages; and that the reductions in these impacts are limited unless existing dwelling stock is addressed with such life-cycle energy influential factors as neighbourhood and dwelling choices, dwelling condition, and occupants behavior.

When considering dwelling types, single detached houses would have the highest environmental impacts, and among neighborhood types, outer suburbs would have the highest environmental outputs per dwelling. Those impacts will be mirrored infrastructure wise thus the consideration should be given to these aspects areas of housing developments.

3. Post Occupancy Evaluation (POE) for MURBs[4]

CMHC, 2014, W.Kujawski, CMHC Project Manager with Morrison Hershfield
and

"How Post Occupancy Evaluation (POE) can benefit owners, designers and occupants of new and existing residential buildings."

W.Kujawski, 2013 - Conference proceedings CESB13, Prague

The author proposed, initiated and managed this innovative project because insufficient information is available in the public domain on the performance of multi-unit residential buildings (MURBs). The work has been conducted by the engineering firm Morrison Hershfield [MH], and the author presented the methodology and preliminary results at Sustainable Building conferences in Toronto (2012) and in Prague (2013).

Both the report [MH] and Prague presentation [WK] are used here alternately for purposes of complementing the summary proving the thesis, while also showing the continuous work on methodology. Only relevant subjects and data are presented here to support the thesis.

POE is based on a much, much older "performance concept" mentioned in the Code of Hammurabi 1800 B.C. and describing: "**what a building is required to do and not how it is to be constructed and that meant that a building should not kill or injure anybody, on pain of death."**

The information obtained throughout the process could help to identify improvements to the benefit of building owners and occupants and to develop benchmark data on performance indicators to further develop building codes, regulations, and guidelines. Evaluating the performance of new, innovative building systems and practices in new construction or retrofits can show whether predicted benefits are actually delivered, potentially easing their adoption by industry and regulators.

One of the best methods of obtaining performance data on MURBs is the Post-Occupancy Evaluation (henceforth called POE) of existing buildings under actual operation [MH, 2012].

POE is a performance assessment of real buildings under actual operating conditions, after all, systems are up and functioning well – usually after a year of full occupancy.

The overall significance of the POE process in relation to the infrastructure is not to be underestimated. The performance of buildings directly impacting on their contribution depends not only on the technical aspects but also on the occupants satisfaction and behavior which may lead to their activities as simple as opening the windows to ease the overheating thus impacting the energy use or closing the shutters due to the glare, thus requiring artificial light to be switched on.

[4] based on **"POE Methodology :** Morisson Hershfield /CMHC, 2012

What can we / should we do to get knowledge about the building performance?

- Ask its occupants, work with the results
- Moreover, measure and assess building's performance

Figure 5. Toronto Tower Renewal , Source : University of Toronto, CMHC

POE typically includes building monitoring to support the findings of the user surveys such as levels of satisfaction, comfort and assess the level of success of various design strategies in meeting design performance targets or known reference baselines. The collection of data qualifying the performance of a group of buildings may also serve to establish baselines and benchmarks[5] where none exist.

It fits in with building performance evaluation or verification, which includes some activities taking place during a building's lifecycle to determine "whether facilities will work for the people that will use, occupy or otherwise be impacted by them" [Mallory-Hill, Preiser, and Watson, 2012].

A POE methodology has been developed towards the following objectives:

- To compare the overall performance of a building relative to baselines or benchmarks.
- To determine the extent to which a building meets their occupants' and the building management team's needs and satisfaction.

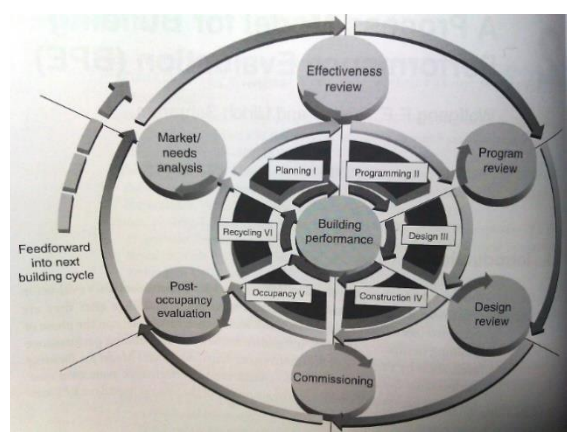


Fig.6. BPE process model- "Enhacing Building Performance" , Mallory-Hill, Preiser and Watson

[5] A baseline is defined as "a usually initial set of critical observations or data used for comparison or control"; a benchmark, on the other hand, is "something that serves as a standard by which others can be measured or judged" [Merriam-Webster, 2012].

- To provide feedback on the building design, construction and commissioning process.
- To evaluate the success of specific innovative measures and systems, and unique building features, compared to conventional technologies.

The POE methodology includes the performance assessment of seven different performance areas and only those ***indicated in bold*** that are (mostly) pertinent to the issues of infrastructure are presented here in more detailed way: ***energy efficiency, water use efficiency*****,** indoor air quality, lighting and the visual environment, acoustics, thermal comfort, ***and building envelope performance***.

Energy Efficiency

Improvements concerning the energy efficiency of buildings result not only in reductions in energy consumption and costs but also in decreases in the use of resources associated with the extraction and delivery of the energy, ultimately, in decreased environmental damage.

Water Use Efficiency

One of the common inadequacies of multi-unit residential buildings is high domestic water consumption (Kernan et al., 2002). The efficient use of water impacts not only the withdrawal of this natural resource from rivers, aquifers, and reservoirs but also the infrastructure required to supply it and to treat it pre- and post-consumption.

The efficient use of water can be characterized using one of many quantitative performance indicators:

- Water consumption per occupied floor area
- Water consumption per unit
- Water consumption per occupant
- Water consumption per bedroom

The water usage per occupant requires identifying the number of occupants in the building; alternatively, the number of bedrooms could be used as a surrogate for the number of occupants.

These performance indicators characterize water use and correlate this to prominent water-consuming building elements. The data permits comparison with design intent, performance target, data compiled from similar building stock, or benchmark data, where available. Available benchmark data is typically given on the basis of the volume of water per square meter and/or per unit.

The findings from POEs of MURBs will be fed back to the stakeholders, to improve the operation of existing buildings, and the design, construction, and operation of new buildings and that will have an impact on the level of the infrastructure use – existing and planned in different scenarios. Relations to the infrastructure while evaluating building performance are apparent and the POE project created an excellent opportunity actually to improve it in many areas. The methodology describes all steps needed to measure the performance while potential benchmarking can create explicit targets for the contribution and the overall improvements in a given or planned infrastructure. The author presented the POE idea under the angle of benefits, and the right conclusions could be drawn.

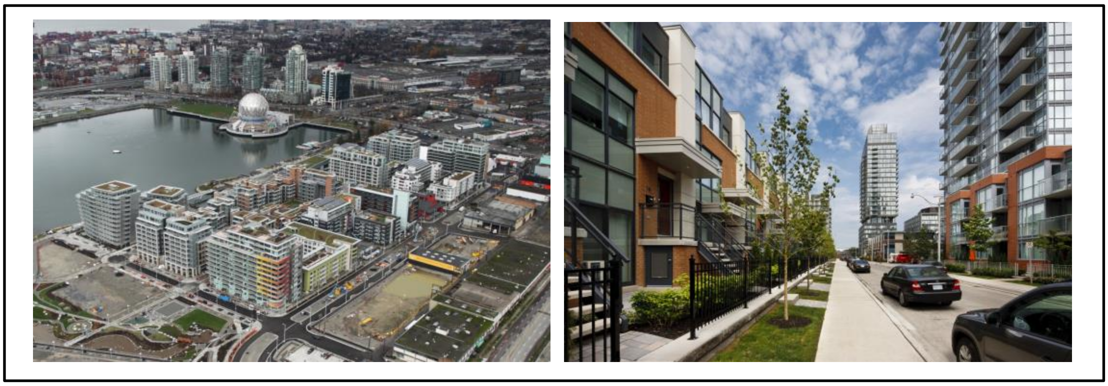


Fig. 7. South East False Creek, Vancouver and Regent's Park, Toronto - two developments with a huge impacts on infrastructure. Source: CMHC

Stakeholders in the POE who are responsible for the infrastructure considerations depend mainly on the building ownership structure, but also on the objectives of the entity requesting the POE and the relevant outcome. Stakeholders –decision makers only - may be any of the following:

- Building developer
- The design team, including architect, mechanical engineer and others
- Building owner (in case of a rental building)
- Individual building owners (in case of a condominium)

The POE can help them better understand the implications for the neighborhood/community infrastructure by showing:

- how well a building is working,
- how its performance relates to the original design intents,
- how it compares to similar buildings or established benchmarks, and
- how a building can be improved.
- How to share the experience with others.

POE benefits in the context of the thesis

- **Short term -** Informed decision making based on the identification of and finding solutions to problems in buildings, thus potentially optimizing the infrastructure
- **Medium-term -** Accountability for building performance by their designers

- **Longer term -** Long-term improvements in building performance; improvement in design quality; strategic review
- **Potential Incentives-** less maintenance, optimized cost [WK]

Conclusions 3

The initial survey determines the extent of occupants satisfaction, Monitoring of equipment and systems gathers the data through all seasons, prepares for further analysis and actions, if needed. Thorough understanding of the functioning of a building can directly link its actual performance to either innovation or corrections. All those measures affect the infrastructure [Bordass, Leaman].

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4. CMHC, 2011-Payback Period for Green Building Features in Single Family Dwellings

W. Kujawski - CMHC Project Manager with Bfreehomes Design

Introduction

There is always a big impact of choice of materials and technologies on all aspects of the building's construction and operation which, in turn, determine energy consumption for space conditioning and water consumption of the occupants, thus two main culprits in the infrastructure consideration.

The intent of this project managed by the author was to take a comprehensive look at the options, costs, and benefits of both energy efficiency measures and sustainable features in single-family detached dwellings that play a major role on the Canadian housing market. For this study, a 'sustainable' feature has one or more attributes that improve the environmental performance of the product and/or the house into which it is incorporated.

The study was limited to profiling sustainable features that would be available to a home buyer and homeowners. The energy (and/or water) saving performance of each feature was evaluated in different house types in different regions.

The key output of this study was a series of Sustainable Feature Profiles. These self-contained, one- or two-page documents provide information about a variety of generic sustainable building technologies and support their implementation by homeowners, builders, and renovators. A secondary output is a Sustainable Features Assessment Framework that provides an initial methodology for estimating costs and benefits of the sustainable features.

The results should increase the understanding of the costs and benefits of sustainable features for new and existing houses, enabling consumers and building industry to evaluate the potential benefits for new and existing homes. Such benefits can play a significant role in educating builders, developers and owners about the best solutions available for a given product and/or technology and that can also be beneficial for the infrastructure size benefitting from optimized energy and water usage.

Methodology

The energy (or water) saving performance of each feature was evaluated in different house types, in different regions. The four archetype houses were studied in six cities (Vancouver, Calgary, Toronto, Montreal, Halifax and Whitehorse). The primary tools used for energy modeling were HOT2000 (version 10.50) and RETScreen. The RiskAMP3 Monte Carlo Add-in for Excel® 2007 was used for stochastic modeling. The Athena Impact Estimator for Buildings v.4 was used for Life Cycle Costing (LCC) Analysis.

The profiles were broken into three groups: energy saving features, water conservation features and products with sustainable features that have no impact on energy savings or water conservation but do have other attributes. The latter is not taken into account in this dissertation.

Energy-saving insulation products and systems were compared across the country to a baseline of EnerGuide Rating System (ERS)-80 for new construction in the four house types, and an existing two story house in Toronto for renovation/retrofit options. High- efficiency, Energy Star space conditioning, ventilation and water heating equipment were compared to standard equipment, with a fuel source most common to each area.

Water conserving equipment was compared to a baseline that encompassed the national average for water consumption and the Hot2000 defaults for hot water use and average regional water and sewerage rates based on volume. Because on-site well and septic systems are present in rural portions of municipalities right across the country, estimated energy savings from reduced well pump usage and lower volumes of wastewater into the septic field were also analyzed.

Stochastic (Monte Carlo) modeling was carried out to determine probable future energy and water costs. Simple payback and internal rate of return (IRR) were also determined. Estimations of capital costs were based on current real-world figures. Analysis of the investment for each product was done over a 20-year planning horizon.

Inventory of Sustainable Features Included in the Study relevant to the thesis

Envelope Insulation

- Mineral Wool
- Dense Pack Cellulose Open Cell Foam
- Closed Cell Spray Foam
- SIPS (Structural Insulated Panels)
- ICF (Insulating Concrete Forms)
- Wood Fibre-Cement Insulating Concrete Forms
- Polystyrene Insulating Concrete Forms
- Extruded Polystyrene Board
- Expanded Polystyrene Board Polyisocyanurate Board

High-Performance Mechanical Systems

Space Heating:

- Energy Star Forced Air/Warm Air Furnace (gas)
- Energy Star Boilers (gas, oil, electric)

- Air-to-Air Heat Pump
- "Mini Split' Air-to-Air Heat Pump Space and Water Heating:
- Air-to-Water Heat Pump
- Geothermal heat Pump (open loop)
- Geothermal heat Pump (closed loop)

Water Heating:

Instantaneous (Demand) Water heater

- Drain Water Heat Recovery (DWHR) Ventilation:
- Heat Recovery Ventilator (HRV) Space Cooling:
    - Energy Star Window Mount Cooling
    - Energy Star Whole House Cooling

Renewable and Alternative Energy Mechanicals

Micro-Cogeneration (combined heat and power) Solar Thermal DHW Systems:

- Flat Plate Collectors (FPC)
- Evacuated Tube Collectors (ETC) Photovoltaic Panels (PV)
- Micro-scale Wind:
    - Vertical Axis
    - Horizontal Axis
- Solar Air Heating Systems

Water Fixtures and Systems

- Toilets
- Low Flow
- Dual Flush Showerhead
- Reduced Flow
- Low Flow Faucets
- Low Flow Kitchen
- Low Flow Bath Greywater Recycling (Small) Greywater Recycling (Large)
- Rainwater Harvesting (potable water use)

The Framework

Figure 8 below and the description that follows illustrate the work steps of the Framework.

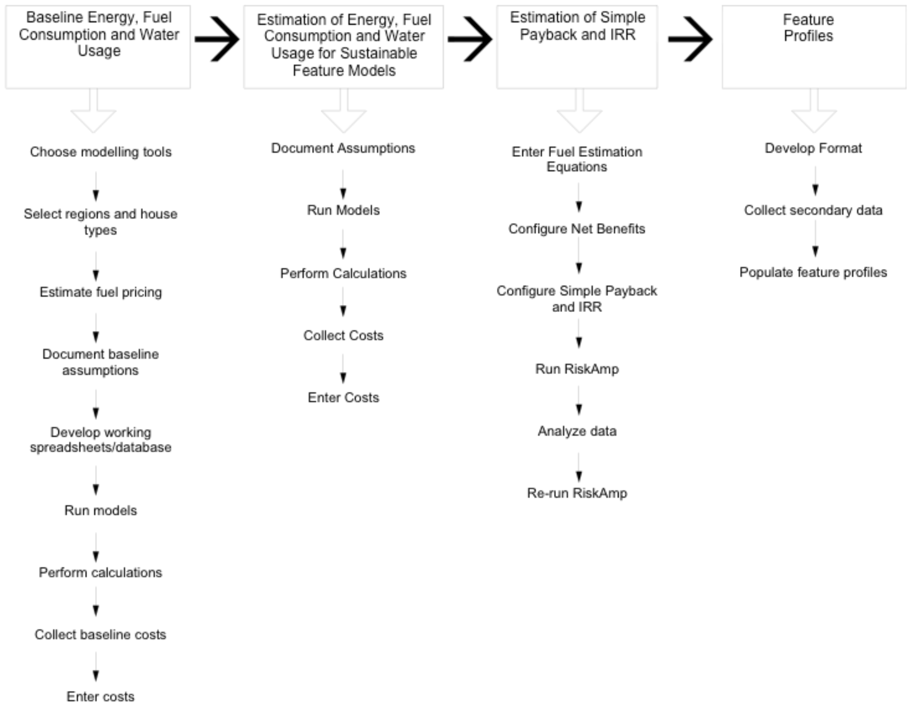

Figure 8. Framework. Source: BeefreeHomes

Estimation of Simple Payback and IRR

The Simple Payback Method

Simple payback[6] is the most common method for analyzing the 'returns' from an energy/housing investment. It measures how long something takes to 'pay for itself' without considering foregone opportunities, interest payments, and so on. Shorter payback periods are obviously preferable to longer ones; however, a serious drawback is that it instills a mindset of 'the quicker, the better' rather than what is the best long-term investment.

Comparing Financial Returns from Energy Saving Measures

Relative financial returns among energy-saving investments options can be ranked according to their Internal Rate of Return (IRR) and then compared to the next best investment alternative. Internal Rate of Return is estimated by analyzing the net cash flows from costs and benefits for each year of the planning horizon. For example, let's say the consumer spends an additional $3,000 in year one for a

[6] Payback period in business and economics refers to the time required for the return on an investment to 'repay' the sum of the original investment. For example, a $1,000 investment that returned $500 per year would have a two-year simple payback period.

high-performance boiler that provides savings for the costs of purchased fuel for year one and the remaining five years of the planning horizon which provides an IRR of 8%. The table below illustrates this fictional example:

	Year 1	Year 2	Year 3	Year 4	Year 5	IRR
Incremental Capital Costs of the High Performance Boiler	$3,000					
Savings in Purchased Fuel Compared to a Conventional Boiler	$600	$650	$700	$750	$800	
Net Benefits	-$2,400	$650	$700	$750	$800	**8%**

Other things such as risk, capital availability and personal preferences being equal, if an energy efficient boiler shows an IRR of 8% over a conventional boiler and the consumer's next best choice is to deposit the incremental cost of the high-performance boiler in real estate that is likely to return 10%, then the consumer would choose the investment. Using IRRs allows projects of different scales to be directly compared providing benefits and costs have been treated consistently.

Use of Internal Rate of Return in this Study

IRR and simple payback are represented as probability distributions represented as percentiles. A percentile is the value of a variable below which a certain percent of observations fall.

Conclusions 4

An approach with using the stochastic modeling and representing internal rates of return - IRRs and simple payback as probability distributions were very useful. It provided insight into the need for precise economic analysis and performance modeling in estimating these values, as well as the importance of factors such as house type, location, fuel type, levels of insulation and air change rates. Without this approach, the consumer can be easily misled by simplistic statements.

The implications of such statements are huge in today's global economy where decisions are based very often on a so-called Big Data and without the proper verification can just be wrong. The materials and systems used in any development be it new construction or existing stock provide the base for efficiency in buildings and the infrastructure. It follows them, thus the reliable performance claims must support their use, and this research was one of the early attempts to provide those claims.

Following is the list of Profiles that are based on the work above and were later updated with the latest information. The profiles are hyperlinked to the CMHC website

- High-Efficiency Air to Air Heat Pump
- Air to Water Heat Pumps
- Drain Water Heat Recovery (DWHR)
- Dual Flush Toilets
- Envelope Retrofit
- Heat Recovery Ventilator (HRV) (included below as an example of a Profile)
- High-Performance Windows
- Instantaneous Gas Water Heater
- Photovoltaic Panels
- Solar Water Heating Systems

Figure 9. Example of the HRV Profile. Source: BeefreeHomes

Sustainable Feature Profile: HEAT RECOVERY Ventilator (HRV) (C.1.00)

Category	Mechanicals Energy Use	*Ventilation Systems & Equipment*	**Application**	New Construction	√	Renovations	√

Estimated average simple payback in years	*Short 0-3*		*Medium 4-7*		*Long 8-20*	√	*20+*	

Benefits

Reduced Energy Consumption:

Ventilation-related space heating costs are reduced by using heat in outgoing exhaust air to warm incoming fresh air in the winter

Cooled incoming air in the summer provides space cooling cost savings

Improved Indoor Environment

Ensured delivery, distribution and circulation of fresh outdoor air throughout the house

Control of indoor air humidity levels helps to prevent moisture problems such as condensation on windows, mold

Odours, humidity can be controlled by ventilating bathrooms and kitchens

Warmed incoming ventilation air provides better comfort

Incoming air is filtered

Moisture can be recovered to help prevent over-drying of home in the winter in Energy Recovery Ventilator (ERV) products

Reduced environmental impact

Reduced energy consumption-related green house gas emissions due to heat recovery

Description

- HRVs are mechanical devices that exchange indoor air with outdoor air (see Figure 1). HRVs transfer heat from the outgoing air to the incoming air by passing the two air streams through a heat-exchange core. ERVs also transfer moisture between the incoming air and outgoing air and therefore may not be appropriate where excess humidity is a problem.
- HRVs provide energy efficient mechanical ventilation for well-built, energy efficient new housing and can provide ventilation for existing housing as well.
- HRVs have multi-speed settings to deal with varying ventilation needs. Automatic controls are available as well.

Design/Installation/Operation/Maintenance Considerations

- HRV systems should be designed and installed by qualified personnel (e.g. designers and contractors certified by the Heating, Refrigeration, Air Conditioning Institute of Canada (HRAI) or other training organization) in accordance with applicable building codes and standards.
- An HRV can supply fresh air directly to each room, and exhaust air from kitchens and bathrooms, through a dedicated ductwork system. They can also be connected to an existing forced air heating system to provide general indoor-outdoor air exchange - a common approach for existing houses. HRVs can also indirectly supply air to the house through the forced air heating system while directly ventilating bathrooms and kitchens.
- The outdoor fresh air intake and exhaust outlet must be carefully located with respect to dryer vents, space heating and domestic hot

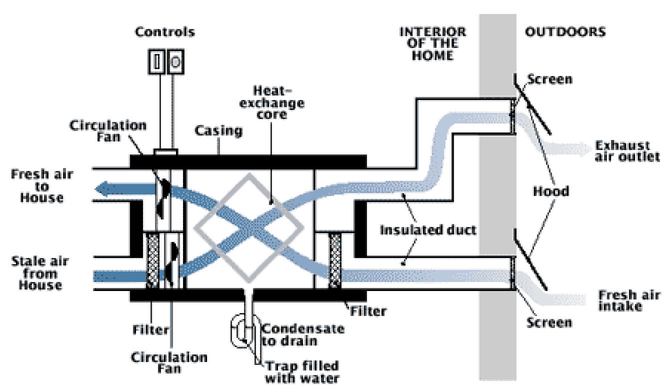

Figure 1: Heat Recovery Ventilator Schematic *(Source: OEE, NRCan)*

water appliance side wall combustion vents and air intakes, windows and doors to avoid cross-contamination problems. The intake and outlet must terminate at certain heights above grade to avoid snow accumulation problems. Do not locate under decks or in garages or attics. HRVs should not be connected to range hoods, cooktop appliances or clothes dryers. • ERVs may be appropriate for houses with very dry air but may not be suitable when ventilation is required to address high indoor moisture conditions.	

Special Maintenance

- HRVs require service and maintenance to ensure energy efficient and safe operation (e.g. filter and heat recovery core cleaning, airflow balancing, inspection and clearing of screens in outdoor intake and outlet hoods). Check manufacturer's literature for requirements.
- The supply and exhaust airflows must be measured and balanced to ensure the HRV does not cause house depressurization or pressurization problems. Airflows can become unbalanced over time and therefore should be checked regularly by a qualified contractor in accordance with the manufacturer's instructions.

What it costs (2010)

- The cost of installing an HRV varies widely, based on whether or not it is a new or retrofit application. It also depends upon the number of rooms, the size of the house and the amount of ductwork required. Installing a 60% efficient HRV in an existing two-story house with a full basement but with no mechanical ventilation or existing ductwork can cost between $3,000 and $4,000 (HRV included).
- The incremental cost of a high-efficiency HRV over a mid-efficiency HRV ranges between $500 and $1,000, depending on the features included and the region.

What it saves

- Replacing uncontrolled air leakage with mechanical ventilation can save money on heating bills.
- In an existing house with no mechanical ventilation, installing a 60% efficient HRV can result in space heating energy savings of 3%.
- In a house with an existing HRV ready for replacement, there is an estimated 20% annual reduction in ventilation-related energy consumption associated with replacing a typical HRV with 60% sensible heat recovery) with a high-efficiency HRV with 80% sensible heat recovery. .

Payback and /or Internal Rate of Return (IRR[7])

- Payback and IRR are dependent on a number of factors including the installed cost of the HRV systems, ventilation rates, heat recovery efficiency and local cost of energy.
- Installing a 60% efficient HRV in a house with no mechanical ventilation may not result in any IRR or simple payback under 20 years due to the capital cost of the installation, the limited associated energy savings and the potential impact of controlled ventilation on air leakage The IRR associated with upgrading from 60% to 80% sensible heat recovery can also be negligible and the payback long-term.

Website Reference

http://www.buildinggreen.com/auth/productsByCsiSection.cfm?csiMF2004ID=3810
http://www.oee.nrcan.gc.ca/Publications/infosource/Pub/hrv/index.cfm?attr=4
http://www.toolbase.org/Technology-Inventory/HVAC/energy-recovery-ventilators

[7] Internal Rate of Return (IRR) takes into account incremental product costs and estimated energy savings. IRR tells you how well your money is working for you compared to other potential investments or the cost of borrowing money. The planning horizon for both IRR and simple payback is 20 years.

5. GBTool/SBtool Assessment Framework

W.Kujawski with N. Larsson, iiSBE, 1997-2004

The Green Building Challenge process and GBTool, its framework based software – both existed shortly under those names between 1997 and 2000, when they were transformed in Maastricht, Netherlands, to Sustainable Building Challenge (SBC) and Sustainable Building Tool (SBTool). The first version of GBTool was developed by the author and was used by the fourteen most developed countries for the first GBC conference in Vancouver in 1998. The subsequent conferences were held in Maastricht, Oslo, Tokio, Melbourne, Helsinki, Barcelona and Hong Kong. 2019 will take place in Goteborg, Sweden.

The SBC process can be described as a consortium of up to forty countries, operating under the aegis of iiSBE, which are taking part in environmental performance assessments of the built environment. One of such systems is SBTool, based on the framework of its first version – GBTool; however, developed much further and on another platform.a second-generation assessment system; one that is designed from the outset to reflect the very different priorities, technologies, building traditions and even cultural values that exist in various regions and countries. In order to use the system, national teams must first adjust the values and weightings embedded in the system, thereby assuring results that are relevant to local conditions. The direct output of this process is primarily at the level of Research & Development (R&D); specifically, a thorough understanding of issues involved in designing such a system, as well as a continuing exchange of ideas on the subject by the best researchers in the field.

However, it extends to the public- and private-sector organizations encouraged to use the results, and this is expected to have positive, practical results for industry applications in several countries. Those European countries that are already developing their own systems are using the GBC process to exchange ideas and to improve their own systems, and GBC has already influenced in certain areas the developments of BREEAM, LEED and Green Globes.

The assessment framework has been produced in the form of software (SBTool formerly GBTool) that facilitates a full description of the building and its performance, and also allows users to carry out the assessments relative to regional benchmarks. Participating national teams test the assessment system on case study buildings in each country.

The primary differences between the GBC framework and other systems that assess the environmental performance of buildings include the following:

1. Existing systems such as LEED, BREEAM, are developed within single countries and are implemented in the market. The GBC framework and GBTool, are part of an international R&D process and are therefore not intended for direct commercial application;
2. Whereas other main systems (BREEAM, LEED) were each developed in a single country and remain primarily applicable to conditions in that country, the GBC framework - the GBTool software - is therefore designed to allow easy identification of local factors and the insertion of region-specific values for benchmarks, weightings, and standards;
3. The weightings of the two highest levels of parameters in GBTool (Issues and Categories) could be adjusted by the user. This not only allowed adjustment to local conditions, but also permitted users to exclude whole issue areas they

consider to be non-applicable, or for which data are not available, such as Service Quality, Economics or Management;

4. GBTool covers a broad range of parameters, including issues not usually covered by other systems. The current assessment parameters included in GBC now include the following issue areas:

- Resource Consumption (non-renewable energy, land, water, materials)
- Environmental Loadings (greenhouse gas emissions, air pollution, ozone depletion, solid waste, liquid waste, effects on adjacent properties)
- Indoor Environmental Quality (air quality, thermal comfort, daylighting, lighting, acoustics,)
- Service Quality (adaptability, maintainability)
- Economics (life-cycle emphasis)
- Management (staff training, tenant performance incentives)

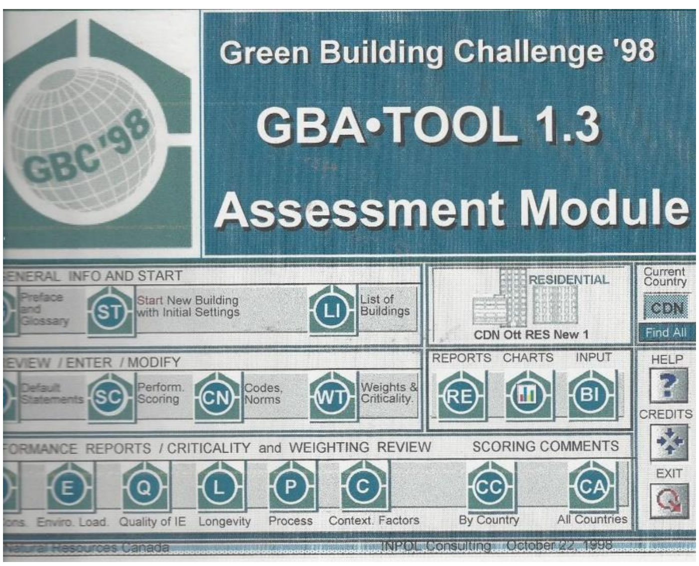

Figure 10. Screenshot of the Home screen of the GBTool 1.3. Source: W. Kujawski

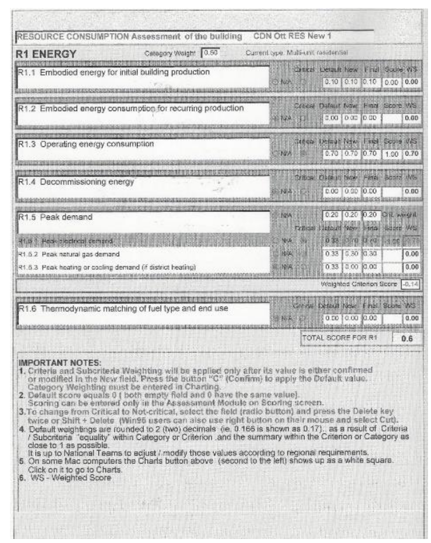

Figure 11. Screenshot of the results screen in GBTool v.1.3. Source: W.Kujawski

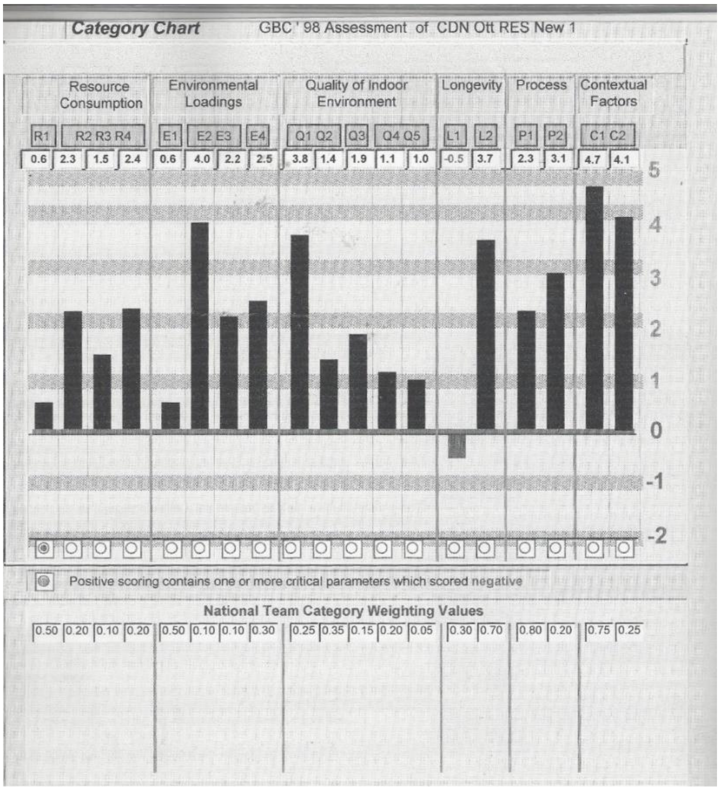

Figure 12. Screenshot from the Canadian MURB for GBC 98. Source: W.Kujawski

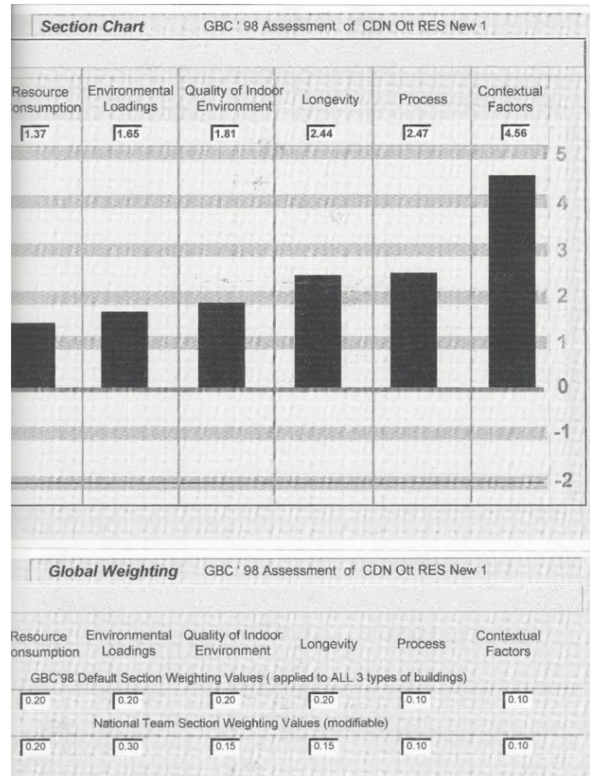

Figure 13. Screenshot from the Canadian MURB for GBC 98. Source: W.Kujawski

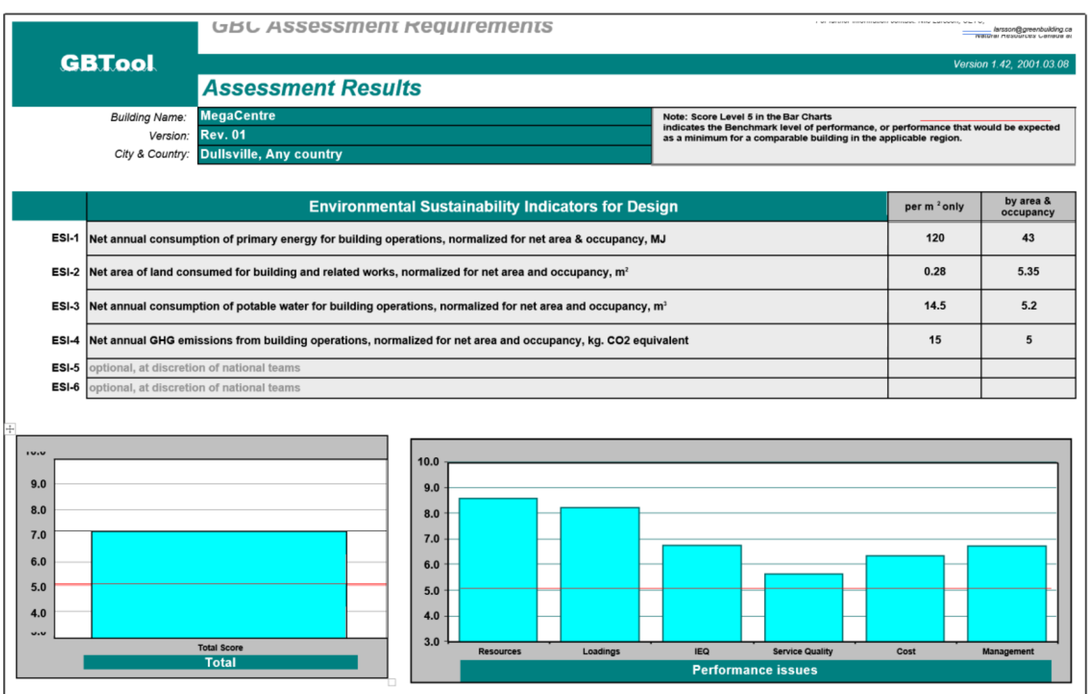

Figure 14. Results in a template of the GBTool v.2. Source: W.Kujawski

Conclusions 5

Whereas other main systems (BREEAM, LEED) were each developed in a single country and remain primarily applicable to conditions in that country, the GBC framework - the GBTool software (SBTool today)- is therefore designed to allow easy identification of local factors and the insertion of region-specific values for benchmarks, weightings and standards;

The weightings of the two highest levels of parameters in GBTool (Issues and Categories) could be adjusted by the user. This not only allowed adjustment to local conditions, but also permitted users to exclude whole issue areas they consider to be non-applicable, or for which data are not available, such as Service Quality, Economics or Management. GBTool started the computerized assessments that were available to all countries, depending only on local and regional adjustments. The author developed the first version of it under the guidance of the International Framework Committee (IFC) representing 14 countries.

Summary of Module 2

Land use patterns can be characterized in terms of amount, density, mix and location of housing, and these elements, directly and indirectly, affect infrastructure requirements, transportation mode choice and the building stock which, in turn, impacts energy and other resource use. Regardless of dwelling type, neighborhood type contributes to the transportation pattern of residents thus to road infrastructure. When considering dwelling types, single detached houses would have the highest environmental impacts, and among neighborhood types, outer suburbs would have the highest environmental outputs per dwelling.

Those impacts will be mirrored infrastructure wise thus the consideration should be given to these aspects areas of housing developments. Despite the decrease in water consumption, total water use will still increase due to the growth of the entire residential sector. The water usage has major dimensions: the supply and the depletion of the water resource and the effects on water quality, partially addressed by urban water treatment infrastructure.

The operating life-cycle stage (direct and indirect) has a much bigger environmental impact than other life-cycle stages; the reductions in these impacts are limited unless existing dwelling stock is addressed with such life-cycle energy influential factors as neighborhood and dwelling choices, dwelling condition, and occupants behavior.

The initial Post Occupancy Evaluation (POE) survey determines the extent of occupants' satisfaction and monitoring of equipment and systems gather the data through all seasons, preparing for further analysis and actions if needed. Thorough understanding of the building's functions can directly link its actual performance to either innovation or corrections. All those measures affect the infrastructure. The findings from POEs can improve the operation of existing buildings, and the design, construction, and operation of new ones. Such improvements will have an impact on the level of the infrastructure use – existing and planned. Relations to the infrastructure while evaluating building performance are apparent and the POE is an excellent opportunity to improve it.

The engagement of the residents in operation and maintenance of their building may also play a key role in the overall energy use and savings. An additional aspect is reserved to human factors such as level of occupant's satisfaction which if positive, limits lost energy in vacancies and unused urban spaces contributing indirectly to the more stable infrastructure loads.

Occupants, with their behavior impacting the building performance, create valuable contribution to the infrastructure underlining the fact that they determine the outcome of most energy efficiency measures. The use of data representing internal rates of return -IRRs and simple paybacks in materials and technologies shows the need for precise economic analysis and performance modeling in estimating these values, as well as the importance of factors such as house type, location, fuel type, levels of insulation and air change rates. Without this approach, the consumer can be easily misled by simplistic statements.

The author developed the first version of GBTool, a building assessment software, under the guidance of the International Framework Committee (IFC) representing 14 countries. Whereas other main systems (BREEAM, LEED) remain primarily applicable to conditions in the country of origin, the GBC framework - the GBTool software (currently SBTool) is designed to allow easy identification of local factors and the insertion of region-specific values for benchmarks, weightings and standards adding to an assessments a possibility of seeing immediately the implications of measures considered in a design.

The implications of such sets of data or statements being received every day are huge in today's global economy where decisions are based very often on a so-called Big Data with the proper, regulatory verification still not existing. The reliable performance claims an anything green must be supported by reliable analytical processes helping, in the end, making right choices.

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Wojciech Kujawski, M.Arch, MRAIC

General rules helping design better buildings, communities and the infrastructure

Module 3

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Introduction to the topic

The unrestrained growth of today's cities and in a much-reduced timeframe compared to the millennia needed for such marvels as Athens, Baghdad, Damascus, Hanoi or Beijing, forces architects and urban planners to develop guidelines for the form and organization of the future cities that have to be energy efficient and resilient while improving peoples comfort in micro and macro scales. Today's urban environment with its unsupportable energy demand for both heating and cooling while being affected by the climate change will force, sooner or later, to pay much more attention to renewable energy economy, if not an outright conversion to it.

"*A sustainable city should be able to create a complex tissue weaving together activities and human beings so that energy use (in all its forms) should be minimized, and human interactions maximized*" [Salat, 2010], and that aspect is presented in the relevant parts of the dissertation.

This module contains the research, reviews of procedures and other publications in forms of guidelines and information about mostly universal design measures applicable to buildings and their urban context. It is essential for the building and its neighborhood to function correctly and be built following the principles established for the sustainable built environment. Several guidelines created or managed by the author establish the design process and procedures, including "intelligence" and performance simulations to create buildings and infrastructure in the way of supporting and benefitting each other.

1. "Net Zero Energy Healthy Housing pilot demonstration guidelines – background information"

W.Kujawski, Project Manager, CMHC, 2006

Introduction

The author, while heading the development of the Guidelines/requirements for the initial stage of the Net Zero Energy Healthy Housing (NZEHH) Initiative renamed in 2007 to the EQuilibrium^{TM} Sustainable Housing Initiative (EQ^{TM}), also prepared the so-called "*Backgrounder*" to facilitate the entry to the competition by providing the essential information about the requirements for NZEHH. Some measures affect the final synthesis and are presented as the examples for further sections; however, the details of some of them are beyond the scope of this dissertation and only parts relevant to building-infrastructure interactions supporting the thesis are presented.

The main chapters in the Backgrounder are Health, Energy, Resources, Environment and Affordability (acronym HERE+A). The initiative also had strong connections to the development of sustainable neighborhood/ community - the primary place for the infrastructure to be contributed to. For better relations with the thesis, the Guidelines are divided into building related characteristics and urban/ community planning issues.

All aspects of a design described in the Backgrounder helped to understand the basic concepts about the new Net Zero buildings and their impact on the environmental management including water-related issues like sewers and stormwater as well as utilities such as power generation and distribution and waste disposal. The impact of buildings on infrastructure, although not named as the contribution, is indicated in the relevant, described sections of the Backgrounder.

Note: It is important to underline that all statements were made in 2006 and had since been proven by the actual performance of all EQ homes built to date; however, for the better support of the thesis some were updated with current facts or commented about the situation today without changing neither the objective nor the results.

Health

Net Zero Energy Healthy Housing promotes pleasing and comfortable indoor environments with superior quality indoor air, water, and lighting as well as minimizing exposure to the background sound. Daylighting and passive heating strategies provide natural light to all living areas and maximize site benefits and views. Careful selection of building materials, finishes, furnishings, maintenance products and building systems optimize the quality and health of the indoor environment.

Indoor Air Quality is one of the aspects of ensuring good air quality and an adequate supply of fresh air by following its guidelines and regulations for Indoor Environmental Quality. As envelope tightness is increased, natural infiltration rates decrease, leading to the potential for higher concentrations of contaminants and pollutants and reduced fresh air for the occupants. It may lead them to actions as simple as opening the windows, thus affecting the energy consumption immediately in both heating or cooling periods and indirectly the infrastructure. Several guiding principles should be considered when designing net zero energy healthy housing:

- Reduction of the level of contaminants ‘built’ into the building;
- Removal of contaminants at the source of production; and
- Dilution of house air with fresh outside air.

Materials, construction systems, and mechanical systems should all be evaluated based on characteristics including outgassing, stability under exposure to varied temperatures and moisture levels, cleanliness, maintenance requirements and durability. Most of these aspects affect the operational side of the infrastructure.

Ventilation

Ventilation strategies ex-change fresh air for exhaust air, and it should be ensured that incoming air is brought into the home in as clean as possible, in the quantities required for a healthy interior and that the fresh air is thoroughly distributed to all areas of the house while operating in a very air-tight building. Strategies to address indoor air quality[1] must be balanced with the need to ensure acceptable comfort levels for the house occupants. Filtration, humidity control, and effective distribution systems must be considered at the design stage, and the result will be reflected in the overall building energy use and therefore impact the size and the operational infrastructure cycle. Elimination /reduction and containment of pollutants takes into consideration all sources of emissions or supportive of mold growth and prevention of vehicle exhausts and contaminants from the attached garage (if any) from infiltrating the indoor space.

Daylighting and Light

Lighting is a relevant environmental factor, which considerably affects people's comfort and visualizing abilities while contributing significantly to energy consumption. Daylight is preferred to artificial lighting since it does not require the additional use of energy and because people find it more pleasant. Fortunately, the aim of introducing more daylight into the home coincides with passive solar and energy efficiency design principles and, the advent of high-performance windows means that designers can plan for daylighting even in rooms with northern exposure - with a lower penalty in thermal performance. The example of strategies used: glazing area < 7% of finished floor area on the south face of the unit/house to optimize the performance.

However, high-performance windows, specifically low-e coated windows, reduce the amount of daylight. The most effective daylighting strategies use windows on two sides of a room to reduce

[1] Canadian Standard Association’s (CSA) publication about Residential Ventilation Systems provides guidance on industry accepted ventilation strategies.

glare. New technologies such as light pipes or solar assisted light wells are available to bring daylight to the interior of the building. Full spectrum artificial lighting, resembling daylighting, can further enhance interior environments for occupants[2]. As in other subsections, the infrastructure is directly affected by the building design, and in the case of passive solar energy requiring exposure to the sun, the other direct benefits are both increased level of daylighting and occupant's satisfaction.

Water Quality

It is becoming increasingly difficult to maintain the infrastructure of potable water and wastewater treatment– with projected costs ranging in the 50 – 80 billion (milliard in Europe) dollars in Canada or build a new one for even more. Moreover, the lack of an available year-round source of water is making the concept of water reuse more acceptable – including rainwater harvesting, and greywater reuse for non-potable purposes.

The recent examples (in relation to the publication year) of such reuse implemented into residential or mixed-use developments: the Bridges (Calgary), Metro Label (Toronto), Roehampton (Toronto), Dockside Green (Victoria), and Quayside Village (Vancouver). Rainwater harvesting is already undertaken in non-urban areas in Nova Scotia, Gulf Islands in B.C, and rural areas of the Prairies.

Energy

NZE Healthy Housing reduces energy use in all home functions, in all seasons of the year, through effective planning and design. It relies on optimum site orientation, a high-quality building envelope, efficient heating and ventilation systems, appliances and fixtures, and use of renewable energies to achieve net zero energy goal and reduced or eliminated the use of standard fuels.

Reducing the demand for energy also increases the viability of renewable energy sources — enhancing the potential for solar space and water heating and ground source heat and allowing for consideration of electrical generation based on renewable sources such as photovoltaics and wind-powered generation. On average, two-thirds of home energy use is consumed by space conditioning — heating and cooling. The operation of lights and appliances accounts for another 17%, while domestic hot water heating accounts for approximately 15%.

The major energy savings over the lifetime of the house from an optimized design will result (in macro-scale) in reduced demand for expensive new sources of energy such as new electrical generating capacity (new power stations) or new fossil fuel sources. They may come from increasingly remote locations thus hugely increasing the size of the infrastructure (necessity to bring fuels from very far – transportation infrastructure, be it road network with all related services, or the fuel pipelines).

[2] LEDs are major contributors today; however, not all their aspects are clearly beneficial to all.

The following strategies (***the latest studies are detailed in Module 1***) are available to the design team to maximize energy efficiency in housing. Any of them should first be based on reducing the demand for total and peak energy by:

- Building orientation and glazing strategies Selection of construction materials considering building mass and reflective surfaces.
- Improving the thermal envelope of the building;
- Improving the performance of heating, cooling and climate control systems; and
- Minimizing the energy consumed by lighting, appliances, fans and domestic hot water.

Passive Solar Design

Passive solar strategies (***the latest studies are detailed in Module 1***) are based on the orientation of the building to optimize solar gains, thermal storage materials to reduce temperature fluctuations, and distribution systems to move heat throughout the building. Passive solar heating can provide much of the heating needs of a well-designed home, and primary design considerations should include:

- Optimizing south-facing glazing and shading control for passive solar gains
- Maintaining east, west and especially north glazing to a minimum required for aesthetics and daylighting;
- Maximizing the glazing to frame ratio
- Sizing thermal mass to keep temperature fluctuations within occupant acceptable ranges;
- Providing for circulation of warmer air to colder parts of the house; and
- Considering wind direction while locating the building entrance in addition to the use of airlocks to reduce infiltration.

Envelope Performance

The design heat loss represents the amount of energy required to maintain acceptable indoor temperatures and is a function of the surface to volume ratio of the building, the thermal resistance of the building envelope, and the natural air leakage rate of the building. Design or predicted heat loss can be reduced through the following measures:

Minimizing Building Surface Area through:

- Design for the lowest possible exterior surface area to floor space ratio.
- Reduction of the surface area of the building which is exposed to the exterior elements

Improved Thermal Resistance:

- Reduce or eliminate thermal bridging across the building envelope
- Install higher insulation levels in foundation and above grade walls and ceilings.
- Install high-performance windows

Airtightness:

- Employ airtight construction practices.
- Install windows and doors with low infiltration rates.
- Minimize penetrations in the building envelope such as those for fans and electrical fixtures.

HVAC Equipment Sizing

Once the heat loss of the building envelope is reduced, the attempt should be undertaken to maximize the efficiency of the heating, cooling and ventilation equipment specified. There is a significant trend in equipment towards smaller components and integrated systems to maximize efficiencies - both in operation and in installation.

Renewable Energy Strategy

Active solar technologies

Active solar heating has been extensively used throughout Canada for the heating of domestic hot water, and less widely for space heating. The roof-mounted collectors supply heat to a remote heat storage chamber, such as a hot water tank with the storage mechanism providing the required heat for domestic hot water, or heating air circulated throughout the house.

Earth energy heat systems

Air source or ground source (earth energy) heat pump systems also offer improved system efficiency. While their capital cost must be considered in relation to a reduced heating and cooling load, earth energy systems use electricity three times more efficiently than electric resistance heating.

Wind, hydroelectric

Wind power, small-scale hydroelectric and photovoltaic generation systems, providing all electricity needs for lighting and appliances have proven viable in many rural and urban locations. For more modest applications, freestanding outdoor lighting units powered by photovoltaic cells and an integral battery are now readily available freeing infrastructure capacity.

Peak Electricity Demand

Peak demand means the highest amount of electricity that utility must supply to all its customers at any given time, in any one month and especially during the summer due to air-conditioning loads and limited electrical generation capacity or during the winter in areas where electric space heating is common. Meeting peak demand energy requirements is always provided through the means of infrastructure sized accordingly. Any improvements in overall efficiency will also reduce peak demand thus reducing the strain on electricity infrastructure systems, limiting the need for electricity imports and the need to construct new generation capacity such as, for example, power stations, nuclear including, or increasing capacity of the existing ones. Through a combination of innovative design, and state-of-the-art equipment, optimized design can significantly cut the operating energy needs, and with the use of control and “smart” technology, it can reduce peak demand by shifting some electricity demand from high-use to low-use periods. That is extremely important today in some Canadian provinces where the Smart Metres are obligatory and the Time of Use is in effect.

Back-up Power and Powering Down

Low KiloWatt Living requires going beyond "House as a System" towards "Community as a System" approaches meaning exploration and optimization of relationships with adjacent municipal infrastructures - and not limit the measures to energy reduction/efficiency measures only at the house level. It is possible to incorporate Energy Elasticity & Resiliency (not just Fuel Switching) by cooperation, conservation and sharing at the community level, for example, the surplus heat/ cold/power can be available from nearby commercial / municipal facilities (that, in fact, only supports the idea of Synergy Zones mentioned earlier).

NZEHH offered to house and community designers the opportunity to unburden the infrastructure during heat waves or cold snaps by managing loads, and also to avoid having to pay peak rate energy costs. Stressed utility grids usually mean brownouts/ outages/spikes. However, the renewable energy and backup power capabilities of NZEHH can be designed to help homes and communities "Power Down". Such approaches appear suitable for both large cities and smaller communities. Expected benefits would include significantly increased use of existing electricity supply resources (via peak load shaving and staged load shedding) including meshing with energy retrofits that free-up capacity for Electric Vehicles, plus GHG reductions.

Lights

Lights generally account for about **two percent (1 000 kWh/y)** of household electrical energy needs for an all-electric house. With improved design strategies and state-of-the-art lighting technologies, lighting needs can easily be reduced to **250** kWh/y ***(author’s note: it was written in 2006; today’s LEDs will cut those numbers at least in half)***. Reducing the need for artificial lighting is the first step in reducing lighting energy needs.

Additional information on Baseload Reductions for Lighting

The provision of daylighting is an energy reduction strategy — using adequately designed windows and skylights, and interior finishes designed to distribute the lighting. The improved design with more lights controlled by individual switches may allow occupants to adjust lighting levels to meet specific room functions and to light specific areas of a room independently. The use of automatic timers and dimmers can also offer potential savings in both building and infrastructure.

Integration of Vehicle Energy and Housing Energy Requirements

Rationale - Housing and commuting (transportation) are considered to be separate entities regarding energy and green house gas (GHG) emissions. However, it is recognized that housing choice has a significant impact on commuting need and hence emissions associated with private transport and urban transit. A novel opportunity exists in energy efficiency improvements that are possible in houses and the development of viable electric vehicles (EV's) for commuting use. Energy savings in a more efficient home (new or retrofitted) can be used to "free-up" enough electricity to charge the batteries in an efficient electric vehicle, without placing additional loads on the utility grid.

A typical level of daily savings for a Canadian suburban family could be 10 kilowatt-hours sufficient to power an EV a distance of up to approx. 400 kilometers per day[3]. With a Hybrid car, it should also be possible to connect the car to co-generate electric power AND thermal power (heat) to meet some of the needs of houses to offset peak loads, and to provide backup power should remote centralized utilities fail. It is possible that the net incremental electrical energy use could be zero (mainly if time-of-use electricity rate structures are in place) AND the overall energy savings of the house-car arrangement could be positive when gasoline for regular commuting is factored in.

It is possible to reduce electricity use in most suburban homes (30-60%) to make electricity available for suburban use of Electric Vehicles (EV's) - without increasing the loads on existing utility infrastructure. EVs have lower operating and maintenance costs than conventional vehicles, produce much less pollution and cost savings (in household electricity use, commuting, maintenance - any other energy usage) may be sufficient to self-fund both the EV costs AND the home energy improvements. The energy integration of house and car provides the possibility of using EV's or hybrids to provide power AND heat to homes - for backup power and daily household demands, potentially contributing to the adjacent infrastructure.

Smaller EVs can now be recharged for local commuting using foldup 2-4 sq.metre photovoltaic arrays (on sunny days) without reliance on other electricity supply sources, and time-of-use electricity rate structures can prevent placing additional loads on electric/gas/oil/water utility infrastructures.

Electricity based commuting will free-up scarce hydrocarbon fuel resources for other needs, reduce emissions into the atmosphere which contribute to pollution, reduce lubricant/fluid contamination of paved surfaces which contribute to pollution of groundwater and rivers.

Life cycle Embodied Energy Strategy

Embodied energy is the total amount of energy required to extract raw materials, process them into products and transport them to the building site. While the energy embodied in the materials and

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[3] Chevy Volt- updated in 2018, http://www.chevrolet.com/electric/volt-plug-in-hybrid# (accessed in April 2018)

products used to construct and maintain a building over its lifecycle is small in comparison to the energy consumed to operate the building, embodied energy is an essential factor to be assessed when considering the sustainability of building designs and as the services follow the buildings, its infrastructure.

Typical values for Embodied Energy of primary construction materials.

Material	**Energy Intensity***
Concrete (average)	1785 MJ/m^3
(ready-mix, regular weight, 2000 psi)	(1335 MJ/yd^3)
Framing lumber	1997 MJ/m^3
(2 x 4 wall studs- int.framing)	(17 MJ per 2 x 4 stud)
Gypsum board	66 MJ/m^2
(4 x 8 12 mm sheet)	

Values shown are based on averages for the Canadian economy in 2004 and *do not* include installation on-site, repair and replacement over the lifetime of the home, or demolition and disposal.

Embodied energy currently makes up a small percentage of overall life-cycle energy consumption of a house; however, with a strive for significant energy efficiency, the embodied energy in a house will become a more significant percentage of its overall life cycle energy consumption. It has been estimated that the energy embodied in the materials represents approx.10-15% of total energy consumption.

As this research is refined further to account for local and manufacturer specific processes, designers and builders will be able to make choices relating to house design and material selection which optimize energy use. In some instances, energy-intensive materials with long life expectancies may be justified. While many insulation materials are energy intensive in their manufacturing, they can be long lasting and dramatically reduce the operating energy needs of the home. The expected useful lifetime of a building product must be taken into consideration.

Energy is required not only in the initial manufacturing and installation but also to maintain, demolish and eventually replace materials, and that also concerns any constructed infrastructure.

Transportation Energy Inputs

Transportation of goods is especially energy intensive when considering the vast distances between major urban centers in Canada. Locally extracted and manufactured products require less energy in transportation and materials should be evaluated based on their availability in the local marketplace. Balancing operating energy savings and system performance with transportation energy requirements will represent another of the trade-offs required in a more holistic approach to house design and it also affects the size of the potentially required infrastructure.

Values shown *do not* include installation

Table 1. Summary of building products for a typical 192 m2 house.

Materials Breakdown	(as built)	Quantity	Unit
1	sand and gravel	50	tonne
2	lumber and timber	41	m3
3	plywood (9 mm)	246	m2
4	plywood (12 mm)	246	m2
5	plywood (15 mm)	562	m2
6	fibreglass batt (89 mm)	149	m2
7	fibreglass batt (152 mm)	249	m2
8	blown mineral fibre (300 mm)	159	m2
9	gypsum board (12 mm)	746	m2
10	paints and related products1	12	L
11	glass, plate, sheet	429	kg
12	ready-mix concrete	81	m3
13	sand lime bricks and blocks	116	each
14	bricks and tiles, clay	3818	each
15	steel bars and rods	111	kg
16	plastic pipe fittings and sheet	335	kg
17	felt, carpet cushion	162	m2
18	carpeting and fabric rugs, mats	162	m2

Source: Sheltair Scientific

Resources

Sustainable Materials

Materials are the architect's palette, the matrix which delivers “commodity, firmness and delight.” The physical performance of materials more than perhaps any other single factor dictates whether over time a building, road or bridge becomes an asset or a liability in both environmental and economic terms.

Materials are critical to determining the environmental sustainability and health impacts of construction. The creation of the built environment, including infrastructure, is closely correlated with many of the most significant environmental and correlated social impacts.

Material efficiency

Reduced requirements for construction materials can be achieved in part through the use of material-efficient design and construction detailing. While there is no official lifetime for the built houses, one could assume at least 60 years (used in Life Cycle Analysis by Athena Institute) with the total overhaul of interiors every 30 years on average which could stand as a benchmark for the renewability analysis. In that context, the building, by the simple fact of being entirely renovated within that time frame, contributes to the specific part of the infrastructure while it can be assumed that every time it becomes more efficient thus, possibly, offsetting some additional consumption.

Recycled and Reused Materials

Because of the energy required for the processing of materials, recycled and reused materials used in construction can offer reduced energy intensity. Building products with recycled materials are increasingly available. Insulation manufactured from recycled newsprint and cardboard, drain tiles and carpeting manufactured from recycled plastics, drywall incorporating recycled board stock, and manufactured wood products employing waste wood are currently being marketed.

Water Conservation

Water is the fundamental resource without which life, in the forms we understand it, will cease to exist, and it is not inexhaustible. Canada is a relatively water-rich nation, and perhaps because of the apparent abundance of water, Canadians are not very careful in how they use it. [4]

Along with the increase in freshwater use has come an increase in the amount of wastewater that needs to be treated and purified. For many municipalities, the cost of providing and expanding sewage treatment and water purification facilities has become prohibitive. For the building community, the consequences have ranged from enforced lower density subdivisions to outright bans on further development.

One of the best ways to reduce the demand for potable water and the production of wastewater is by improving the efficiency of water use. The use of water meters, for example, has shown that residential water use can be cut by at least 30 to 50 percent with no attendant effect on lifestyle. While some of these savings are the result of changes in habit, others are the result in changes to water-using hardware as well as to use appropriate water quality for intended purposes such as rain water for watering the garden, potable water only for drinking and food preparation,.

Indoor Use: Water-Efficient Fixtures and Appliances

An understanding of where water is consumed in the household can give a good indication of how to reduce its use. On average the bathroom accounts for sixty-five percent of water use in the home. Low-flush toilets require only 3.5 - 6 liters per flush (a 35 -50 percent reduction in household demand). Low-flow showerheads can reduce flow rates by 50 percent (10 liters per minute as opposed to 20 liters per minute). Moreover, low-flow aerators can reduce faucet flow by 50 percent as well. Some strategies to save water indoors ***(Note: 2006 data):***

- Toilets equipped with water-saver or ultra-low flush units using 3.5 - 6 L/flush (e.g., compost toilets, waterless technology)
- Low-flow showerheads, using 9.8 L/min or less when tested at 551 kPa
- Lavatory and kitchen faucets using 8.3 L/min or less when tested at 413 kPa
- The inclusion of alternative sources of water supply in the design (e.g.rain or grey water)
- Water efficient planned appliances

Outdoor Use Water Efficient Techniques

Residential water use can double during the growing season due primarily to lawn and garden

[4] The average daily domestic consumption in Canada (2004) is 326 litres per person. In Canada, those with meters use, on average, 40% less water than their fellows who pay a flat rate.[4]

watering. Outdoor residential water use can be significantly reduced by employing alternative landscape designs. The goal is to design landscapes that survive on precipitation alone- establishing Xeriscaping - landscaping that requires the minimum amount of maintenance and irrigation.

Woodland shade gardens and wildflower meadows are also water-efficient alternatives that have ecological benefits, such as creating wildlife habitat and reducing the urban heat island effect.

Hardscapes, such as stone walks and patios require no water inputs at all.

Since impermeable pavements like asphalt and concrete prevent stormwater infiltration, use permeable hard surfaces such as precast pavers designed for infiltration. Such measure is essential for enabling trees and other plants to get the water they need and for reducing stress on municipal stormwater systems, in other words, the infrastructure.

Rainwater harvesting can be used for nonpotable purposes, e.g., flushing, irrigation, and washing purposes. Some strategies for outdoor water use:

- The inclusion of the rain storage tank for irrigation in planned water reuse systems
- Reduction of potable water use for maintenance of lawns and gardens
- Reduction of household potable water consumption to 0.15 m3/person/day or less (taking into account the re-use of grey water and captured rainwater)

Stormwater management

Stormwater from large paved sites and roof areas has severe impacts on local ecosystems (oil accumulation, erosion of natural water-courses and flooding of treatment facilities) and municipal systems (storm sewers are sized for peak periods). Landscaping that keeps stormwater on-site, such as rain gardens, are a right way of groundwater recharge without adding to the stormwater system. Cisterns and rain gardens can have positive ramifications for municipal infrastructure, by limiting the amount of run-off that has to be appropriately managed.

On a typical urban lot, the roof of the house or other building covers one-third of the area. Consequently, with an adequately sized rain garden or cistern in place, there would be approximately one-third less run-off entering the sewer system thus reducing stress on infrastructure with the additional positive effect of reducing the incidence of basement flooding caused by sewer back-ups.

Principles of proper stormwater management:

- At least 65% of the site (if lot > 0.1 ha) not paved and planted *(turf, other landscape)*
- The paved surface that is permeable to exposed walkways, patios, playgrounds, recreation courts, aprons, and driveways.
- Permanent erosion control measures included in a design.
- Permanent stormwater controls installed (i.e.vegetated swales, on-site rain garden)
- Green roofing integrated into the design.
- Grease and oil filtering provided from impervious runoff from the site
- As the best strategy, if possible, 100% of stormwater retained on site.

Adaptability/Flexibility

Flexible and adaptable design solutions enable the home to easily adjust to an occupant's changing needs and capabilities, both financial and physical, responding to the dynamics of the demographics and readily adapting to the evolving needs of tomorrow.

Finding a good match between the population and the housing stock contributes to higher energy efficiency per capita from the operation of the house.

It is essential that new housing be designed to accommodate several changes in occupancy over its lifetime. Much of the demand for new housing units could be met more efficiently by retrofit of existing housing stock. Such initiatives would make the best use of the investment in both the housing and the infrastructure of existing residential neighborhoods.

Solid Waste Management

As much as 2.5 tonnes of waste is produced by the construction of a typical new house in Canada. That and an even higher rate of waste generation incurred in the demolition and renovation of homes represents a waste of resources and energy and places an additional burden on landfill capacity. Construction practices can be altered to minimize wastes. Central cutting areas allowing for easier access to off-cuts — improved site storage procedures designed to minimize water damage thus reducing needs for water treatment plants expansions as part of the infrastructure, and improved inventorying procedures can optimize resource use.

Waste Water Management

Typical residential wastewater use can be easily reduced by up to fifty percent. However, that still leaves a significant amount of wastewater in need of treatment. Plumbing systems can be designed to separate grey water (water which contains no sewage) from black water (water with sewage). The water that drains from bathroom basins, tubs, showers, and laundry rooms is the best source of grey water. Water from the kitchen is also considered grey water, but the fats, oils, and greases from dishwashing make kitchen water hard to filter, and a likely breeding ground for disease.

One percent of raw sewage entering sewage lines leaks into the surrounding soil and eventually into ground or surface water. Also, during heavy rains, when plant capacity is breached, raw sewage can be released into surrounding waterways. Regional plans regarding source water protection might address it.

If greywater is to be recycled, there will need to be significant adjustments made to standard plumbing systems to capture the water and transport it to its secondary use. Also, grey water for re-use in certain areas, such as gardens, may have to undergo some form of pre-treatment. Some new water-efficient plumbing systems include wastewater treatment and recycling systems thus c0ontributing directly to water infrastructure.

NOTE*:As indicated in the Methodology of the dissertation, parts of some publications are shared between different modules and in some cases, not in their original format; however, the goal is to be more consistent with the overall conclusions that can easier connect with the origins of given research studies.*

NZE Healthy Housing encourages site planning and community design that reduces land requirements, impacts on habitat, agriculture, and fisheries, promotes resource-efficient landscaping and considers broader community issues such as efficient transportation, reduced infrastructure, and preservation and restoration of natural features. Durability and longevity of designs are emphasized, taking into account future adaptations of buildings where possible.

Conventional construction practices result in the disposal of a significant amount of toxic and hazardous materials. Paint, solvents, caulkings, treated wood off-cuts arid a host of other contaminants conventionally find their way to our dumpsites — polluting the land and leaching into groundwater impacting the infrastructure in a significant way requiring it to be constantly upgraded and increased in many cases. Canada’s relatively vast supplies of fresh water are becoming polluted at an alarming rate. Houses contribute significantly to the deterioration of our streams, lakes, and ponds through the disposal of hazardous materials into the sewage system and through leaching of outdoor household chemicals into the groundwater. Moreover, many municipalities are finding it increasingly difficult and expensive to keep up with the growing requirements for fresh water and sewage treatment facilities.

Effective land use planning

More than sixty percent of Canada’s housing stock is made up of single-detached dwelling units - the least dense of housing options and the most consumptive regarding land, energy and even water. Single-detached homes accommodate some 60 percent fewer people per net hectare then row-houses. Sprawling development patterns not only require large tracts of land for housing, but for the required roads which this auto-oriented form of development entails. At the same time, sprawling developments place higher demands on the urban infrastructure in the form of roads, water and sewer systems, transit and schools. The suburban development pattern is also more energy intensive, in both construction and operation. Detached houses consume anywhere from 15 to 67 percent more energy for space heating than other common ground-oriented housing options such as multi-unit buildings -apartment buildings, row houses. Data from a CMHC study: A 2-story detached home loses 20% more heat than a semi-detached one and 50% more than a middle unit in a row of townhouses of the same size, heating system, insulation levels and windows.

Half of the greenhouse gases (GHG) from energy use by individual Canadians come from passenger road transportation. Land use planning significantly influences how far Canadians drive from their homes to reach their daily destinations, such as schools, jobs, and shopping. People living in centrally-located neighborhoods that are compact, mixed-use and pedestrian/transit-friendly generate up to 2/3 less GHG from urban travel than those in dispersed, single-use neighborhoods on the urban fringe. Transit-friendly design needs 17.5 houses per hectare (7 per acre) or more for transit to be economically efficient; higher densities also allow for more public green space. Many suburban developments are 10–17 houses per hectare (4–7 per acre).

Indirect design features related to buildings mitigating creation or increase the size of the existing infrastructure by encouraging alternatives to the motor car as a means of transportation, such as including bicycle lanes, or using traffic calming, certain elements should be considered such as:

- Designing the project for the use of transit through its allocation
- Narrower, interconnecting streets with sidewalks and pedestrian cut-throughs.
- The use of traffic calming techniques.
- Dedicated bicycle-lanes.
- Greenways, for hiking, cycling, and horseback riding.
- Car-free residential areas, where people park their cars and walk to their homes.
- Overall trip reduction plans (also known as transport demand management).

2. "Net Zero Energy Healthy Housing (NZEHH) Guidelines"

W.Kujawski, Guidelines Project Manager, CMHC, 2007

This section is a part of actual Guidelines for teams competing in NZEHH Initiative shortened to issues related mostly to urban/ community planning issues as opposed to subjects of building itself. The goals are to differentiate both and to show clearly the Backgrounder with the general information on all subjects and the Guidelines with more focused requirements.

A NZE Healthy House design should address planning issues that will shape the communities of the future. These include density, land use mix and site considerations – all affecting the infrastructure and including:

- selecting a site near daily destinations such as shopping, jobs, and schools.
- locating near transit nodes (within a 5-minute walk or a subway, bus or commuter rail station)
- ensuring housing is in mixed-use neighborhoods
- enhancing pedestrian connectivity through street and pathway design
- making better use of existing infrastructure, including linear infrastructure (sewers, roads, services) and community infrastructure (schools, fire, police)
- provision of more affordable and varied house types responding to demands and needs
- enhancing the opportunities for cogeneration, district heating/energy production and sharing
- the preservation/protection of green corridors and watersheds
- encouraging alternative water and wastewater treatment and delivery systems
- reducing the per unit cost of all infrastructure

moreover, in larger projects (more than 50 units)

- Involving compact, mixed-use developments with village or neighborhood centers in larger projects, so that people have a place to gather, and perhaps do some local shopping.
- encouraging the development of local economy and reducing the need for residents to drive, involving elements such as:
  - zoning land for commercial and/or industrial uses
  - encouraging home-based businesses
  - encouraging 'live-work' units (light industrial/commercial/limited retail)
  - creating a local economic development strategy
  - provision of a greater variety of urban spaces and amenities to create a livable community and improve quality of life

Site planning issues

The site plan determines how the house interacts with the surrounding neighborhood and environment. Careful site planning can contribute to the efficiency of the individual house (through optimization of building location, orientation, and landscaping), minimize the impact of the house on the surrounding environment and contribute to a 'healthy' social environment.

It could include:

- creating an ecological and habitat inventory of a site
- retention of significant natural features, such as trees, creeks, swamps and nesting sites.
- green space protection, through, for example, conservation covenants
- use of native species in landscaping
- creation of greenways and nature trails and desirable micro-climates
- more efficient use of land
- creation of friendly streetscapes, workable open spaces.

Building(s) on such site will contribute to infrastructure. That may happen through: the right ***Orientation*** to provide optimization of solar exposure for the house and site and ***Landscaping*** to provide maximization of winter wind buffering and summer shading. Other measures can include planting species that do not require excessive amounts of water; and minimization of impermeable surfaces, provision for local food production and natural habitats and utilization of natural or green infrastructure solutions.

Sediment and erosion control of the construction site

Urban development and the increase of impermeable pavement is a key to watershed health – poor land use planning, particularly in areas close to receiving waters and their riverbank buffer zones, further exacerbate the situation – leading to increased downstream flooding, degraded water quality, and loss of aquatic and river bank habitat for a host of species (fish, wildlife, migratory birds). This, in turn, leads to commercial and recreational water activities losses in fisheries and tourism, and increased costs for drinking water treatment due to impacts of sedimentation into waters - litigation and clean up costs; sedimentation of storm drainage systems – increased costs for maintenance, plugged systems, increased flooding risks- all related to the maintenance and operation of the infrastructure.

Conclusions 1– a compilation of research 1, 2

Planning densities and design goals in the Net Zero Energy Healthy Housing (NZEHH) approach promote solutions that adequately balance occupant's needs and desired activities with community needs and functions. Building materials are specified from local renewable resources; construction waste is reduced and well managed, construction impact on the surrounding area and watershed is reduced through reduced erosion and durability of building components is emphasized.

The proposed housing uses efficient water and wastewater systems, and site design and landscaping provide for on-site rainwater use, stormwater retention and reduced infrastructure costs. The designs can minimize the need for raw materials extraction - be it forest-, petroleum- or water-based resources, thus the environmental impact of housing. It will require new approaches to community planning, housing design, materials selection, construction techniques and the regulatory approvals process as well as the integration of processes.

NZEHH offered to house and community designers the opportunity to relieve the infrastructure during heat waves or cold snaps by managing loads, and to avoid paying peak rate energy costs. Too stressed utility grids usually mean outages or spikes. However, the renewable energy and backup power capabilities of NZEHH can help homes in both large cities and smaller communities.

Filtration, humidity control, and effective distribution systems must be considered at the design stage, and it will be reflected in the overall building energy use and therefore impacting the size and the operational infrastructure cycle.

The aim of introducing more daylight into the home coincides with passive solar, energy efficiency design principles and availability of high-performance windows and designers can plan for daylighting even in rooms with northern exposure. The major energy savings over the lifetime will result in reduced demand for costly new sources of energy such as new electrical generating capacity (power stations) or new fossil fuel sources from increasingly remote locations. That aspect alone will hugely increase the size of the infrastructure (necessity to bring fuels from very far – transportation infrastructure, be it road network with all related features, or the fuel pipelines).

Through a combination of innovative design, and state-of-the-art equipment, the optimized design can significantly cut the operating energy consumption, and with the use of "smart" technologies, it can reduce peak demand by shifting some electricity demand from high-use to low-use periods.
It is possible to incorporate Energy Elasticity & Resiliency (not just Fuel Switching) by cooperation, conservation and sharing at the community level, for example, the surplus heat/ cold/power can be available from nearby commercial / municipal facilities (supporting the idea of Synergy Zones)

The provision of daylighting is an energy reduction strategy - using adequately designed windows and skylights, and interior finishes designed to distribute the lighting. The improved design with lights controlled by individual switches may allow occupants to adjust lighting levels to meet specific needs in different areas of a room independently. The use of automatic timers and dimmers can also offer potential savings in both building and related infrastructure.

Electricity based commuting will free-up scarce hydrocarbon fuel resources for other needs, reduce emissions contributing to pollution, reduce lubricant/fluid contamination of paved surfaces which contribute to pollution of groundwater and rivers. Balancing operating energy savings and system performance with transportation energy requirements will represent another of the trade-offs required in a more holistic approach to house design, and it also affects the size of the potentially required infrastructure.

Reduced requirements for construction materials can be achieved in part using material-efficient design and construction detailing. The building, by the simple fact of being entirely renovated within 30 years time frame, contributes to its relevant part of the infrastructure and it is assumed that with time it becomes more efficient thus, possibly, offsetting some consumption.

One of the best ways to reduce the demand for potable water and the production of wastewater is by improving the efficiency of water use. It can happen as the result of changes in habit, in changes to hardware (the use of water meters can cut residential water use by at least 30 to 50 percent) as well as by using appropriate water quality for intended purposes. Outdoor residential water use can be significantly reduced by employing alternative landscape designs – like Xeriscaping requiring the minimum amount of maintenance and irrigation. Use of permeable hard surfaces designed for infiltration is essential for enabling trees and other plants to get the water they need and for reducing stress on municipal stormwater systems.

Stormwater from large paved sites and roof areas has severe impacts on local ecosystems (oil accumulation, erosion of natural water-courses and flooding of treatment facilities) and municipal systems (storm sewers are sized for peak periods). Proper stormwater management can reduce stress on the sewer system with the additional positive effect of reducing the incidence of basement flooding caused by sewer back-ups. Even after using all measures of water saving, a significant amount of wastewater is in need of treatment. Plumbing systems can be designed to separate grey water (water which contains no sewage) from black water (water which contains sewage).

It is important to add that given the thesis also supported through transportation subjects, some of the impacts of buildings are not only about indirect transportation emissions, but also from the built infrastructure such as highways, feeder roads, streets which must be constructed and maintained in a long-term with all other services such as water drainage, stormwater, electrical services - lighting, traffic light, controls. Such infrastructure must survive winter, and that means considerable expenses in snow clearing and extensive repairs every year to the majority of roads due to “freeze and thaw” cycles.

A sustainable community is a community that supports healthy ecosystems and healthy living conditions and offers a variety of types and sizes of buildings, social, educational and cultural facilities. Full diversity of land use, commercial and service opportunities along with public space, and easily accessible, connected and affordable communication systems.

Integrated planning on a scale of sustainable neighborhood or community can provide significant benefits including costs. Analyses with the optimization of buildings and the area around can create opportunities for energy and water integration as well as the use of renewable energy and waste within the community systems. District-scale development planning can also facilitate pedestrian-friendly alternatives such as walking and cycling routes as well as better developed public transportation.

At the scale of a community, it is necessary to include social aspects that are reflected by the satisfaction of translating into better understanding of the environment that leads inhabitants to better, healthier life. Such an approach goes than to the infrastructure as a direct impact of buildings in which people save energy and water energy and care about waste while biking to their workplace

The design requires extensive community engagement and stakeholder involvement with a thorough understanding of the relationships between the diverse elements and functions of the built environment and seeks to capitalize on the interconnections between elements and systems (e.g., waste from one area providing fuel for another). Designing at the neighborhood/community scale provides opportunities to integrate systems (such as water and energy systems) across multiple buildings and land uses. The infrastructure always benefits from such actions, and sustainable community projects in Canada and elsewhere demonstrate that specific, mentioned above, principles apply universally, although they are, or should be, interpreted locally to suit the particular context of the neighborhood or community. Communities that are designed with these principles can, in relation to the impacts on infrastructure, significantly reduce energy and waste, reduce demand for urban resources and preserve ecosystems.

The new housing should be designed to accommodate several changes in occupancy over its lifetime. Much of the demand for new housing units could be met more efficiently by retrofit of existing housing stock. Such initiatives would make the best use of the investment in both the housing and the infrastructure of existing residential neighborhoods.

3. "Upgrade to Tap the Sun"[5]

CMHC, 2008 - W.Kujawski, Project Manager with C. Mattock, Habitat Design.

Original "Tap the Sun," published in 1997 quickly became a very popular publication, and with fast technology improvements and innovations, it was apparent that several "technological" sections of it would require a comprehensive review and subsequently, an update/upgrade and re-publishing. The author was designated as a manager of the Upgrade and worked with a consultant over several years on increasingly complicated task, as the market was changing as well.

One of the critical aspects was the creation of EQuilibrium™ Housing Initiative that was immediately in need of such a publication. "Tap the Sun" contributes not only to the building itself but to all other aspects of the built environment, infrastructure including, both directly and indirectly through the optimization of the building design features relevant to the thesis. The guide introduces the fundamentals and physics of solar energy and the basic geometry of solar entry into homes for given geographic position. It then follows with the design process, from site planning and building orientation, through heat collection, distribution, and storage, to envelope types, heating and ventilation systems and solar integration at each stage.

Only the summarized content of chapters supporting the thesis is presented in an overview format while repeating some publications in other modules. The difference remains in their more detailed approach and the goal of publishing for the builders, not for researchers or politicians.

"Tap the Sun" helps future homeowners, building professionals, architects—anyone interested in using solar energy in their either newly designed or renovated, home. It presents the fundamentals of solar energy, solar home design, examples of homes in Canada that use solar energy in various ways and information resources listed for many technical aspects of solar design.

Solar Homes are Healthy and Sustainable

Free solar energy can reduce dependence on purchased energy. Designing a home around solar energy is an opportunity to carefully consider light and comfort; quality materials, such as windows; and health matters, such as ventilation and indoor air quality. Many solar homes respond to other environmental issues, such as water conservation and waste reduction.

Solar Homes and Sustainability

Solar homes, by using clean, renewable sources of energy, help reduce significant environmental impacts of energy exploration, processing, and use. The aspects of sustainability in such homes that have direct and indirect impacts on the infrastructure are:

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[5] Original version: ftp://ftp.cmhc-schl.gc.ca/chic-ccdh/Archives/CA1_MH_08T17.pdf

Advanced energy features;

- Highly insulated and airtight building envelope.
- High-efficiency heating and heat recovery ventilation (HRV) systems.
- Solar hot water systems.
- Solar electrical (photovoltaic) systems.

Water-saving features

- Low-flow fixtures.
- Drought-tolerant plant materials.
- High-efficiency garden irrigation.
- Rainwater collection and reuse system.

Waste recycling features

- Convenient consumer recycling systems.
- Organic waste composting facilities.
- Greywater reuse system.
- Composting toilets.

Sustainable materials

- Reused materials.
- Materials with recycled content.

Healthy interiors

- High-performance ventilation.
- High-performance air filtration.

Methodology

"Tap the Sun" provides achievable solar goals for typical situations, with guidance for further explorations. It also tells how to build a house with advanced passive solar design, an energy-efficient envelope, appropriate technologies and materials and provides examples for every climatic region in Canada.

A range of house types, including detached, off-grid, rural, urban, and low-rise apartment buildings, as shown in architectural styles that vary from traditional to modern. Some of the solar designs rely more on heat storage, and a few employ advanced materials and mechanical systems.

Conclusions 2

The use of solar power in all aspects of it became a staple within the design circles of progressive architecture. With clear guidelines for What and How to do it, the architects can quickly follow the path, making sure that their efforts also go towards the adjacent, almost always indispensable and essential, infrastructure. Very often such measures are unnoticed, being almost automatic- the water saving mitigates the size of plumbing systems as energy conservation reduces HVAC system's size. However, all still depends on the sound design and the will of designers to pursue the goals.

4. "CMHC 2009-Low Impact Housing Final Report"

W.Kujawski as a Project Manager with Abri Sustainable Design & Consulting - report not published

Housing and the environment are inextricably linked at all levels. This study looks at housing that incorporates several aspects of 'green' building technology: energy efficiency and indoor air quality, resource and water conservation measures, use of renewable energy and energy sources with low greenhouse gas (GHG) emissions, sustainable materials choices, comprehensive life-cycle cost analysis, and last but not least, affordability.

The name 'low impact' was chosen because this seemed to address the broadest range of features. The environmental impact of each building has wide-ranging effects at all stages of its life-cycle: fabrication of materials, construction, operation, maintenance, and demolition. House design, construction and operation methods that show the significantly reduced impact on all aspects of the environment are the focus of these case studies.

This study aimed to document the best existing examples of low impact housing in Canada and cold-climate regions throughout the world. The project includes single detached, attached, multi-unit residential buildings (MURBs), and community configurations, focusing on those built between 1996 and 2006, or projects in the design or construction phase between 2004 and 2006. The goal was to educate and influence industry players and enable them to achieve significant environmental benefits and an improved value product.

The project team identified 173 projects in locations in Canada, the northern tier of the US, northern Europe and Japan and 24 case studies were developed [Table 2]. The selection criteria included: technologies used, climate and location, dwelling type and size, cost-effectiveness, replicability. Projects were grouped into five climatic zones, roughly corresponding to those found in Canada and attempts were made to represent different house types in each of these five zones. The case studies were rated with a matrix defined by CMHC's Healthy Housing^{TM} Principles [Table 1].

Table 2: Matrix of Features Under CMHC's Healthy Housing^{TM} Principles

Occupant Health	**Energy Efficiency**	**Resource Conservation**	**Environmental Impact**	**Affordability**
Daylighting	Building Envelope	Potable Water Usage	Waste Management	Reduction of Utility Bills
Acoustics	Air Sealing	Site Selection	Noise Pollution	Operations & Maintenance Costs
Lighting	Primary Energy Use	Occupant Waste Management	Air Pollution	Economics/Life-cycle costing
Ventilation	Secondary Energy Use	Building Reuse & Reclamation	Light Pollution	Economic Considerations
Low-emitting materials	Renewable Energy Considerations	Materials & Resources Used	Wastewater Management	
Thermal comfort & control		Local Materials	Sustainable Sites	
Universal Design			Transportation	
Performance requirements	Performance Requirements	Performance requirements	Performance requirements	

Table 3: Summary of Case Studies

Location		Construction		Occupancy		Built Area m2	Lot Size (m2)	Cost $CAD per m2
Single Family		Type	Date	BR	Units			
Factor 9 House	Regina, SK	Urban	2007	3		301	n/a	n/a
Irwin House	Stevensville, MO	Rural	2001	3		136	n/a	$1,065
Ketchum House	Orangeville, ON	Rural	1998	2		149	n/a	$1,557
Luet House	Carcross, YT	Rural	2001	2		211	n/a	$535
Lunenburg Acadian	Lunenburg, NS	Rural, Reclaimed	2003	2		160	n/a	n/a
Duplex/Row								
9-10 Stock Orchard	London, England	Urban Brownfield	2004	2	2	474	800	$1,447
Affordable Green	Madison, WI	Suburban	2003	2/3	2	223	726	$990
Blair Towns	Silver Spring, MD	Urban Brownfield	2003	2-3	78	9970	9190	$1,043
Ecovillage Cleveland	Cleveland, OH	Urban	2004	2	20	2973	4645	$1,750
Houses without Heating Systems	Göteborg, Sweden	Suburban, Row	2001	3	20	2400	n/a	$2,385
Oak Meadows	South Molton, England	Suburban, Row	2004			2800	n/a	$2,300
Zero Energy	Etten-Leur, Netherlands	Suburban, Row	2002	3	21	3360	n/a	n/a
Low Rise (3 - 6 Storey)								
EcoCité	Montréal, QC	Urban Infill	2004		8	766	n/a	$1,958
Faelles Bo	Herning, Denmark	Urban	1999	1/2	84	3670	n/a	n/a
Gold Dust	Missoula, MT	Urban Infill	2003	1 – 3	18	1812	1591	$1,517
Hedebygade	Copenhagen, Denmark	Urban, Retrofit	2002		281	10500	n/a	$6,476
Linden Street	Somerville, MA	Urban Brownfield,	2004	1-3	42	4765	6000	$1,550
Nassau Brewery Ice House	Brooklyn, NY	Urban, Retrofit	2003		6	1300	n/a	$1,077
Olz Bundt	Vorarlberg, Austria	Urban	1997	2	13	940	n/a	$1,748
Papenkamp	Hanover, Germany	Urban	2000	1-4	120	8520	n/a	n/a
High Rise (+ 6-storey)								
Brandaris	Zandaam, Netherlands	Urban, Retrofit	1999		384	30720	n/a	$489
Deutsche-Annington	Flansberg, Germany	Urban, Retrofit	1999		112	5700	n/a	$950
Community								
Ekoviikki	Helsinki, Finland	Suburban, New	2003		500	64000	n/a	n/a
Solar City	Linz, Austria	Suburban, New	2005		1300	101,000	32 Ha	$4,356

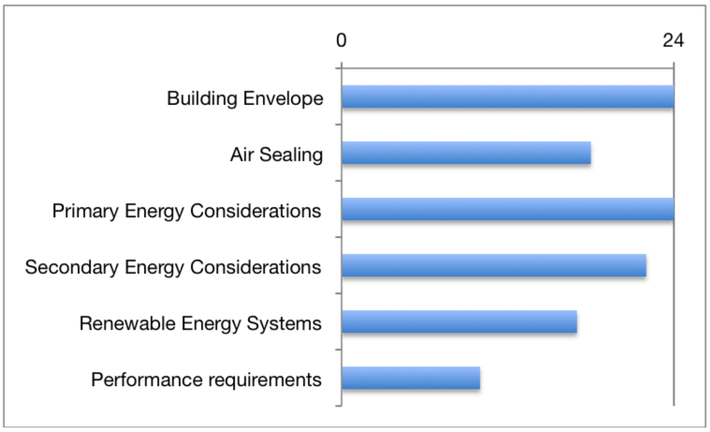

Figure 1. Energy Efficiency Measures. Source: CMHC

Sustainable sites

Green roofs, permeable sites, minimized building footprint, maintained trees, and restoration of degraded areas were all mentioned in at least one project. Green roofs were highest on the list, featured in six houses. One green roof prevented a significant amount of rainwater runoff per year. In addition to a green roof, another house featured a garden and a chicken run. The on-site food production provided about 50% of the food supply for the occupants.

Four projects directed stormwater over lawns and plantings or into retention basins to minimize storm system infrastructure. This approach to stormwater management also increased the amount of permeable surface on the site, which in turn helped to reduce the heat island effect of urban development.

Lessons learned / emerging trends

Subdivisions continue to be laid out without regard for solar orientation, and this has a massive effect on buildings potential passive solar contributions to infrastructure. The orientation of roofs is a possibility for nearly any subdivision, but often this is blocked by requirements for variations of rooflines and front elevations. The drawback is that **both solar thermal and PV systems are added costs to the house, whereas a house optimized for passive solar does not necessarily incur any extra construction costs**. Several projects indicated that construction costs were not increased, but some noted the incremental costs associated with the consulting and one also reported dropping the LEED silver certification process due to the overall costs of the certification.

The Zero Energy Houses in Etten-Leur showed that by integrating PV into the, a better quality/cost ratio could be obtained. Given the combination of high-efficiency ground-source heat pump, solar thermal and PV, the insulation levels could have been lower, and the project would have still met the zero energy target for the location.

In existing buildings where increasing the effectiveness of the building envelope through insulation and air, sealing is not an option, this configuration of zero energy/zero emission mechanical systems holds promise for reductions in purchased energy use.

The overall conclusion of a post-retrofit evaluation done on the Hedebygade project in early 2005 pointed to the need for more explicit guidelines for benchmarks, references, and goals, as well as criteria for overall green performance. The design and construction of the green roofs on the Nassau Ice House were a learning process where the pre-mixed substrate, pre-washed stones, and a less expensive membrane would have reduced the costs. Overall, the green roof design and consulting fees accounted for less than 4% of the total installed roof costs.

The results of the solar façade retrofit on the Deutsche-Annington multi-unit residential building (MURB) showed that it was possible to carry out a renovation based on using solar energy. However, successful implementation of solar measures often remains dependent on external subsidies.

List of Sustainable Building Standards used in determining the ratings for the case studies

BREEAM (UK EcoHome)
LEED
PATH (BEES spreadsheet)
Green Building Challenge
R-2000
C-2000
Hi-Star
Energy Star
(HERS) CHEERS Home Energy Rating System
Green Globes
Green Star (Australia)
HQE (France)
GB Tools

Conclusions 3

Several conclusions are drawn, and all seem to be very relevant to the building contribution to infrastructure while describing the various strategies and techniques for helping it. Relevant observations:

The poor solar planning is a major issue in the context of site decisions. The tentative “replacement “of such strategies often includes the increases in insulation causing the loss of about 7.5% of floor area, and in embodied energy effects of the typical insulation products. A slightly larger footprint can offset this measure, but the overall building to land ratios should often correspond.

Integrating solar thermal and PV into the building envelope can result in a better quality/cost ratio. If increasing the effectiveness of the building envelope through insulation and air sealing is not an option, configurations of zero energy/emission mechanical systems (high-efficiency geothermal, solar thermal and PV) hold promise for significant reductions in purchased energy.

Adding solar energy to the building envelope in renovations or retrofits can be undertaken with excellent results. However, **regardless of jurisdiction, successful implementation of solar measures still often remains dependent on external subsidies.**

Other sustainability features such as green roofs, permeable sites, minimized building footprint, maintained trees, and restoration of degraded areas were all mentioned in at least one project. Some projects directed stormwater over lawns and plantings or into retention basins to minimize storm system infrastructure needed when water runoff overflowed into the sewage system, flushing sewage into the surrounding rivers. This approach to stormwater management also increased the amount of permeable surface on the site, which in turn helped to reduce the heat island effect of urban development. The overall primary conclusion from this “worldwide” research is that **there is a need for benchmarks, references, clearer guidelines and goals, as well as criteria for overall green performance ratings as it may be difficult to assess with confidence and consistency.**

5. "Analysis of Renewable Energy Potential in the Residential Sector Through High-Resolution Building-Energy Simulation" [6]

CMHC 2008, W.Kujawski -Project Manager, with A.Fung et al., Department of Mechanical Engineering, Dalhousie University, Halifax,

The primary goal of this research was to provide a technical assessment of the potential of renewable energy systems in low-rise housing that would allow analysis of various scenarios from different angles[7]. One of the strategies to reduce fossil fuel consumption and the resulting GHG emissions is to increase the use of renewable energy thus also to optimize the infrastructure in both size and capacity. The description is edited to the most relevant parts of the dissertation.

More than 80 percent of total residential energy use is for space heating and domestic hot water heating. Technological advances in low-grade residential heat sources and distribution systems, coupled with distributed renewable energy generation, are an opportunity for overall end-use energy savings. However, to take full advantage of these technologies, research was needed to assess the technical and environmental suitability of such systems.

The first part of the project assesses the feasibility of adding a hybrid, renewable-energy system of roof-mounted, solar photovoltaic (PV) panels and a micro-wind turbine to existing housing.
The second part proposes, models and analyzes an energy-efficient, renewable energy-based heating, ventilating and air-conditioning (HVAC) and domestic hot water (DHW) heating system for new houses.

This study investigated the economic and environmental impacts of a roof-mounted PV and micro-wind turbine energy system considering 600W and 1000W micro-wind turbine generators.
PV system sizes were dictated by the size and orientation of the roofs of representative houses in different regions and only roof surfaces facing east, south and west were considered for PVs.

Fifty-seven test-case houses were selected based on province, age, and space-heating fuel type. Construction and thermal characteristic and attributes of the typical test-case houses were determined by analyzing the data in the databases. To account for the effect on the house electrical and thermal loads of electrical appliances usage, the 15-minute interval-based electricity-load profiles were estimated for each test-case house that was then simulated in ESP-r (Environmental Systems Performance; r for "research"), building energy and environmental simulation software. Two sets of simulations estimated the thermal and electrical energy needs of the test-case houses. Both were compared and the results extrapolated at the national level to assess the potential GHG reductions from integrating the roof-mounted PV and micro wind turbine system. [Figure 2] is a flowchart displaying the methodology used to study existing housing stock.

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[6] https://www03.cmhc-schl.gc.ca/catalog/productDetail.cfm?lang=en&cat=142&itm=19&sere=2&start=1&stfl=Analysis%20of%20Renewable%20Energy%20Potential%20in%20the%20Residential%20Sector&fr=1529071973155

[7] The Canadian residential sector consumes 16 percent of Canada's total secondary energy, resulting in about 70 megatonnes1 (Mt) of greenhouse gases (GHG) being released a year. Between 1990 and 2004, overall energy consumption has increased by around 23 percent, creating an increase in GHG emissions of 24 percent in all sectors.

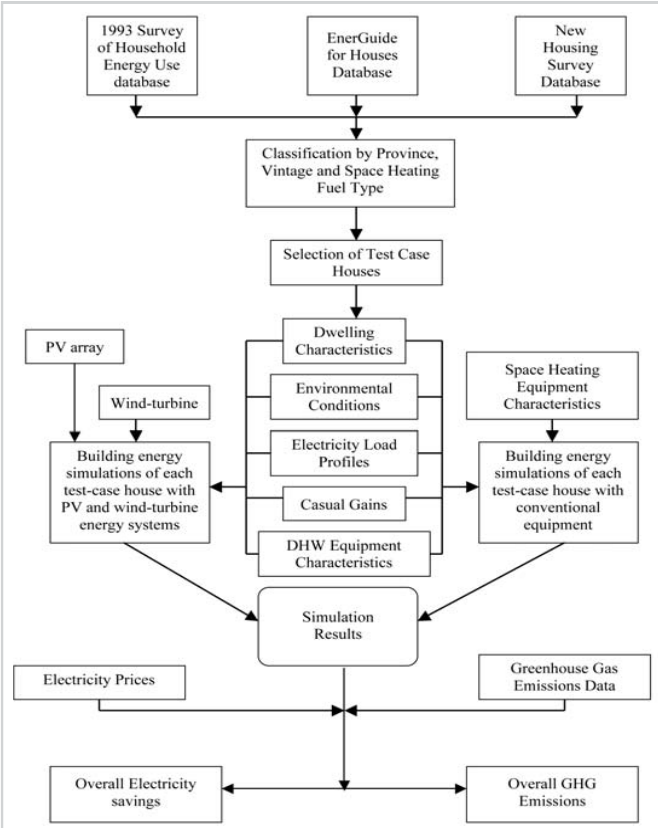

Figure 2. Flowchart of the methodology for the study of existing housing stock. Source: A.Fung

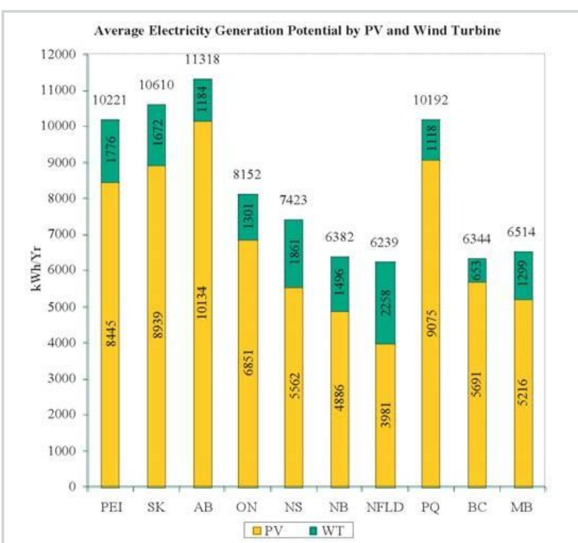

Figure 3. Average annual electricity generation potential using the combination of PV and wind turbine energy system for test-case houses. Source: A.Fung

Integration of PV and Micro-wind Turbine into Existing Housing

Figure 3 shows the average electricity generation potentials in kWh/year with the integration of the PV and micro-wind turbine energy system in the test-case houses.

Total electricity generation potentials vary significantly from province to province in Figure 4, with the lowest in Newfoundland and the highest in Alberta.

However, in Newfoundland, the electricity generation potential from wind was the highest and from PV the lowest being attributed to the province's windy and foggy climate. Total reductions of GHG are shown in Table 4.

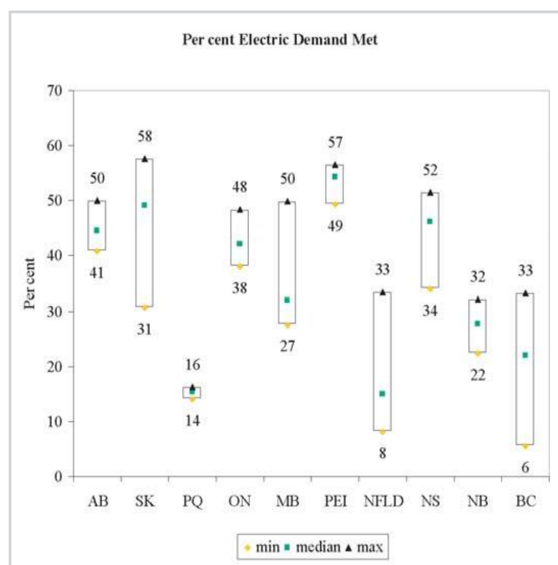

Figure 4. Percentage of electricity demand met by the PV and wind-turbine energy system on time. Source: A.Fung

Table 4. Total annual GHG emission reduction potential at national level

Emission intensity factors	GHG savings with PV and 600 W wind-turbine (Mt)	Percent saving compared to total base-case GHG emissions	GHG savings with PV and 1 kW wind-turbine (Mt)	Percent saving compared to total base-case GHG emissions
Average	4.1	14.1	4.4	15.3
High	11.9	19.5	2.7	20.1

Conclusions 4

The assessment of the potential of renewable energy systems in buildings to meet part of their energy demand may be crucial for the long-term urban planning and assessments of needs meaning the opportunities that also impact on the existing or future infrastructure.

In such context, it allows various scenarios to be analyzed under the angle of the potential building contribution. Layout and local climatic conditions are essential factors to consider when siting any building, but particularly so with sustainable or buildings that may produce their own electricity from renewable sources. In the case of PVs, for example, buildings must be oriented to receive the highest possible amount of solar radiation[8].

The level of this research is beyond a single building and its design; however, its usefulness is unquestionable, as it merely shows what could be viable in any particular location in Canada and the research, as such, may be used by the policymakers anywhere in similar climatic zones and economy.

The study focused only on solar PV, micro-wind turbine, and ground-source heat pump technologies without considering other measures, such as energy-efficiency upgrades and solar thermal systems. It concluded that without substantial reduction in the overall energy demand, in both electricity and thermal, in conjunction with the utilization of passive and active solar thermal systems in existing and new housing, the technologies investigated could not meet the energy demand in the residential sector. It recommends that all of these measures should be incorporated and investigated holistically in future studies.

The study shows that the buildings can supply the energy complementing the existing grid; however, the total dependence on renewable sources would not be possible in the near future unless using all available measures.

[8] A solar mapping tool, developed by the Canadian Forest Service (Great Lakes Forestry Centre) in collaboration with the CANMET Energy Technology Centre (CETC-Varennes), estimates the amount of electricity that can be generated by PV arrays and gives an average daily amount of sunshine anywhere in Canada. The maps provide monthly, and yearly data for six PV array orientations (a sun-tracking orientation and five fixed south-facing orientations) and the database includes data for 3,500 individual municipalities

6. "Intelligent building or intelligent designer";

W.Kujawski - Architektura 10, 1999 - "Inteligentny budynek, czy inteligentny projektant?"

The temptation to define intelligence and its thresholds in humans is and has always been strong for various reasons. In the case of a building, the threshold of intelligence, for which the building passes or fails the examination, does not exist, at least not yet. The only measure of intelligence is the ability to combine solutions with the needs of users. Some major aspects of the publication are summarized and presented with the conclusions.

In one of the issues of the "Intelligent Building," a professional magazine published in Wrocław, there was a definition given by the American Institute of Intelligent Building:
- it is a building that will give us a productive and efficient working environment by optimizing elements, structure, systems, services, and management. An intelligent building helps owners, managers, and users achieve their own goals regarding cost, comfort, convenience, security, long-term flexibility or marketing".

These goals emphasize the fact that the operating concept of building intelligence is very closely related to the complex concept of environmental protection, often turn into a misunderstanding. A simple example will be ventilation windows, which, without connection to the heating system, will cause substantial heat losses when they are opened, and energy saving, health, and comfort. This fact of integration is very often untouched at all, and the systems can work independently of each other, quite often very efficiently. Without the context, this performance can it would be enough for sensors to turn on the heating, when not necessarily needed.

As recent years have shown, increasing problems in areas such as energy and environmental protection or increased awareness of users about the causes and consequences of the poorly functioning buildings, have produced a rapid increase in research on both new and old buildings. It is easy to fall into the trap of "Art for Art" and forget why we design CO^2 sensors for automatically turned on ventilation or the "presence" sensors for lighting, omitting, of course, the mundane goals of reducing operating costs or better marketing and nothing more.

The technological revolution itself will not change much in designers' consciousness as long as they work only in their fields and without close cooperation, without creating the conditions for teamwork that is so necessary from the very beginning of the project. The lack of simultaneous agreement between the client-owner, investor, designer or user is often also caused by factors such as:

- Lack of knowledge about technological possibilities with a simultaneous rapid increase in requirements for better indoor air quality, waste reduction, material recovery,
- Poor buildings performance due to limited understanding of the concept of a building as a system where all subsystems must work together to make the building technically sound.
- Limited ability by the industry to document the benefits of new, advanced technologies entering

the market,• Difficulties in raising qualifications in the construction industry and creating the ability to apply new technologies in practice.

Conclusions 5

More than 95% of constructed buildings in the world are neither "intelligent/smart," nor "environmentally friendly." However, with the levels of the technical advancement of today, the intelligent building will soon be everywhere.

It is the future of the buildings, as the ultimate goal of automation also is, or should be (in addition to the simplified management and increased profits of manufacturers and developers that are the part of a reality), both health and comfort of the user and, of course, the protection of the environment by a proper treatment of the Nature. The "intelligence" allows to manage the operations of the built environment such as new and existing buildings and their networks around and by that also the entire construction process requiring not only the creation of roads but also the entire accompanying infrastructure and fuels polluting our eco-systems. In summary, the building intelligence is already on the smartphones, but people must learn how to use it in the best possible way.

7. "Review and evaluation of computer simulation methods in building design that meets the principles of sustainable development - examples of the use of simulations for designers and investors."

W. Kujawski, Ministry of Regional Development and Construction, Warsaw, 2001
*(**Original title:** Przegląd i ocena metod symulacji komputerowej dla potrzeb projektowania budynków spełniających zasady zrównoważonego rozwoju. Przykłady zastosowania symulacji dla projektantów i inwestorów., Ministerstwo Rozwoju Regionalnego i Budownictwa)*

combined with similar, abbreviated version of:

8. "Computer simulations for architects as a professional necessity"

W.Kujawski -„Architektura-Murator"- „Symulacje – niezbędna pomoc dla projektanta" 12/2000

Both publications were designated as educational tools although for different audiences. The first written for the Ministry of Regional Development treated simulations as an indicator for policymakers to overview the quality of the construction while the second one was published in the magazine for architects showing them directly the necessity and benefits of simulations in their work. It was stressed that comparison of both predicted and later, actual, performance are needed in almost every project, even if typically, not required at all. Are simulations so necessary and beneficial?

They, regardless of the type, can create the opportunity to evaluate many solutions and choose the option that best meets the assumptions, or predicted performance, thus significantly improving the quality of buildings, providing that the assumptions or predictions aim at the high-performance targets. It is particularly crucial in the implementation of sustainable features, where the number of requirements is usually quite extensive, and they can often be contradictory, for example, levels of energy efficiency and interior comfort. The final solution is usually a good compromise after the analysis of many options.

At the concept stage, the simulations are necessarily or, by default, superficial, but they still can show the main design options, which, however, can only be verified after the project's full simulation. The risk can be substantial, but the benefits are much higher. What kind of answer does the client get from the architect to the question whether the building will be energy efficient? A confirmation, because every designer knows that there is almost no chance of real verification (i.e., simulation) on the spot, and it would be challenging to be held accountable for such "falsification."

Simulations - necessary help for the designer

The complexity of the design process now requires the use of model simulations. The object- a building, should not only be correct in form and function but also energy and environmentally - efficient, healthy and comfortable to live in.

The simulation is commonly understood as the ability to present different architectural versions, enter them into the landscape, rotate the object, replace construction and installation materials, virtually visit every space. However, this is only a "coating" under which the building "works" depending on climatic conditions, types of installations, energy supplied, lighting methods or user behavior during operation.

The definition of the simulation described below, i.e., energy and environmental, covers the full range of building parameters, their variations, and analysis of the behavior of the designed building while assuming the behavior of its occupants in the "real world."

The programs can be separated into two groups:

- assessing/labeling a building regarding sustainability principles, requiring data entry for relatively simple numerical calculations, such as LEED ™, BREEAM or SBTool, in their original and national / adapted versions, which use "sheet" systems scoring.
- simulating to conduct analyses of the building's energy performance, based on complex mathematical-physical algorithms.

The firsts are not in themselves complicated by the level of mathematical theory, but they use other simulation programs for the energy, lighting, internal environment, and other factors, compiling them for the necessary analyzes. An example is the LEED ™ program where the user quickly realizes that the required data is only available from a simulation program such as DOE-2.1 or EnergyPlus. The proper simulation (in this case energy) can be divided into three stages:

- building analysis (data entry and model creation)
- simulation with the introduction of solution options
- analysis of results, adjustment of assumptions with the adoption of the optimal version

The other group uses full energy simulations or internal comfort as elements that are slowly becoming the most critical components of the design process; the concept of simplicity/complexity of the program with "simple calculations" should not be confused here. They are not complicated in themselves, but they use the results developed in other powerful simulation programs, compiling them for the necessary analyzes. Refer to Figure 5 below.

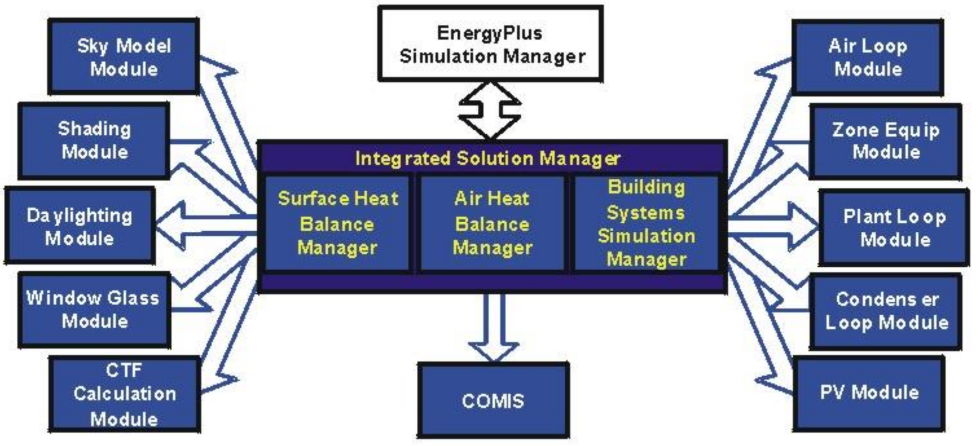

Figure 5. Example of modular program building. Source: U.S. Department of Energy

Modeling is understood as the method of processing a building project in a manner "suited" to the requirements of simulation. Once the model has been created, then any theoretical analysis can be performed on it.

The simulation, which allows the analysis of the thermal behavior of the building as a whole, is called thermodynamic simulation, taking into account such elements as the effect of the thermal mass of the building, the local climate, method of use, heat recovery, ventilation, cooling, heating, and lighting. The results are then automatically transferred to the final calculations of the simulations, which optimize the decisions being made during the process. The full simulation includes such analyses as:

- operating energy (heating, cooling, lighting, accessories)
- heat and cooling demand
- thermal comfort
- visual comfort
- indoor air quality including temperature and humidity, volatile compounds, and other
- daylight access
- user activity - Occupancy Schedule -is critical as the base for the predicted performance)
- connections to external space/outdoors
- operation of all systems in the building

The first element – the operating energy, often the essential one costs wise, may also include various energy sources and the choice of related devices, fuel cells, photoelectric cells, and sub-simulations like, for example, three-dimensional heat flow analysis in the building envelope giving a more accurate picture of thermal losses. Simulations are only a part of the solution, which should also include appropriately applied control systems that allow the use of all device operation options.

The best simulation programs are backed by years of research and experience, and their model calculations required substantial capital costs. It should be noted that proper modeling can be not only very time-consuming but also sometimes impossible to process due to the lack of required data, which the designer or the device manufacturer does not have. Often, the primary benefit of computer simulation, which is an optimization, is not used in practice for convenient reasons, such as lack of time to re-enter data or re-run the simulation with a new interpretation of results.

One of the aspects to be addressed may be, for example, the type of heating system - which means, for example, heat supplied from a CHP plant, electrically generated or in gas heaters. A relatively new process of analysis that results in a thorough understanding of the characteristics of energy systems is called "exergy" meaning, by definition, “the maximum ability of matter to perform work in a given environment.”

In the process based on simplified energy models, factors such as storing thermal energy (for example in thermal mass), the impact of heat losses on the ground around and under the building are taken into account. This last element is vital for system components that can be stacked both on- and underground, including the building itself and existing heating and cooling networks. Energy analysis is based on the first law of thermodynamics regarding energy conservation/maintenance, while the analysis of "exergy" is based on the second law related to energy states (e.g., natural changes of energy concentration). It allows better recognition of systems' imperfections and their deficiencies. Exergy is the part of the energy that is available to perform useful tasks and is absorbed during real processes and preserved during ideal ones.

Often the second law of thermodynamics is not respected during simulation, which results in erroneous results- the fundamental mistake of many analysts - simulators. Such violation sometimes occurs in modeling and simulation (such as the flow of thermal energy from lower to higher temperature) with only the first law of thermodynamics considered. Infrastructure, besides the assessment tools such as, for example, the Infrastructure Costing Tool, by CMHC, very often require also simulations with complicated calculations related to the nature of their relevant process.

District heating networks use hot water pipes for heating and hot water receivers, while cold water is used for cooling, and cold water in the system. The pipes can be above ground or underground. For a realistic analysis, heat losses during the shipment of energy carriers (usually fluid) should be taken into account even if the pipes are well insulated, which means that systems are always less than 100% efficient. Thermal connections between pipes and soil can be very complicated, hence the need for dynamic process simulation, which has to consider not only weather data for the interaction between soil and air but also thermal and hydraulic properties of soils, on which the heat and moisture transfer depends. The enormous complexity of the problems stresses the need to include "exergy" for energy simulation and for accounting for heat losses related to the surrounding land.

The task of the simulation is to provide not only the cost of energy but also, or above all, data on possible design solutions and their optimization. Multidirectional (multi-domain) analyses allow managing the building in an energy-efficiency mode while maintaining a high standard of thermal, visual, acoustic comfort and high quality of indoor air. In a situation where the users can define each domain, and additionally, they interact with each other, the analysis of interaction becomes much easier. A few examples of such cooperation:

- heat / lighting - light sensors for light on / off control
- heat/air (air stream) - use of air flow in a double building envelope for preheating the ventilation air
- heat / CFD (fluid dynamics) - dynamic analysis of local comfort in a large glazed space
- heat/ventilation and air conditioning (HVAC) - use of thermal mass to control heating and cooling requirements
- heat/electric - use of electrical power and recuperation/heat recovery from photoelectric modules on the façade

• heat/humidity/analysis of local condensation in combination with potential fungus

A primary requirement of the architecture and integrated design is to optimize the technical installations through the correct choice of form, function, structure and construction products to substantially reduce construction and follow-up costs and by following the principle "as little technology as possible, just as much as needed," to also reduce operating costs.

Life cycle costs analysis, a way to assessing total building cost over time, should be completed for a maximum period of twenty years. This analysis should include the following elements:

- Initial capital costs – including land and construction costs (as per above 5.1) but excluding (for clarity and comparison purposes): design fees, survey, permits, mortgage fees, sales expenses, financing and carrying charges, serviced land, general overhead, and profit.
- Operating costs – including energy, water/sewage, waste, recycling and other utilities;
- Embodied energy costs based on Athena software calculations (optional by the third party)
- Maintenance, repair and replacement costs;
- Other environmental or social costs/benefits – impacts on transportation, solid waste, water, energy, infrastructure, occupant health/productivity, outdoor air emissions, and other.

Conclusions 6 – a compilation of research 7 and 8

Simulations create the opportunity to evaluate many solutions and choose the option that best meets the requirements or goals, thus significantly improving the quality of the building, providing that the assumptions or predictions aim at the high-performance targets. A primary requirement of the architecture and integrated design is to optimize the technical installations through the correct choice of form, function, structure and construction products to substantially reduce construction and follow-up costs and by following the principle "as little technology as possible, just as much as needed," to also reduce operating costs. The simulated performance of the building and its adjacent parts becomes a crucial component in the entire integrated process.

Simulations are the indispensable tool in determining the contributory side of buildings towards the infrastructure and can also evaluate it from many perspectives vital for either extension or reduction and analysis of its behavior under given or required circumstances.

An example would be projections of catastrophic events, where the most improbable disaster scenarios are simulated on models exactly corresponding to real buildings and, in turn, to their surroundings by default also related to the infrastructure. Similar simulations are conducted in relations to the climatic events and their effects on the built environment including the site related infrastructure where the disasters like Sandy, Katrina and similar calamities can be shown as examples.

Simulations are also crucial in cost projections where different scenarios are analyzed through all phases based on an Integrated Design Process during which a life cycle cost analysis has to be completed. The components of such analysis should be reasonable and realistic, and the estimations should be supported with appropriate simulations and documentation.

Summary of Module 3

Various initiatives and programs offer to buildings and community designers the opportunities, by managing loads, to relieve the infrastructure during heat waves or cold snaps, and to avoid having to pay peak rate energy costs. Such situations also trigger utility brownouts/outages or spikes that can be avoided using renewable energy and backup power capabilities that appear suitable for both large cities and smaller communities.

The infrastructure, size of which depends on the buildings operational requirements, must be built and maintained with its other parts with different, but not lesser, importance such as water drainage, stormwater, electrical services - lighting, traffic light and other.

The building contribution depends on the various strategies and techniques but also on the specific context – the immediate neighborhood and then the urban pattern. The poor solar planning, site related, is a primary issue impacting the integration of solar thermal and PV. The use of solar power became a staple within the progressive architecture, but often, regardless of jurisdiction, successful implementation of solar measures still depends on external subsidies.

Planning densities and design goals in the Net Zero Energy Healthy Housing (NZEHH) approach promote solutions that adequately balance occupant's needs and desired activities with community needs and functions. Building materials are specified from local renewable resources; construction waste is reduced and well managed, construction impact on the surrounding area and watershed is reduced through reduced erosion and durability of building components is emphasized. The proposed housing uses efficient water and wastewater systems, and site design and landscaping provide for on-site rainwater use, stormwater retention and reduced infrastructure costs. The designs can minimize the need for raw materials extraction - be it forest-, petroleum- or water-based resources, thus the environmental impact of housing. It will require new approaches to community planning, housing design, materials selection, construction techniques and the regulatory approvals process as well the integration of processes.

Through a combination of innovative design, and state-of-the-art equipment, the optimized design can significantly cut the operating energy consumption, and with the use of "smart" technologies, it can reduce peak demand by shifting some electricity demand from high-use to low-use periods.
It is possible to incorporate Energy Elasticity & Resiliency (not just Fuel Switching) by cooperation, conservation and sharing at the community level, for example, the surplus heat/ cold/power that can be available from nearby commercial / municipal facilities (supporting the idea of Synergy Zones mentioned in).

One of the best ways to reduce the demand for potable water and the production of wastewater is by improving the efficiency of water use that can come as the result of changes in habit, others in changes to hardware (the use of water meters can cut residential water use by at least 30 to 50 percent) as well as to use appropriate water quality for intended purposes. Outdoor residential water use can be significantly reduced by employing alternative landscape designs – like Xeriscaping requiring the minimum amount of maintenance and irrigation. Use of permeable hard surfaces designed for infiltration is essential for enabling trees and other plants to get the water they need and for reducing stress on municipal stormwater systems.

Stormwater from large paved sites and roof areas has severe impacts on local ecosystems (oil accumulation, erosion of natural water-courses and flooding of treatment facilities) and municipal systems (storm sewers are sized for peak periods) and proper stormwater management can reduce stress on the sewer system. Grey water can still a subject of concern even after all measures of water saving due to a need of treatment and separation of it in plumbing systems should be considered.

The thesis is also supported through the subjects related to transportation where impacts of buildings are not only about indirect transportation emissions but from the built infrastructure such as highways, feeder roads, streets. All of it must be constructed and maintained in a long-term with all other services such as water drainage, stormwater management, electrical services - lighting, traffic light, overall controls. The infrastructure must survive winter, and that means huge expenses in snow clearing and extensive repairs every year to the majority of roads due to “freeze and thaw” cycles.

Integrated planning of sustainable neighborhoods/communities can provide significant benefits including costs. Analyses followed by the optimization of buildings and the area they are built on can create opportunities for energy and water integration as well as the use of renewable energy and waste within the community systems. District-scale development planning can also facilitate pedestrian-friendly alternatives such as walking and cycling routes as well as better developed public transportation. The resulting satisfaction translates into the better understanding of the environment leading inhabitants to live better, pay attention to resources they use, they save, and look after. That is an impact of buildings in which people care about what they have.

The new housing should be designed as flexible housing to accommodate changes in occupancy over its lifetime while making the best use of the investment in both the housing and the infrastructure of existing residential neighborhoods. “Tap the Sun” publication provides achievable solar goals for typical situations, with guidance for further explorations. It also tells how to design a house with passive solar design, an energy-efficient envelope, appropriate technology and provides examples for every climatic region in Canada.

The use of solar power in all aspects of it became a staple within the design circles of progressive architecture. With clear guidelines for ***What and How*** to do it, the architects can quickly follow the path, making sure that their efforts also go towards the adjacent, and essential, infrastructure. Very often such measures are unnoticed, being almost automatic- the water saving reduces the size of plumbing systems as energy conservation reduces HVAC system's size. However, all still depends on the sound design and the will of designers to pursue the goals.

While looking at world examples of the low -impact housing several conclusions seem to be very relevant to the building contribution to infrastructure, such as the poor solar planning with the insulation "replacement", integration of solar thermal and PV into the building envelope resulting in a better quality/cost ratio, successful implementation of solar measures still often remaining dependent on external subsidies. The overall primary conclusion from this "worldwide" research is that there is a need for benchmarks, references, clearer guidelines and goals, as well as criteria for overall green performance ratings as it may be difficult to assess with confidence and consistency.

The assessment of the potential of renewable energy systems in buildings is crucial for the long-term urban planning and evaluations of needs meaning also the opportunities impacting on the existing or future infrastructure. In the context of the thesis, various scenarios were analyzed under the angle of the potential building contribution. The level of research was beyond a particular building and its design; however, its usefulness was unquestionable, as it merely shows what could be viable in any particular location in Canada and the research, as such, may be used by the policymakers on a national scale in any location in similar climatic zone and economy.

The research concluded that without substantial reduction in the overall energy demand, in both electricity and thermal, the solar technologies may not meet the energy demand in the residential sector and the incorporation of all measures is recommended. Thus, such a conclusion supports the thesis that the buildings can supply the energy complementing the existing grid; however, the total dependence on renewable sources would not be possible in the near future unless using all measures available and perhaps on a global scale.

The research established background information for similar studies that, when combined with high-quality energy simulations, can give the best results within the predicted performance of buildings. Such data is then used to establish the infrastructure capacity which, by default, is then optimized on a scale of a neighborhood or a community with all measures analyzed through the building design process.

The architects can quickly follow the solar path if they have clear guidelines, making sure that their efforts also go towards the adjacent, always indispensable and essential, infrastructure. If significant reductions in purchased energy are not possible through increased insulation levels and significant mitigation of air leakage, they may happen with configurations of zero energy/emission mechanical systems (high-efficiency geothermal, solar thermal and PV). However, such ideas are in apparent contradiction with the fundamental statement that "first the best design and only then technologies, if needed at all."

Other features related to infrastructure such as green roofs, permeable sites, minimized building footprint, maintained trees, and restoration of degraded areas are all "a must" in sustainable design.

Such design should minimize storm system infrastructure and also increase the amount of permeable surface on the site.

"Intelligence" is the future of the buildings, with the ultimate goal of health and comfort of the user and the protection of the environment. It allows to manage the operations of the built environment such as buildings and the infrastructure and by that also the entire construction process requiring the building of the roads with the entire accompanying infrastructure and fuels polluting the eco-systems.

Simulations create the opportunity to evaluate many solutions and choose the option that best meets the requirements or goals. They are the indispensable tool in determining the contributory side of buildings towards the infrastructure and can also evaluate it from many perspectives vital for either extension or reduction and analysis of its behavior under given or required circumstances.

. The disaster or climatic event scenarios can also be simulated on models exactly corresponding to real buildings and real cities and to their surroundings by default related to the infrastructure.

An example would be projections of catastrophic events, where the most improbable disaster scenarios are simulated on models corresponding to real buildings and, in turn, to their surroundings by default also related to the infrastructure. Similar simulations are conducted in relations to the climatic events and their effects on the built environment including the site related infrastructure where the disasters like Sandy, Katrina and similar calamities can be shown as examples.

Simulations scenarios developed through the design development process should be based on an Integrated Design Process (IDP), the crucial element in any design of a significant size. The use of an IDP from the moment of the project inception to the commissioning of a net zero or net-positive energy building will contribute, in turn, through its extreme energy and water efficiency goals, to the reduction or elimination of the standard infrastructure. A primary requirement of the IDP is to optimize the technical side of the design through the correct choice of form, function, structure and construction products and by following the principle "as little technology as possible, just as much as needed," These measures substantially reduce construction cost and later operation and maintenance (O&M) costs that are all related to energy and water in all forms, thus to infrastructure.

Simulations are also crucial in cost projections where different scenarios are analyzed through all phases based on an Integrated Design Process during which a life cycle cost analysis has to be completed. The components of such analysis should be reasonable and realistic, and the estimations can be supported with the appropriate simulations and documentation.

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Wojciech Kujawski, M. Arch, MRAIC

Impact of urban design on municipal infrastructure

Module 4

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Introduction to the topic

The purpose of this topic is to present the type of information that could help visualize the locations and their contexts with already implemented right (or wrong) principles of urban design on a scale of neighborhood or community. Urban design and development do not exist without buildings that are built in an urban context with specific urban planning ideas. Some of them are shown in this module presenting the improvements to the urban life while affecting the infrastructure in many, well described, ways that support the thesis about the the building's contribution.

1. Water-Sensitive Urban Design

2014, W. Kujawski - CMHC project officer with C. Barraclough, Wm.Lucey, Aqua-Tex Scientific Consulting Ltd., Victoria, B.C.

Water-Sensitive Urban Design (WSUD)- what is it and why should we do it?

It is an approach to water management in urban areas, first made popular in Australia due to severe water problems there. It has since been adopted around the world and been expanded to include not just stormwater management, but all aspects of the water cycle including rainwater, snowmelt, wastewater (including blackwater and greywater) and drinking water, in addition to natural freshwater systems. Its widespread adoption may be due, in part, to the value WSUD provides to both the developer and the community regarding the benefits to the infrastructure through the urban and building planning, technical design and operation of the buildings, mitigating the required sizes and volumes through the various WSUD measures.

For example, the costs of treating and delivering water are growing; by harvesting rainwater on-site or reclaiming and reusing stormwater and wastewater for non- potable purposes, the amount of precious drinking water required by development is reduced. Similarly, in water-limited areas, planning to use water that is "fit for its purpose" (drinking water for drinking and cooking, rainwater or reclaimed water for toilets flushing and irrigation) may be the only way to secure enough water to build the project in the first place.

The objective of WSUD is to maintain or replicate the pre-development water cycle through the use of design techniques to create a functionally equivalent hydrological landscape.

When urban development occurs, large surfaces (roads, rooftops, sidewalks) are made impermeable. Stormwater runoff from properties and roads intensifies flows increase and contaminants from residential and commercial activity, and vehicles flow into the streams and watercourses. Traditionally, stormwater generated from urban areas is conveyed efficiently to piped drainage systems to reduce stormwater ponding and flooding risk to roads and properties with the effect that has included:

- **the intensification of flows** in watercourses often resulting in erosion and sedimentation;
- **a reduction in groundwater recharge**;

- **the contamination of streams** with substances that hurt water quality
- **an increase in the use of potable water** for domestic, commercial/industrial uses as well as outdoor irrigation of gardens and open space areas; and
- **more severe flooding** and increased areas of flooding due to the increased volume of runoff.

WSUD integrates various Best Management Practices (BMPs) for the sustainable management of the urban water cycle through the design of urban environments by limiting the negative impacts of urban developments on the total urban water cycle.

If the WSUD is considered strictly within the borderlines of the thesis, the aspects that are the most relevant are the first; however, all of them are shown to allow more flexibility in the readout. Therefore WSUD is about:[4]

- **trying to match the post closely- and pre-development runoffs** in both quality and quantity;
- **reducing the amount of water transported between watersheds**, by reducing consumption and reusing treated effluent;
- **optimizing the use of rainwater that falls on urban areas**; (building infrastructure for usage, and reducing it for evacuation)
- **adding value while minimizing development costs** (i.e., drainage infrastructure costs);
- **improving the quality of, and minimizing, polluted water discharges** to the natural environment;
- **incorporating collection, treatment and/or reuse of runoff**, including roof water and other rainwater;
- **protecting water quality and quantity** of surface and ground waters;
- **minimizing impacts** on existing natural features and ecological processes;

moreover, these having lesser direct impacts from the buildings creating an urban environment:

- increasing social amenities in urban areas through multi-purpose green space;
- landscaping and integrating water to enhance visual, social, cultural and ecological values;
- accounting for the intersection between water use and wider social and resource issues; and
- harmonizing water cycle practices across and within the institutions responsible for waterway health, flood management, pollution prevention and protection of social amenities.

Watershed health – the role of proper planning and design

Planners and designers (including architects, ecologists, engineers, landscape architects and others) have the ability to influence watershed health profoundly. Water is often seen as the domain of the “roads and drains” department or as the task of stormwater engineers on a development project; rarely are architects and planners involved; however, water touches every aspect of design, and the entire design team needs to be involved if water management is to be genuinely integrated.

So, when such a crucial element of the existing or future infrastructure is at stake, a WSUD approach at the planning/design stage would be to start at the context of the watershed with questions which, again, will have to be compartmentalized into items more relevant or less, or not at all in relation to buildings contributions. However, the overall depiction of the conditions requires the inclusion of all aspects, and within them, the potential impacts from the related information and measures planned to be undertaken in the context of urban planning which comprises buildings.

- Was the site forested? Was it a wetland? How much water ran off naturally vs. infiltrated the soil? What can be done to keep the site as natural as possible?
- How much water (rain and snow) falls on the site in a typical year? What are the predicted changes in a changing climate? What measures need to be taken to account for this?
- Where does the potable water come from? Is there adequate supply to support the development and also meet in-stream ecological needs of the watershed? Is the density appropriate in this context?

Design teams must remember that, apart from the technical aspects of the infrastructure, the health of neighboring watersheds (i.e.water supply and wastewater release) can also be affected by their development.

- Where will stormwater runoff go?
- What can be done to reduce it, infiltrate rainwater and reduce erosion?
- Are green roofs appropriate?
- Can bioswales[1] or other Best Management Practices (BMPs) be used to treat and convey water?
- Can porous paving be used to reduce runoff?
- Where will treated wastewater go? Can an opportunity be created to treat and reuse this water for non-potable purposes and to reduce demand on the potable water system?
- Can this project be linked to neighboring developments to obtain an economy of scale? This question may be crucial when cost analyses are performed but also underlines by itself the importance of water management in neighborhoods consisting of buildings that determine the water usage level.
- Can rainwater be captured for non-potable uses such as toilet flushing and irrigation?
- What are all the ways water is being used or moved on site? Is water used for cooling (air conditioners)?
- What is quality of water needed for each use?
- What is the function of the landscaping?
- What is the overall value (economic, ecological, social) of implementing these measures?

All of these questions need to be asked before any infrastructure is designed or built. The answers

[1] a long, channeled depression or trench that receives rainwater runoff (as from a parking lot) and has vegetation (such as grasses, flowering herbs, and shrubs) and organic matter (such as mulch) to slow water infiltration and filter out pollutants

will directly affect the size of piping, layout, and surfacing of the roads, design of buildings, elevation of buildings (flood risk), nature of the landscaping and even the density of the development.

The following case studies provide different scales and stages of the design.

Urban high density

NOTE: *Dockside Green[2] is also presented in the main part of the dissertation, and only the most significant (and missing there) features are shown here. The vital part of the development was only recently, in 2014, transferred to the City of Victoria allowing the second phase to be re-planned with the significant community engagement and some descriptions apply only to the early design stage when this study was conducted.*

Dockside Green is a 15-acre (6.07 ha) planned LEED™ platinum community on a former brownfield site in the heart of Victoria, B.C. Dockside's design team rejected conventional water management practices by adopting a "fit-for-purpose" approach to water use. Water enters the site two ways: in pipes from the local drinking water reservoir, and directly through rainfall. Piped water is first used for potable purposes such as drinking, cooking, and bathing.

High-performance water fixtures and appliances save water, reduce potable water consumption by 65 percent over traditional developments. Wastewater for the entire development is collected and treated on-site using a membrane bioreactor to a level of treatment fit for unrestricted public access. The treated, reclaimed water is then reused as many times as possible for non-potable purposes including toilet flushing, landscape irrigation, irrigation of balcony planters, rooftop gardens, and water supply for a human-made stream channel.

Annually, the volume of reclaimed water that is collected and reused is equivalent to one day's consumption for the entire Greater Victoria region (pop. 300,000) on the driest day of the year. Consequently, recycling water in this one development has created a benefit to the entire region.

Figure 1.Dockside Green waterway and path is attractive even in the early winter. Source: Aqua-Tex Scientific http://www.aqua-tex.ca (access April 2018)

The Dockside Green site was designed to mimic the natural hydrological cycle. Rainwater is captured and filtered by green roofs, bioswales, and cisterns, and stored in the waterway for final treatment and then used on site [Fig.1], [Fig.2].

2 www.docksidegreen.com accessed in March 2018

Figure 2. An aerial view of the Dockside Green waterway and green roofs. Source: Aqua-Tex Scientific http://www.aqua-tex.ca (access April 2018)

Water is celebrated on the site through design.

It is visible pouring from the open downspouts, splashing over mini-waterfalls instead of stormwater pipes, burbling down the man-made stream that runs the length of the site and soaking into rain gardens that are landscaped with native plants.

Making water infrastructure visible has proven to be very successful at Dockside Green.

Conclusions 1

Water touches all aspects of our lives, and thus should touch all aspects of our design. The objective of the Water-Sensitive Urban Design (WSUD) is to integrate urban design with natural ecological processes and add value to the development of scale with its water infrastructure.

In other more scientific words: to ***maintain or replicate the pre-development water cycle through the use of design techniques to create a functionally equivalent hydrological landscape*.**

The Water-Sensitive Urban Design can become routine practice once its value to a project is recognized. The key is to have the right people on the team, including ecologists, who can help guide the team in its technical decisions.

The specific questions need to be asked before any infrastructure is designed or built. The answers will directly affect the size of piping, layout, and surfacing of the roads, design of buildings, elevation of buildings (flood risk), nature of the landscaping and even the density of the development.

2. Urban Heat Island Mitigation Measures and Regulations in Montréal and Toronto

Research Highlight and Summary Report CMHC, 2014, W.Kujawski- CMHC Project Manager with University of Montreal Research Team: Y.Baudouin, S.Lefebvre,

This guide, which is intended for municipal stakeholders, sets out the broad parameters and identifies the major steps needed to reduce the impact of heat islands. The Heat Island Research Group at the Quebec University in Montreal (UQAM) has studied mitigation measures and planning and regulatory tools in Montréal and Toronto that can help reduce the number of heat islands.

A heat island is defined as an urbanized area where summer temperatures can be 5 to 10ºC warmer than the immediate environment. This phenomenon is felt more acutely when combined with increased pollution, thus the periods of smog the direct reason for a study concentrating on Montreal and Toronto.

The heat island phenomenon has been increasing steadily around the world in the past 150 years. As a result, it is not unusual to find temperature differences of 10, 15 and even 20ºC and over in the same city or town within a few hundred meters. The causes are many, but this work focuses on the loss of vegetation-covered space, the mineralization of the territory, the physical properties of some covering materials, their wear, the densification of built-up space and the increase in impermeable surfaces.

The proliferation of heat islands is of concern because they affect the health of the public, especially seniors, young children and the underprivileged. It is enough to remember about the 70,000 deaths in Europe in 2003 or about the 800 fatalities in Chicago in 1995. These figures only take into account deaths relating to heat waves, but if air pollution is brought into the picture, the numbers spike dramatically.

This project consisted of three steps:

- Completion and analysis of the thermal pictures of Montréal and Toronto.
- Inventory and selection of appropriate mitigation measures
- Review and summary of the planning and regulatory tools in both cities

Thermal pictures

The surface thermal pictures of Montreal in the summer of 2011 [Fig.3], [Fig.4], [Fig.5] and Toronto in the summer of 2010 were developed using Landsat 5 satellite images. The heat maps of different scales were produced along with Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) maps. A land-use analysis was also performed.

Inventory of mitigation measures

Various mitigation measures were identified based on a literature review and observations made in several cities. In addition, it was noted that, in order to reduce the presence of heat islands, it was preferable to combine mitigation measures rather than to opt for just one measure.

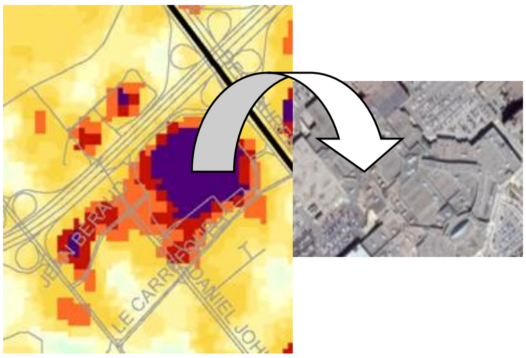
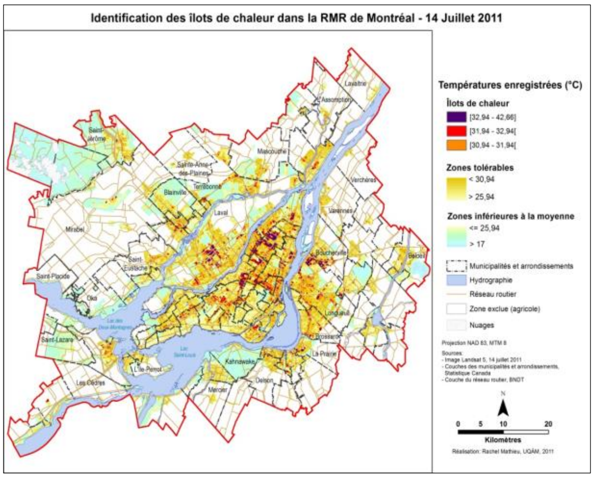


Figure 3. Example of a heat island (purple) located in the Carrefour Laval shopping centre in Laval. Source: UQAM, https://uqam.ca/english/about/

Table 1: Summary of the various parameters and fundamental notions associated with heat islands.

Parameter	Definition	Examples
Albedo	Albedo is the relationship between reflected solar energy based on incident solar energy. Its value varies from 0 (black) to 1 (white). It is affected by several factors such as texture, humidity and age (level of material wear)	Water = 0 New asphalt = 0.04 Tar paper = 0.05 Asphalt (5 years) = 0.12 Elastomer = 0.8 Snow = 1
Emissivity	Emissivity quantifies the capacity of a body to absorb and re-emit the heat releasing it. Its value varies between 0 (low capacity) and 1 (high capacity) or it can be expressed as a percentage.	Unpainted aluminum = 0.04 Elastomer = 0.4 Tar paper = 0.93 New Portland cement = 0.9
Solar reflectance index (SRI)	SRI is derived from the combination of emissivity and albedo. It is increasingly used by the construction industry (materials) Its value theoretically varies from 0 (low) to 100 (high) It was developed to guide choices. ASTM standard E-1980-01[1] shows how it is calculated.	Tar paper = 2.2% Elastomer = 83.1% Note that even though tar paper scores well on emissivity, its low albedo directly affects its SRI.
Urban canyon	Urban canyons are based on urban geometry and microclimates where, on a reduced scale, the density of the built space is taken into consideration along with the height and width of buildings	See the sky view factor.
Sky view factor (SVF)	The sky view factor, also called the angle of opening to the sky, represents the level of obstruction of a site. Various methods of calculation are used, but essentially the height (H) of buildings and their width (W) are taken into account. Its value is positive and varies from 0 (very open) to more than twice the H and W ratio (presence of a canyon)	When the height/width ratio is <0.25, it will be considered open. An H/W ratio = 0.5 or H/W = 1 will be dihedral, less open; and a ratio of H>2W will be considered a canyon, not very open[2].
Permeability	Permeability is the soil's capacity to allow a liquid to penetrate it. High permeability will be conducive to vegetation and will lower the incidence of surface runoff.	Residential area (low density) ≈ 70% Densely constructed area = 20%

Materials with higher albedo and emissivity, the preservation of and increases in the number of green spaces (roofs and facades), which contribute to evaporation, more permeable surfaces, adapted morphology and architecture and bona fide regulations to this effect would help reduce the risk associated with heat waves in an urban environment.



Thermal picture of Montréal

70 km2 of the 480 km2 (i.e. 15%) of the Montréal Island [Fig.4] are considered heat islands (>30.94ºC). They are mainly found in the center/south, north and east. The tolerable range (>25.94ºC and <30.94ºC) represents the majority (64%) of the Island (300 km2), and the coolest part (that is, below average) is located mainly on the west part of the island and accounts for 21% (100 km2).

Figure 4. Heat map of the Montréal CMA on July 14, 2011 Source: Landsat 5, band 6, UQAM. https://uqam.ca/english/about/

Given the increasing urbanization, the countryside character of the suburbs will continue to worsen from a thermal standpoint if development practices are not changed.

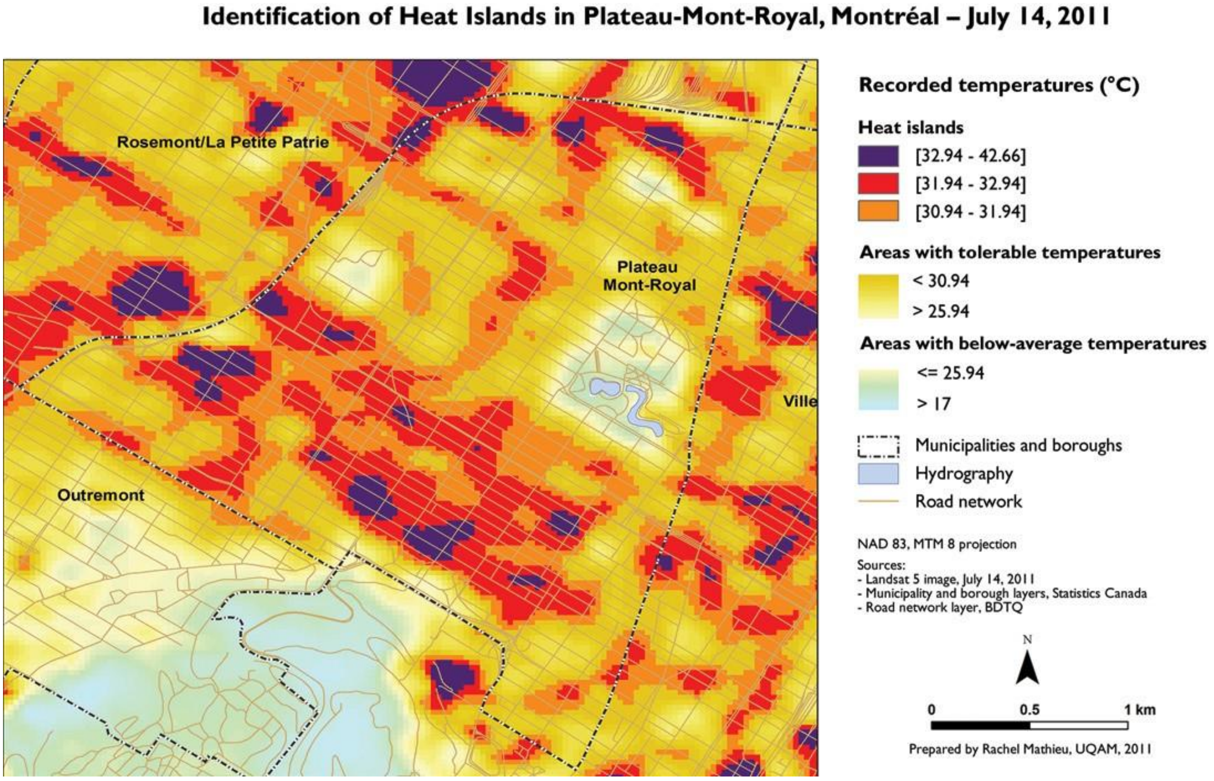


Figure 5. Thermal picture of the Montréal CMA on July 14, 2011 (Source: Landsat 5, band 6).

A heat island can affect a neighborhood more than 100 m away. For example, the average temperature of residential space will have not only its own temperature, but also those of its industrial and commercial neighbors. Consideration must not be given to functions that cover the most extensive surface area, but also to those that boost the temperature of the area in question.

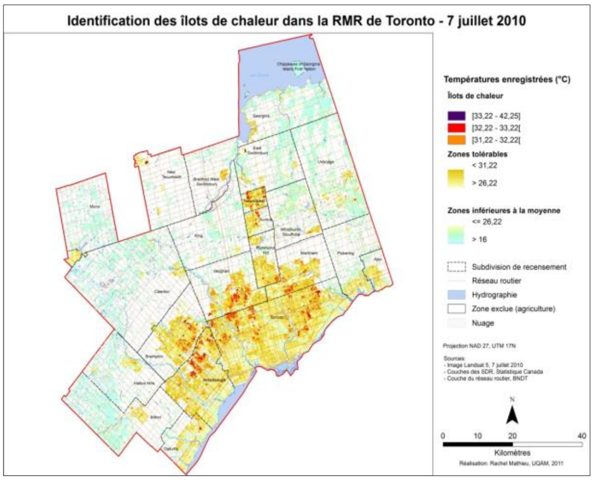


Figure 6. Thermal picture of the Toronto CMA (Source: Landsat 5, band 6).

Thermal picture of Toronto

The approach taken to analyze the Toronto region was the same one that was used for Montréal. However, one must avoid comparing Montréal and Toronto from a thermal standpoint, as Lake Ontario has a substantial effect on Toronto's thermal situation.

Furthermore, the presence of cirrus and cirrocumulus clouds on the Toronto satellite image affected the results to some degree. About 53% (1,400 km2) of the Toronto CMA [Fig.6], [Fig.7] is under the average temperature of 26.22oC. As a result, only 4% (115 km2) of its territory is affected by heat islands.

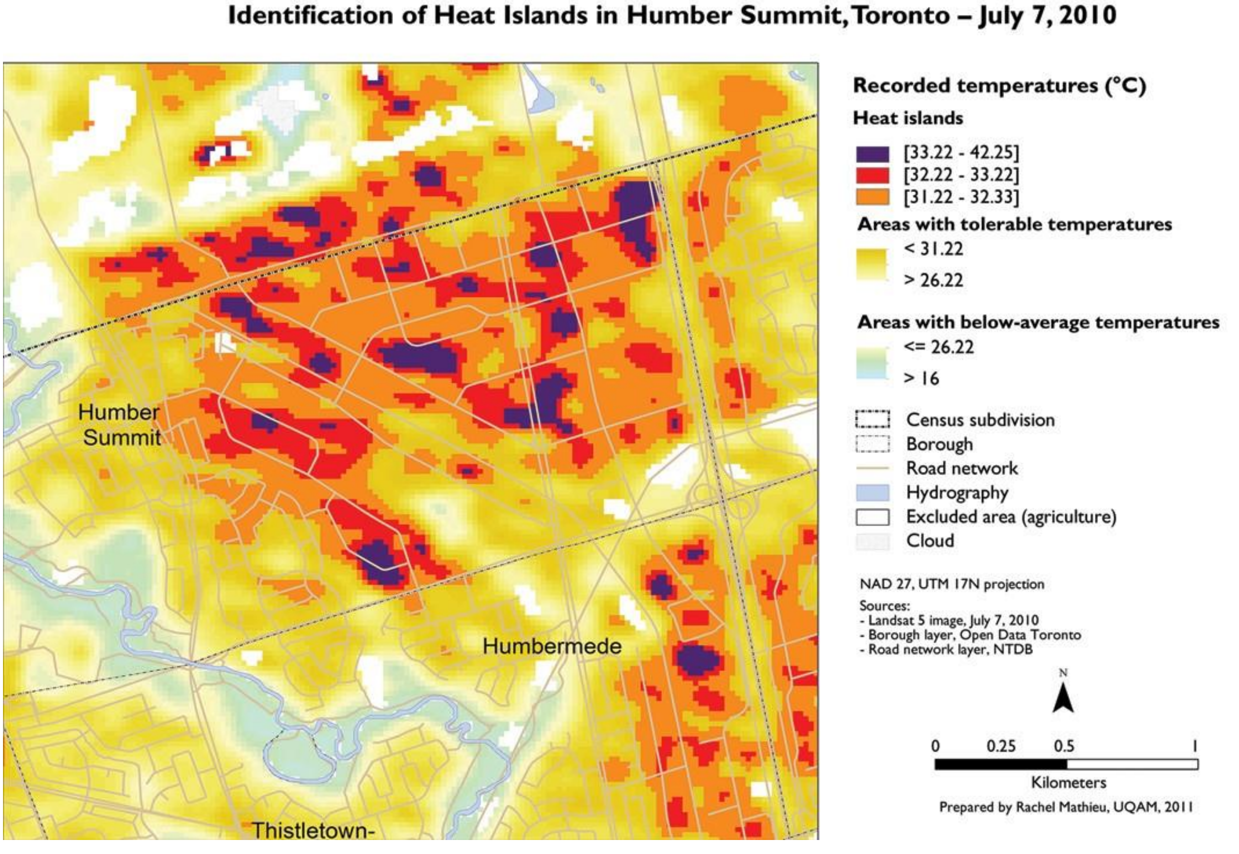


Figure 7. Thermal picture of the Humber Summit sector (Source: Landsat 5, band 6).

Municipal planning and regulatory tools

The normative urban planning and land-use planning frameworks in Toronto and Montréal were studied to identify all of the measures likely to lower temperatures in the built-up area.

Three levels of planning are generally followed.

- **Indicative planning**, involving a series of recommendations and guidelines, which do not entail mandatory compliance or any form of accommodation.
- **Incentive planning** involving offering grants or various forms of relief to encourage stakeholders to comply with the proposed measures.
- **Normative planning**, consisting of a series of urban planning bylaws or other such mechanisms that all development or new construction must comply with.

Montréal

In the general normative framework of metropolitan Montréal, no guideline pertains directly to heat islands, but several sustainable and environmental developments and greening policies do incorporate specific measures for that effect. In addition to the reduction of motor vehicle transportation, the development of green spaces and the accommodation of active transportation, the framework does address planning for landscape plantings and the reduction of mineralized and/or impermeable surfaces. Parking spaces are particularly covered by these measures, as are the roofs of large buildings (commercial, institutional or industrial) where provision is made for the establishment of green or white roofs.

Toronto

The normative framework of the Toronto region is far more explicit than Montréal's regarding heat islands. All of the regulations about major arteries and the natural environment identify several mitigation measures that are either indicative or normative [Fig.8]. Specific programs (Toronto Green Standard, Design Guidelines for Greening Surface Parking Lots, Green Roof Bylaw, Eco-Roof Incentive Program) are dedicated to reducing temperatures of parking spaces and to greening roofs. The compulsory measures pertaining to both types of space are highly detailed and have already been incorporated into the municipality's urban planning bylaws.

Figure 8.Toronto: Use of climbing plants on the facades of old industrial buildings converted into dwellings; June 2011. Source: UQAM

Proposed mitigation measures

To combat heat islands effectively, the simultaneous introduction of various mitigation measures is the more efficient approach with early adoption of measures and with specific attention paid to commercial and industrial sectors. Implemented measures produce benefits such as lower surface and felt temperatures, reduced mortality, better quality of life, less smog, smaller temperature variances, the longer useful life of materials, energy savings, higher property values and fewer floods.

Reduce parking spaces

- Give priority to multi-story parking garages (with green roofs) and underground garages.
- Increase shading by planting vegetation.
- Establish green strips.
- Reduce surfaces and increase bicycle parking areas.

Change roofs and facades

- Introduce cool roofs and cool facades by using materials with a high solar reflectance index (SRI).
- Maintain and clean roofs on a regular basis.
- Promote and construct green roofs and gardens
- Go with vegetation on the facades (facing south and west).
- Plant trees with deciduous leaves.

Reconsider some architectural and urban design and landscaping practices

- Avoid constructing buildings in enclaves and in topographic depressions.
- Vary the height of buildings.
- Maintain the height/width ratio at less than 1.
- Encourage strong ventilation in the districts with the highest densities.
- Consider orientation both in the construction of buildings and the planting of vegetation.

Increase permeability, surface water catchment and water bodies

- Incorporate water bodies into new projects.
- Arrange for surface water catchment for watering vegetation.
- Reduce the width of roadways.
- Promote geothermal energy.

Prioritize vegetative covers

- Increase vegetation-covered surfaces using plants that can withstand local conditions.
- Eliminate artificial vegetation-covered surfaces.
- Plant trees with deciduous leaves along road arteries.
- Conserve and increase the number of parks.
- Conserve and increase public shoreline spaces.
- Develop regulations to conserve existing green spaces.

Select covering materials carefully

- Promote the use of cool pavements.
- Review covering surfaces on roads.
- Reconsider highly mineralized tourist areas.
- Avoid using synthetic materials (for example, artificial turf) to the detriment of natural materials.

Conclusions 2

Our urban environments are thermally deteriorating, but various positive approaches are being taken to mitigate that. Mineralization is the main culprit in the degradation, but making smart choices, before projects are undertaken, can help better prevent heat islands and their effects on health.

Conserving existing green spaces, using more appropriate materials, opting for designs that address both the issues and their impacts, reducing impermeable surfaces and developing a better public transit policy should reduce the presence of urban heat islands.

To combat heat islands effectively, the simultaneous and early introduction of various mitigation measures is the most efficient approach with specific attention paid to commercial and industrial sectors. Implemented measures produce public benefits such as lower surface and felt temperatures, reduced mortality, better quality of life, less smog, smaller temperature variances, the longer useful life of materials, energy savings, higher property values and fewer floods. Most of these measures also affect the infrastructure through its synergies with buildings and their surroundings.

3. Sustainable Urban Regeneration,

"Zrównoważona Rewitalizacja Miejska, W.Kujawski -Zawod: Architekt, #25 -" 2012

The "Mayor's Tower Renewal" program (MTR) - developed at the request of the mayor of Toronto is an example of a balanced approach to urban revitalization. It was proposed and developed when it turned out (not suddenly) that there is a problem with almost 2000 residential high-rise buildings in the Greater Toronto area (the so-called Great Toronto *). It is impossible to even plan to demolish such a large number of buildings and build new ones, especially with several hundred apartments on average in each one of them, not metioning occupants with 10 to 20 different nationalities.

The author, cooperating with the City of Toronto and participating in the work related to the Tower Renewal in several projects, presented the findings in a seminar in Wroclaw, Poland for SARP (Association of Polish Architects) and also wrote an article for the professional magazine for active architects. The overview and its conclusions are presented herewith.

The process of renovation of the degraded buildings, complexes and entire urban districts is necessary not only for the health and well-being of residents, but also to assure the proper functions of the city as an organism. The guidelines for action, like for the Tower Renewal had to be created.

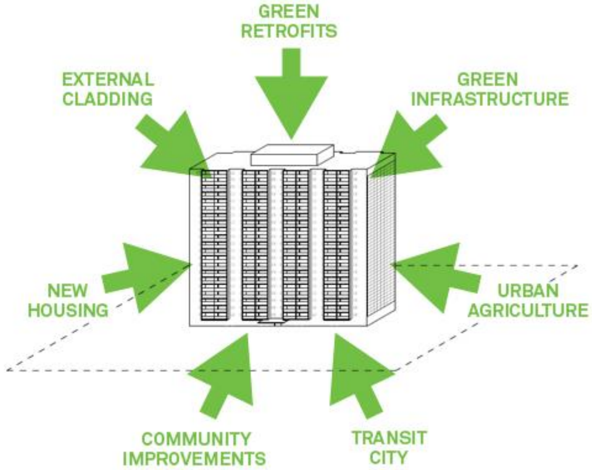


Figure 9. Elements analyzed during the sustainable modernization of the building. "Standard" thermal modernization, i.e. warming of external walls, is just one of many factors. Source: Mayor's Office, City of Toronto

The "guidelines" concerned, however, the buildings themselves, while the problems had (and still have) a much larger range. In fact, the long-term goal of the Mayor's Renewal Program is to revitalize the old and often devastated, to a certain extent, buildings that form entire residential districts. It is a program for buildings using broadly understood sustainability pillars: environmental, economical, social, and cultural (societal) that, in order to improve the state of Toronto concrete housing towers and the surrounding areas, applies these principles to local communities.

It combines the use of green technologies with the revival of social ties to create new, sustainable neighborhood units or local communities, taking into account such mixed elements as:

Envelope "treatment."

- thermo-modernization of façades in addition to improvement of insulation,
- possibility of running mechanical and electrical systems, and evacuation of waste within the envelope,
- and installation of solar systems (it is worth noting that thermal modernization is only a very small part of the process!),

Green modernization

- clean energy,
- gray water recycling,
- intelligent control systems,

Green infrastructure

- geothermal heating and cooling,
- wind and solar heating,
- green roofs,
- rainwater retention,
- gray water recycling,

Municipal items

- use of empty spaces around or above parking lots and towers,
- Transit-oriented developments - minimization or elimination of car dependence
- Improvement of the neighborhood - attractiveness of areas, local jobs,

Conclusions

Thermo-modernization is the primary element of energy efficiency improvement, and it is tasked to create a durable high-performance envelope with low maintenance costs over the life cycle of a building. The direct benefits of the renovated envelope are easily measurable: smaller heating loads translate into minimization of heating and required energy storage systems affecting the infrastructure loads directly as well as providing less sensitivity to current and future fuel and energy prices while, with smaller demand, opening realistically the field of the renewable energies.

During the thermal analysis of the properties of building partitions covered by the revitalization program, several problems were found and, as a result, the following technical targets of renovation were adopted:

- Achieving high air-tightness of the envelope,

- Lower thermal conductivity of the envelope components,
- Application of high-performance windows and doors systems,
- Elimination of thermal bridges,
- Reduction of summer heat gains and winter losses.

One of the most interesting dilemmas was the insulation of balconies: to re-build them with windows or just cover the balcony slabs with insulation because, traditionally (in Canada), no balcony slab was ever insulated and neither any thermal break was used. With extremely low energy prices in the years of construction, none of such savings made sense because the payback (return on investment) would hardly ever happen during the developer's or building owner's life. Therefore it was decided that if the fire safety conditions allow glazing to provide adequate daylight and provide ventilation needs, then the preferred strategy will be to build a balcony enclosure. Only the second option would be then to insulate the balcony slab.

For designers the essential aspect of the MTR program was to achieve the best results through good design, not high technologies, often obscuring errors and undesirable design. The right decisions regarding solutions, supported by energy simulations, and then the proper selection of materials and contractors, may lead to the situation that such technologies will no longer be needed, or at least to a lesser extent. It is the most effective way to achieve energy goals leading not only to direct energy savings but also to the reduction of the infrastructure tied to the buildings.

4. “Designing Sustainable Communities

2012, "Projektowanie Zrównoważonych Spolecznosci", W.Kujawski -Zawod: Architekt, #25

One of the most significant challenges facing architects and urban planners today on every continent is the need to design sustainable neighborhoods and communities due to their impact - through buildings and infrastructure - on soon ending access to raw materials, continually rising energy costs, the volume of waste and environmental degradation. Sustainability may concern the form of buildings, urban density, natural conditions, transportation infrastructure, and viability of energy and water supply [and its drainage] as well as the creation of nearby jobs, education, and leisure. In short, it covers all aspects of everyday’s life.

Urban design, in which all related disciplines are included, usually has a major impact on the environment through the developed land tied with the road network and adjacent, related infrastructure. The buildings are the main consumers of energy, raw materials and also the area they are built on. In the field of architecture, then - their size and location, the materials and technologies used as well as infrastructure and service systems, determine the quantities of raw materials needed for construction and operation, thus having a substantial environmental impact through their embodied energy.

Many elements, such as public transport or pedestrian traffic, are often taken for granted and are not analyzed. A similar situation may happen with the possibility of the heat that can be delivered to homes by connecting to the district heating network, but such approach is not even analyzed.

Is the size of the energy demand being thoroughly analyzed during a design phase taking into account the energy optimization of the buildings themselves by simulating the behavior of the building? The correct simulation can lead to substantial changes in infrastructure design, and thus to the cost of entire communities.

Since the end of the nineties, sustainability initiatives have expanded from home design (building) to sustainable neighborhoods/communities). Integrated planning on such a scale provides greater benefits and reduced costs. For example the operational analysis of several buildings and the area optimization can create opportunities for energy and water integration as well as the use of renewable energy and waste within the community systems. District-scale development planning can also facilitate pedestrian-friendly alternatives such as walking and cycling routes as well as better developed public transportation.

Programs and guidelines for community design

In the early 21st century in Canada and the USA people began to identify design principles commonly used, regardless of the context such as Smart Growth, LEED® for Neighborhood, Living Building Challenge and One Planet Living. One of the main North American problems is the requirement to reduce the use of resources for transportation and to provide alternative solutions, many of which (public transport, walking, cycling) is feasible only from a population density achieving a certain amount. An important problem is also the fact that occurs in every developed country: people desire to live in separation from others, in a community oriented towards private cars, which is not a model of sustainability.

Examples of elements of project integration in the scale of the local community /neighborhood:

- heat recovery from sewage or other waste sources and use of it in energy systems,
- rainwater irrigation, rainwater treatment, use of rainwater for toilet flushing
- food waste composting,
- integration of energy solutions in building design (e.g., PVs on the roof or facade) added then to the energy systems of the community,
- creation of mixed-use compact units connected to nodes of fast public transportation
- reduction of the need for cars,
- optimal use of land and buildings that creates more liveable neighborhoods,
- integration of the built environment in rural areas and areas of nature conservation.

It is important to point out that we the talk here is about the scale of a community, not about the scale of a single building. The assumption is, however, that the "sustainable housing community" consists mainly of energy-saving and ecological buildings.

The section from the Backgrounder to Guidelines for the EQuilibrium Sustainable Housing Initiative (EQ^{TM}), formerly NZE Healthy Housing;

CMHC, 2006 - W.Kujawski

Note: *As indicated in the Methodology, some publications have to be shared between different modules. The EQ^{tm} Initiative had the community related urban components presented herewith.*

NZE Healthy Housing encourages site planning and community design that reduces land requirements, impacts on habitat, agriculture, and fisheries, promotes resource-efficient landscaping, and considers broader community issues such as efficient transportation, reduced infrastructure, and preservation and restoration of natural features. Durability and longevity of designs are emphasized, taking into account future adaptations of buildings where possible.

Conventional construction practices result in the disposal of a significant amount of toxic and hazardous materials. Paint, solvents, caulkings, treated wood off-cuts arid a host of other contaminants conventionally find their way to our dumpsites — polluting the land and leaching into groundwater impacting the infrastructure in a significant way requiring it to be constantly upgraded and increased in many cases. Canada’s relatively vast supplies of fresh water are becoming polluted at an alarming rate. Houses contribute significantly to the deterioration of the streams, lakes, and ponds through the disposal of hazardous materials into the sewage system and through leaching of outdoor household chemicals into the ground water. Many municipalities are finding increasingly difficult and expensive to keep up with the growing requirements for fresh water and sewage treatment facilities. Thus each measure that reduces water demand, reduces also infrastructure needs. Minimizing environmental impact by any, or all measures means doing more with less, optimizing our use of precious land resources and minimizing our draw on this fixed commodity.

Effective land use planning

More than sixty percent of Canada's housing stock is made up of single-detached dwelling units – the least dense of housing options and the most consumptive regarding land, energy and even water. Single-detached homes accommodate some 60 percent fewer people per net hectare then row-houses. Sprawling development patterns not only require large tracts of land for housing, but for the required roads which this auto-oriented form of development entails. At the same time, sprawling developments place higher demands on the urban infrastructure in the form of roads, water and sewer systems, transit and schools.

The suburban development pattern is also more energy intensive, in both construction and operation. Detached houses consume anywhere from 15 to 67 percent more energy for space heating than other common ground-oriented housing options such as multi-unit buildings -apartment buildings, row houses etc. Data from a CMHC study: A 2-story detached home loses 20% more heat than a semi-detached one and 50% more than a middle unit in a row of townhouses of the same size, heating system, insulation levels and windows).

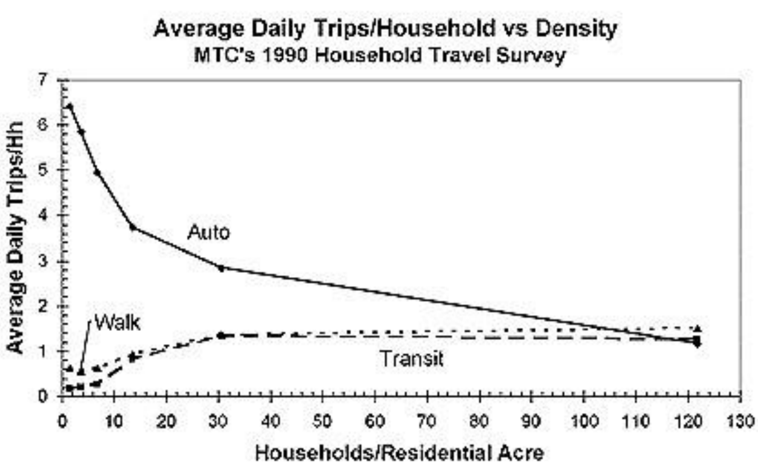


Figure 10. Daily trips per household by density, 3 U.S. cities. Source: Holtzclaw

Half of the greenhouse gases (GHG) from energy use by individual Canadians come from passenger road transportation. Land use planning significantly influences how far Canadians drive from their homes to reach their daily destinations, such as schools, jobs and shopping.

People living in centrally-located neighborhoods that are compact, mixed-use and pedestrian/transit-friendly generate up to 2/3 less GHG from urban travel than those in dispersed, single-use neighborhoods on the urban fringe.

Transit-friendly designs needs 17.5 houses per hectare (7 per acre) or more for transit to be economically efficient; higher densities also allow for more public greenspace. Many suburban developments are 10–17 houses per hectare (4–7 per acre).

Indirect design features related to buildings mitigating creation or increase the size of the existing infrastructure by encouraging alternatives to the motor car as a means of transportation, such as including bicycle lanes, or using traffic calming, certain elements should be considered such as:

- Designing the project for the use of transit through its allocation
- Narrower, interconnecting streets with sidewalks and pedestrian cut-throughs.
- The use of traffic calming techniques.
- Dedicated bicycle-lanes.
- Greenways, for hiking, cycling and horseback riding.
- Car-free residential areas, where people park their cars and walk to their homes.
- Overall trip reduction plans (also known as transport demand management).

Community Planning Issues

An NZE Healthy House design should address planning issues that will shape the communities of the future. These include density, land use mix and site considerations including:

- selecting a site where homes are near daily destinations such as shopping, jobs, and schools - can be done through intensification, such as infill, conversion or brownfield redevelopment.
- improving the viability of shared and distributed infrastructure solutions
- locating near transit nodes, (within a 5-minute walk or a subway, transit or commuter rail station)
- ensuring housing is in mixed-use neighborhoods
- enhancing pedestrian connectivity through design to make walking a more viable option
- making better use of existing infrastructure, including linear and community infrastructure
- provision of more affordable and varied house types responding to changing demands and needs
- community economic vitality
- enhancing the opportunities for cogeneration and district heating/energy production and sharing the preservation of green corridors and watersheds by developing one corner of the site and legislating against development in the other
- conducting a proper ESA (Environmental Sedimentation Assessment) before development.
- encouraging alternative water and wastewater treatment and delivery systems
- reducing the per unit cost of all infrastructure and in larger projects
- emphasizing compact, mixed-use developments with village or neighborhood centers
- encouraging the development of local economy to reduce the need for residents to drive, involving elements such as:
    - zoning land for commercial and industrial uses
    - encouraging home-based businesses
    - encouraging 'live-work' units (light industrial/commercial/limited retail, plus live-above)

- creating a local economic development strategy
- provision of a greater variety of urban spaces and amenities which create livable community and improve quality of life

A livable, viable community, although often broadly defined, is used to refer to facilities such as parks, tot-lots, a community hall, or facilities for the arts, seniors or youth. The elements include:

- Parks, tot-lots, open space, beyond the minimum 5% requirement
- Community allotment gardens
- Space for a community hall, a church, or place of worship
- Schools in the middle of the community, as opposed to on the edge
- Seniors center, facilities for teens
- Implementation of the arts
- Negotiating a strategy to finance and build community facilities

The site plan determines how the house interacts with the surrounding neighborhood and environment. Careful site planning can contribute to the efficiency of the individual house (including optimization of building location, orientation, and landscaping), minimize the impact of the house on the surrounding environment and contribute to a ‘healthy’ social environment.

A sustainable community is a community that supports healthy ecosystems and healthy living conditions and offers a variety of types and sizes of buildings, social, educational and cultural facilities. Full diversity of land use, commercial and service opportunities along with public space, and easily accessible, connected and affordable communication systems.

Designing such a community requires an interdisciplinary design team working as part of an integrated design process that involves a broad involvement of the community and stakeholders. Designing on the neighborhood scale gives the possibility of integrating water and energy systems in micro- and macro-scales. Responsibility for sound design for customers and all those interested in and for future generations should be borne by designers who also have an excellent opportunity to discover new ways of creating architecture and urban planning.

5. ”Taking an Integrated Approach to Sustainable Community Design: A brief overview of EQuilibriumTM Communities projects and a sample of other national and international projects” [3]

CMHC, 2011, article for Ontario Association of Architects - with input from Woytek Kujawski (Project Manager), M.Steele, freelance writer, D.Pollard, and S.Fisher, CMHC

Sustainable community design, one of the challenges facing urban and rural communities today, is critically important because of the impact of housing, neighborhoods, and communities on the limited Earth resources and limited capacity to absorb the waste. The buildings are major consumers of land, energy and raw materials. The size and location of buildings, the materials, and technologies used in construction and operation of the infrastructure and systems supplying services, all influence the number of resources required to construct and operate buildings, thus their impact on the environment.

Essential among universal design principles is the use of an integrated design process to maximize the synergies among the diverse elements and functions of the built environment. The study focuses attention on the EQuilibrium™ Communities Initiative but also includes examples of other sustainable community projects in Canada and Europe, and they are described in other parts of the dissertation.

As sustainability initiatives broadened the focus from houses to the sustainable neighborhood and community design, working at the neighborhood scale provides opportunities for benefits as a result of integrated planning. For instance, multiple buildings and land uses can integrate energy and water systems and potentially capitalize on renewable and waste energy as a min fuel in community energy systems. Planning on a neighborhood scale can also facilitate pedestrian-friendly design features, making transportation alternatives such as walking, cycling and public transit as viable options.

The typical features of sustainable communities have all the necessary amenities, activities and opportunities for daily life (i.e., housing, culture, employment, entertainment, healthcare, recreation, schools, shopping etc.) within easy access by walking, cycling or using public transit. A sustainable community supports both healthy eco-systems and healthy living conditions. Specific principles apply universally regardless of context, and many sustainable community initiatives have identified sets of such principles or performance objectives to guide their work (e.g., Smart Growth, LEED® for Neighbourhood Development, Living Building Challenge and One Planet Living).

Smart Growth[1] is shown as an example, as there are no substantial differences on a basic level.

It is an urban planning and transportation theory that concentrates growth in compact, walkable urban centers to avoid sprawl and advocates land use and development principles for creating sustainable communities. It encourages a mix of building types and uses, diverse housing and

[3] Taking An Integrated Approach To Sustainable Community… (n.d.). http://www.oaa.on.ca/oaamedia/documents/Taking%20an%20Intergrated%20Apporach%20t accessed March 2018

[1] https://smartgrowthamerica.org/our-vision/what-is-smart-growth/ http://en.wikipedia.org/wiki/Smart_growth

transportation options, development within existing neighborhoods, and community engagement that require to:

- Encourage a diversity of land uses to ensure that each neighborhood includes a mixture of homes, retail, business, and recreational opportunities.
- Build well-designed compact neighborhoods where residents can work, shop and access recreation areas in close proximity to where they live;
- Provide a variety of transportation choices including walking, cycling, transit and driving;
- Create diverse housing opportunities to include individuals and families with varying income levels and at different life stages;
- Encourage growth in existing communities;
- Preserve open spaces, environmentally sensitive areas and areas of natural beauty;
- Protect and enhance agricultural lands;
- Utilize smarter, less expensive infrastructure and green buildings;
- Foster a unique neighborhood identity; and
- Nurture engaged citizens.

Planning at the community scale provides opportunities to capitalize on the interconnections among various objectives including optimization of the infrastructure. For example, providing pedestrian and bicycle paths through the specific urban and buildings design will encourage activity, which supports improving health, reducing energy consumption and pollution and creating active, safer streets and at the same time decrease the road infrastructure, thus contribute to the overall environmental impact. Other examples show opportunities to integrate various elements and systems related to the infrastructure through the design of homes, such as:

- recovering heat from sewage or other waste sources for use in community energy systems;
- directing stormwater to soil volumes in planting pits, basins or swales to reduce run-off and improve stormwater quality, for example, bioswales:
- composting food waste into soil for use in on-site gardens;
- integrating energy solutions (such as photovoltaic panels) into the design of buildings so they blend in, are unobtrusive and feed into the community energy systems;
- capturing rainwater for use in toilet flushing and irrigation;
- creating compact, mixed-use development concentrated around transit nodes, such as rapid transit stations to reduce car use and make community energy systems more viable;
- including a variety of land and building uses nearby and connected with pedestrian-oriented pathways to create more vibrant neighborhoods and reduce the need to travel by car for daily needs; and
- integrating the built environment into natural habitats and open spaces

The Initiative was providing support to developers of selected sustainable community development projects that were designed to achieve high environmental and energy performance levels and that were financially viable and affordable. Support was made available for research, feasibility studies, design costs as well as activities to improve performance in projects, and the on-going monitoring and information sharing of projects to allow other developers across Canada to benefit from the experience gained by the project development teams.

The EQtm Initiative was structured around six interrelated themes that focus on design elements that are most directly impacted by urban form and are measurable.

- **Energy:** an energy-efficient community that balances energy supply and use to minimize greenhouse gas emissions;[4]
- **Land Use and Housing:** a compact community with a balanced mix of activities, housing choices and commercial, institutional, recreational and industrial land uses;
- **Water, Wastewater and Stormwater:** a community that will minimize the use and disposal of water and negative impacts on watersheds;
- **Transportation:** a community that reduces fossil-fuel use from personal vehicle travel and provides opportunities for resource-efficient and healthy alternatives;
- **Natural Environment:** a community that protects, enhances and restores the natural environment; and
- **Financial Viability**: a marketable community that through its design, operation, integration and financing, is economically viable over the long term.[14]

Indicators for measuring performance across these themes are shown in Table 1.

Table 1 – EQuilibrium™ Communities Performance Indicators[15]

Performance Indicator	**Description**
Energy Consumption in Buildings	Estimate of annual energy use in MJ/m^2 for each building type Estimate of total energy use across all buildings
Neighbourhood Use of Renewable and Waste Energy	Estimate of annual energy planned for capture from renewable and industry/operational waste inputs (in GJ)
Housing Affordability	Percentage of dwellings with price/rent equal to/or lower than the average for the area Breakdown of dwelling types
Land-Use Diversity	Breakdown of land area for each land use type (residential, mixed-use, commercial, industrial, agricultural, civic, public open space and natural habitat)
Proximity to Daily Destinations	Percentage of dwellings within 800m of grocery store, restaurant or café (coffee shop) and pharmacy

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14 http://cmhc.ca/en/inpr/su/eqsucoin/eqsucoin_001.cfm (April 2, 2018).
15 http://www.cmhc-schl.gc.ca/en/inpr/su/eqsucoin/upload/indicators-pub-Eng-final.pdf (April 2, 2018).

Performance Indicator	Description
Proximity to Jobs	Number of jobs within a 5 kilometre radius of centre of development site
Proximity to Civic Amenities	Number of civic amenities (e.g., schools, libraries, community centers) within 800m of the center of the development site
Transit-Supportive Density	Number of occupants per hectare Number of jobs per hectare
Transit Proximity and Quality	Percentage of occupants and jobs within 400m of public transit access point. Transit frequency Percentage of dwellings within 800m of a rapid transit station
Pedestrian Route Connectivity and Safety	Number of pedestrian route intersections per hectare Number of pedestrian route connections per kilometer of boundary
On-Site Stormwater Infiltration	Percentage of stormwater falling within the development project site that will be infiltrated on-site
Potable Water Use Reduction	Percentage of dwellings with dual-flush, 3 or 4.5-litre toilets, low-flow fixtures, water-efficient front-loading clothes washers Percentage of dwellings with water recovered from non-potable sources (e.g., greywater, wastewater, rainwater) per end-user. Percentage of the landscaped area that is a water-efficient landscape type (e.g., xeriscapes, woodlands, wildflower meadows/prairies and low-maintenance lawns)
Tree Canopy Intensity	Total percent of the project area with a tree canopy Percentage of tree canopy from existing trees
Open Space Proximity and Quality	Percentage of dwellings within 400m of a public open space Quality/size of open space
Natural Habitat Protected, Restored, Enhanced or Created	If the project site has existing significant natural habitat area, the percentage of that area to be protected, restored or enhanced Percentage of the project site area for habitat creation
Agricultural Land Protected	If existing productive agricultural land is part of the development site, percentage that is maintained or enhanced
Access to Locally Produced Food	Area of dedicated food growing space per dwelling Percentage of dwellings within 800m of farmers' market
Watershed Protection	Plans for minimizing or eliminating adverse effects to watercourses (both on- and off-site) and the lands that drain into them

Lessons Learned From EQuilibrium™ Communities Projects

(descriptions are based on the initially planned targets, and not on current status)

Station Pointe, Edmonton, Alberta

The Station Pointe project is a transit-oriented, brownfield development located on former industrial lands in the northeast part of Edmonton. The design is based on Passive House concepts while remaining affordable[16] and features:

[16] http://www.stationpointegreens.ca/ June, 2011.

Energy: The project is targeting a 75% reduction in whole building energy use by focusing on passive design features, including a superior envelope design.

Land Use and Housing: The mixed-use plan includes 220 affordable and residential market units in a mix of townhouses, mid-rise, and high-rise apartments. It also includes more than 1,400 m^2 of commercial and retail space, a daycare center, and community facilities.

Water, Wastewater, and Stormwater: The target is to treat all wastewater produced in the development on site and re-use it for toilet flushing and irrigation and also to divert stormwater from the municipal sewer through a combination of on-site infiltration, capture, treatment and re-use on-site.

Transportation: Within walking distance of a light rail transit station and bus terminal.

Natural Environment: As a former brownfield site, no natural habitat or agricultural land were removed, and new landscape and stormwater runoff reduction features are planned.

Regent Park Revitalization, Toronto, ON

Toronto Community Housing is leading the Regent Park Revitalization that transformed Canada's oldest and largest social housing community into a mixed-income community for 5,100 households in Toronto's east downtown. The EQuilibrium™ Communities Initiative supported activities in Phase 1 of the revitalization which created 360 affordable rental units for low- to moderate-income residents and 670 market-priced condominiums as well as office, retail and community use.

The project includes a green building education program to encourage residents to reduce water and energy consumption. Water and energy use will be monitored regularly and communicated back to residents, enabling them to monitor and adjust their consumption patterns.

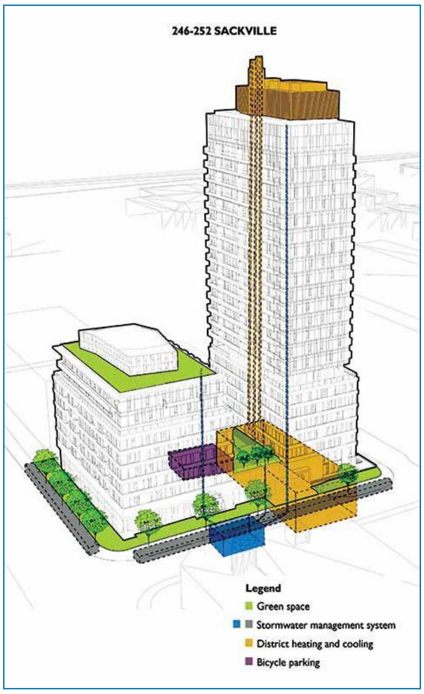

Figure 11. Rainwater capture from roof to underground infiltration tank. Source: CMHC

Energy: The development is projected to reduce energy consumption by between 40 and 50% (compared to the Model National Energy Code for Buildings). Energy savings will occur due to energy-efficient building envelopes, lighting, appliances and mechanical systems and through connection to a community energy system. TCH plans to use commercial waste heat (through its connections to a community energy system) for residential heating that will also contribute to energy savings

Land Use and Housing: The project includes a mix of townhouses and apartments (mid-and high-rise) in rental units for low to moderate income and market condominiums. In addition to being a mixed-income neighborhood, it is a mixed-use neighborhood, including two daycares, community agency space, a learning center, employment hub and over 2,500 m^2 of retail and commercial services space, including a bank and a large grocery store.

Water, Wastewater, and Stormwater: The project targets a maximum runoff volume of 50% of average annual rainfall through strategies such as green roofs and porous pavers. Strategies for reducing potable water use include low-flow fixtures and water-efficient landscape design.

Transportation: Located in Toronto's east downtown, Regent Park offers excellent access to public transit, places of employment, civic amenities and other frequent daily destinations, all within easy walking distance, in a pedestrian-friendly, interconnected design.

Natural Environment: Despite the high density, the design includes more public open space than in the previous lower density garden city design. Open space is connected to the pedestrian network, encouraging walking and cycling. New tree canopy coverage and green roofs enhance the natural environment.

Figure 12. Regent Park (view from balcony), credit: CMHC

Figure 13. Regent Park, street view. Source: CMHC

Ampersand, Ottawa, Ontario

Ampersand, developed by Minto, the Otawa developer, is a transit-oriented development (TOD) adjacent to a retail/transit hub in Barrhaven, a suburban area of Ottawa (Fig.5). Phase 1 has 300 units in the form of stacked townhouses and four-story condominium apartments. At completion, Ampersand will offer over 1,000 residential units including high-rise units, as well as proposed commercial-retail and civic uses.

Figure 14. Ampersand plan. Source: CMHC

Figure 15. NetZero building. Source: W.Kujawski

Figure 16. View of an interior street. Source. W.Kujawski

Figure 17. Ampersand view. Source: W.Kujawski

Figure 18. View of the Park and tree coverage. Source: CMHC

Energy: A 14 unit condominium apartment, targeting net-zero energy consumption and featuring photovoltaic panels, was completed in 2011. Other buildings include design features such as improved building envelopes and mechanical systems and energy-efficient appliances to reduce energy consumption. Minto was investigating the feasibility of a community energy system powered by biomass and other renewable energy sources such as photovoltaics.

Land Use and Housing: The project plans to include more than 1,000 new homes of various design including stacked townhouses and mid-rise apartments and approximately 25,000 m^2 of commercial/retail space, public facilities and public open space.

Water, Wastewater, and Stormwater: Minto was targeting stormwater run-off reduction from permeable pavements and green roofs and rainwater capture and treatment for non-potable water applications, such as irrigation and also explored greywater re-use opportunities.

Transportation: The site is adjacent to some daily destinations including grocery stores and restaurants and is a short walk to a rapid transit bus station and a proposed light rail transit station.

Natural Environment: A tree canopy covers 30% of the site providing areas for community and home-scale food growing.

Conclusions 3

Sustainable communities can be described as communities that support healthy ecosystems and healthy living conditions. They have all the components necessary for daily life within easy walking or cycling distance or within a short public transit ride. They offer a diversity of housing types and sizes; a spectrum of social and cultural amenities; a full mixture of land uses; a range of commercial opportunities; an easily accessible, and affordable transit system; and pleasant public spaces.

Planning at the community scale provides opportunities to capitalize on the interconnections among various objectives including optimization of the infrastructure. For example, providing pedestrian and bicycle paths through the specific urban and buildings design will encourage activity, and at the same time decrease the road infrastructure, thus contribute to the overall environmental impact. Other examples show opportunities to integrate various elements and systems related to the infrastructure, such as:

- recovering heat from sewage or other waste sources for use in community energy systems;
- directing stormwater to soil volumes in planting pits, basins or swales to reduce run-off and improve stormwater quality, for example, bioswales:
- composting food waste into the soil for use in on-site gardens;
- integrating energy solutions (such as photovoltaic panels) into the design of buildings so they blend in, are unobtrusive and feed into the community energy systems;
- capturing rainwater for use in toilet flushing and irrigation;
- creating compact, mixed-use development concentrated around transit nodes, such as rapid transit stations to reduce car use and make community energy systems more viable;
- including a variety of land and building uses nearby and connected with pedestrian-oriented pathways to create more vibrant neighborhoods and reduce the need to travel by car for daily needs; and
- integrating the built environment into natural habitats and open spaces

The design requires extensive community engagement and stakeholder involvement with a thorough understanding of the relationships between the diverse elements and functions of the built environment and seeks to capitalize on the interconnections between elements and systems (e.g., waste from one area providing fuel for another). Designing at that scale provides opportunities to integrate systems (such as water and energy systems) across multiple buildings and land uses. The infrastructure always benefits from such actions, and sustainable community projects in Canada and elsewhere demonstrate that specific, mentioned above, principles apply universally, although they are, or should be, interpreted locally to suit the particular context of the neighborhood or community.

Communities that are designed with these principles can, about the impacts on infrastructure significantly reduce energy and waste, reduce demand for urban resources and preserve ecosystems.

With the responsibility of designing sustainable communities and neighborhoods, there also comes an opportunity to explore new expressions of urban form. The planning and design should focus on the passive approach, solar energy, daylight, shading and natural gravity ventilation following the energy pyramid: starting on the building envelope (thermal insulation), then heating / cooling systems, sanitary and kitchen ventilation, and only at the end – if needed at all – the renewable energy systems. If the building is to "green" by design, not by the technology used then the related infrastructure will be smaller and likely more efficient.

Integrated planning on a scale of sustainable neighborhoods or communities can provide significant benefits including reduced costs. Analyses followed by the optimization of buildings and the area they are built on can create opportunities for energy and water integration as well as the use of renewable energy and waste within the community systems. Neighborhood planning can also facilitate pedestrian-friendly alternatives such as walking and cycling routes as well as better developed public transportation. At the scale of a community, it is necessary to include social aspects that are reflected by the satisfaction of translating into a better understanding of the environment that leads inhabitants to better, healthier life. Such an approach goes than to the infrastructure as a direct impact of buildings in which people save energy and water energy and care about waste while biking to their workplace

An essential objective of EQuilibrium Communities was to share lessons learned from the analysis and implementation of new design approaches and technologies in the projects, and it resulted in a summary on the subject of green infrastructure. It contains specifically stormwater practices for Low-Impact Development and landscape best practices, such as habitat protection.

Rather than taking a one-size fit all approach, the practices in each project are unique and customized to their site conditions, context, future occupant needs, budgets and regulatory environment. For example, the design of Ty-Histanis[5] on Vancouver Island, British Columbia, emphasizes habitat protection and re-establishment, whereas, for the other projects, there was no existing habitat and few, if any, trees along with insufficient space for habitat creation. In the denser projects, such as Regent Park, every surface had to be optimized for vegetation, permeability, and reduction of stormwater runoff and pollutants. For dense projects like these, practices such as green roofs and permeable pavers form an integral part of the design.

Each project integrates the stormwater and landscape practices into a system, working in harmony with the buildings, open spaces and surrounding context and indirectly with infrastructure.

[5] http://https//www.cmhc-schl.gc.ca/odpub/pdf/67077.pdf accessed November, 2017

6. "The Green Islands of Wroclaw"

W. Kujawski, Advanced Buildings Newsletter #3 (Canada) -– iiSBE, 2004 based on "Wroclawskie Zielone Wyspy" by Dr Alina Drapella-Hermansdorfer, Department of Architecture, Wrocław Technical University, Poland,

The project proposes the protection of an urban area of 11 km2 In the form of two islands created artificially centuries ago within Wrocław city limits: the smaller Opatowicka Island, and the larger Great Island. For the sake of the study, the area is called the "Green Islands". Both islands are the result of an accumulation of individual housing estates, exhibitions and areas of greenery. At present, the area requires urgent steps towards in controlling land speculation and parking and commuting issues, both of which induce environmental degradation.

The first step of intervention by a Wrocław City Council was to take control of both islands individual protection plans. The second one was to implement local planning arrangements and the pro-ecological project package for the area (a Local Agenda 21 project) with the purpose of building a city district, which will become the benchmark for other, similar areas of Wrocław.

As Dr.Wojciech Kosinski commented... *"the main goal was to make green Islands a magnet for visitors and for regular inhabitants - all who deserve comfort and beauty of the healthy and friendly environment. The project shows a variety of possibilities to improve environmental conditions - limiting traffic noise, particle and gas emissions, retention of rainwater, managing water resources, development of greenery and safety for the native fauna."*

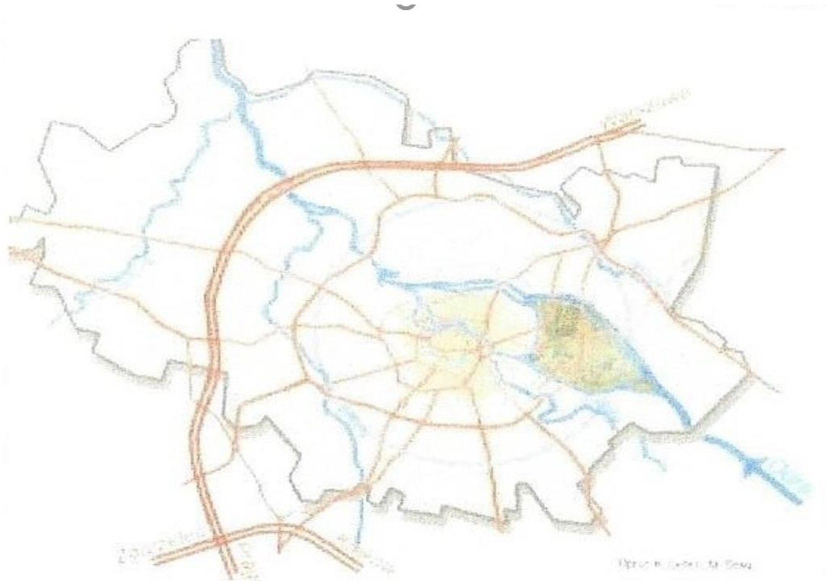

Figure 19. Map of urban traffic and protected green areas. Source: K.Cebrat, M. Sowa

The goals of the Green lslands project include:

- **Spatial order**: preservation of the landscaping identity, improvements in building standard, commuting and climatic conditions, development of site-specific public spaces
- **Natural order**: use of rainwater, improvement in the quality of soil, biodiversity;

- **Social order**: organization of the system of partnership activities, ecological education;
- **Economic order**: raising the effectiveness of investments, and providing a clear description of goals and measures to achieve them

Assessment Framework

The team has developed its own "Green Audit" based mainly on several existing international rating systems. The finał framework consists of the following categories and criteria:

- **Location**: site selection by natural and cultural conditions, public transportation;
- **Site development**: density, location, rainwater collection and use, garages and parking spaces, fauna, greenery and water elements, reduction of the heat island effect;
- **Building structure**: form- natural/cultural features, green energy.

Analysis of the Green Islands shows that steps should be taken to reverse the process of creating isolated ecosystems resembling islands of green being absorbed from all directions by artificially developed areas. The idea of protected zoning within the city limits may not always be applied.

No transitional area would protect greenery against other, frequently strongly degrading impact of its neighbors as it appears in the case of the Green Islands. The assumption was that the only way to protect them, is to make all urbanized areas “penetrable” to nature.

The project focuses then on the directions and methods of "city naturalization" with a simultaneous promotion of specific approaches to nature and the society. As part of local agenda 21, the Green islands projects shows the opportunities and methods to be used by local community wishing to become involved in managing landscape unique to the city, region or country.

The project developers expect that all individual projects within the area will also follow the four principles:

- do no harm
- strengthen the existing natural interrelations and preserve site landscaping tradition
- develop the existing networks of natural interrelations by making built-up areas of available indigenous plants and animals
- use to the maximum the existing natural resources to meet human needs.

Conclusions 4

The Green lslands project is still quite theoretical, but it points out a direction that is quite promising - as long as implementation follows the roadmap defined in the plan. Within the city limits, the idea of protected zoning may not always be applied. No transitional area would protect greenery against other, frequently strongly degrading impact of its neighbors as it appears in the case of the

Green Islands. It has been assumed that the only way to protect is to make all urbanized areas permeable to nature affecting the operation of infrastructure by a “natural” and positive way.

7. "Angus – retrofit of the locomotive factory in Montreal."

Architektura Murator, 09/2001 (Poland), W.Kujawski -

Introduction

The Locoshop Angus (Angus), an initiative of the Société de Développement Angus (SDA), is the first phase in the development of a new 6.5-hectare business park, the Angus Technopole, in east-central Montreal. The project, the result of collaboration between different levels of government, the private sector, associations, and experts, is the first industrial redevelopment with a green building approach in Canada. It illustrates the use of ecological criteria in the transformation of the locomotive workshops at the Angus yards into a multi-functional industrial center. The description contains mostly features related to the thesis and the overall concept of the interrelations between buildings and infrastructure.

Dating to the turn of the XIXth century, the Angus locomotive shops constituted the most extensive industrial complex in the country, and one of the largest and the best-equipped workshops in America. The premises were shut down in 1992 due to changes in the railroad industry. In 1998 modernization began of the old single-story structure, 20 m high at its apex and more than 300 m long, with one-third of the site transformed into a hybrid complex of light industrial and commercial mixed-use, a two storey "industrial mall" with an area of 12,000 m^2. Construction of this $10M project was completed in fall 1999. Main development criteria included:

- To market the Locoshop by the principles of community economic development and sustainable development sensitive to the existing urban context.
- To develop a building concept with added value features within its economic, historic and social contexts and at a competitive cost.

Building Form and Orientation

The fundamental issue of this project was the integration of different functions, integration of the industrial mall and the Technopole within the neighboring urban fabric. The immense volume of the building together with the cost of the land because of its urban context had to be dealt with.

The scale and character of the building were preserved and reinforced. Particular attention was given to the linkages of the existing street grid and streetscapes, the diversified land uses, the relatively high density, and the proximity of existing and new amenities. That way both new and existing infrastructure was also automatically optimized to new conditions.

Energy Strategies

A computerized system manages heating and ventilation of the central mall area (including smoke extractors as nighttime free cooling). Large roof overhangs and the preservation of existing structures coupled with the plantation of new trees provide shading of the south face of building and wind control of the parking area.

Minimizing Impact on Ecosystems

Both building and the entire site were subjected to thorough environmental analysis and the decontamination of was a major concern after a century of extensive industrial activity. The responsible environmental objectives were achieved through an efficient, cost-effective method. The risk management approach was the first redevelopment of a brownfield (land exploited for heavy industrial use) in eastern Canada.

Construction Waste and Operating Solid Wastes

Demolition waste was negligible, the vast majority of existing components were recycled on site. About 35m^2 space has been allotted for the collection of solid waste.

Ensuring the Longevity of the Building

The structural grid, both existing and new, are at maximum length to provide open and flexible floor area. Clear height of 6.5 to 10 meters allows for increasing useful floor area with mezzanines.

Reducing the Use of Automobiles

51 units car parking is provided on site as per strict minimum zoning requirements, intentionally well below the industrial average of one unit for every two occupants. A bus stops directly on site. Direct access to public bicycle path network is designed in the Technopole site plan (Montreal's bicycle path network is regarded as one of North America's most extensive urban network).

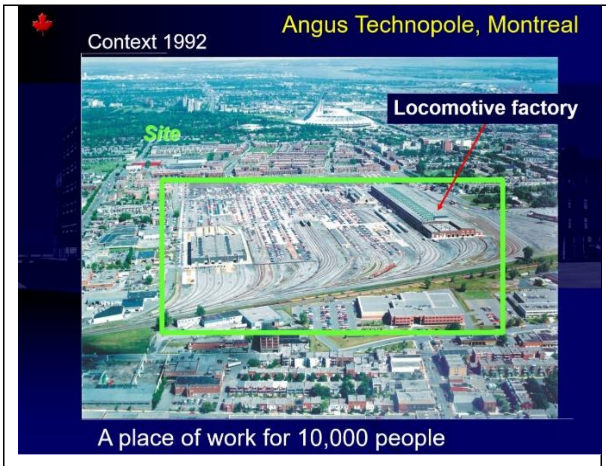

Figure 20. Angus in its good days. Source: Aedifica/Angus Technopole. http://www.technopoleangus.com/en/a-propos-2/nos-valeurs/sustainability/

Figure 21. Angus Technopole development plans. Source: Aedifica/ Angus Technopole http://m.aedifica.com/en/projects/sustainable-design/technopole-angus

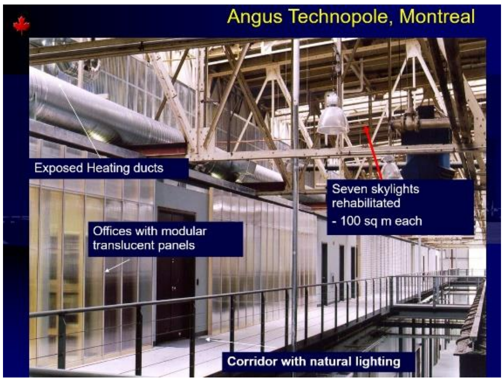

Figure 22. Angus Technopole interiors. Source: Aedifica http://m.aedifica.com/en/projects/sustainable-design/technopole-angus

The project has no equal on the North American scale, and maybe even the world. It is an example of "sustainable" unique action in the industrial zone of the city on a large scale. The project has covered most of the possible aspects of sustainability, and the renewal process of the complex is a model for the industrialized world.

As Guy Favreau, the chief architect of Ædifica and a chief designer, said: “*Angus Technopole gives away what she has lost in the last thirty years”*. The adopted new development strategy of former Angus plants is based on the dynamics of sustainability processes and can be summarized by specialization within new, green technologies.

Project requirements (under the so-called Montreal conditions - "not-to-be-refused proposal") referred to the employment of the region's inhabitants, the purpose of the facility for small and medium-sized manufacturing enterprises and linking business with other existing research and development organizations, unions, schools and local administration. The aim was to create development opportunities for local initiatives, partnerships, and information flow.

Design criteria

Pre-design work included the analysis of the following urban context criteria:

- the connection of the existing street network;
- ensuring harmonious integration of various land development methods;
- taking into- account diversified functions: offices, studios, workshops, wholesaler
- reserving the area for a large park between the residential part and industrial zone
- the preservation of a coherent architecture of Angus Technopole;
- location of car parks in the back;
- resignation from external warehouses;
- separate access for trucks;
- limiting the number of parking spaces (due to easy access to the subway and buses).

The concept and construction of the building

Techniques to save energy, recover materials and use alternative energy sources thus supporting the infrastructure:

- rigorous application of savings standards and programs;
- segregation of existing materials;
- use of high-quality insulation and sealing of windows, doors, skylights;

- natural ventilation by opening windows use of installations reducing water consumption;
- creation of a retention pool to avoid costly drainage;
- maximized daylight;
- use of passive and active solar, geothermal and thermal storage;
- installation of heat recovery systems for production processes;
- use of existing brick walls as climatic shields;
- use of low emissivity glass;
- reuse of most of the old bricks and broken concrete in roads and pavements;
- use of the translucent fiberglass and acrylic elements indoors to increase the daylighting;

Conclusions 5

The project, the result of collaboration between governments, the private sector, associations, and experts, is the first industrial redevelopment with a green building approach in Canada. Main development criteria included marketing the Locoshop as the flagship of the Technopole, planned with the principles of sustainable community development sensitive to the existing urban context and to develop a building concept within its economic, historic and social contexts, at a competitive cost.

All measures applied to Angus Technopole Locoshop directly affected the entire site and its infrastructure. With the pressure of the community, all objectives were achieved including energy-efficient green building, optimized environmental aspects, water use, treatment, recycling and reuse of most materials, saving on resources, and indirectly on production and transportation of materials. Most of these aspects directly influence the capacity and operations of the infrastructure by contributing to it.

8. Integrated Design Charrette for the Beaver Barracks, Ottawa

- Project Manager - W.Kujawski, CMHC, 2012

Integrated design charrettes have been useful in encouraging communities and their building professionals to think positively and innovatively of building design and construction. As brainstorming workshops, they can elicit positive community visioning looking ahead to guide present actions. Through discussion among a range of experts, owners, developers, designers, community members and property managers (all stakeholders), new solutions can be found. Charrettes initiate more integrated design process starting from the project inception through the development and construction to the final commissioning of the building or development.

The publication presents the process with a goal to link it to the thesis. The direct citations are made referring to the future which has already happened, but that fact does not interfere with the intent of to support the thesis. The development was monitored, and its performance was verified through the POE – the Post Occupancy Evaluation in 2015. Both activities were proposed and prepared by the author in 2014 while at CMHC.

Background

In the spring of 2007, the City of Ottawa proposed the development of an infill property Beaver Barracks, for affordable housing while demonstrating environmental responsibility. The design team proposed a compact design of at least 180 housing units in townhouses and multi-story residential buildings with commercial space and underground parking [Fig.23].

Figure 23. The Beaver Barracks concept. Source: Hobin Architecture https://www.hobinarc.com/projects/beaver-barracks-redevelopment/ accessed May 2018

The design charrette, part of the required integrated design process, had the following objectives closely aligned with the subject of the dissertation (the other aspects are not shown in details). To achieve major energy and water use goals such as in LEED® Neighbourhood Development (LEED® ND) requirements the following decisions affecting the infrastructure were made:

- Reduce energy use by at least 50 percent compared to typical city projects.
- Explore energy sources and district heating potential, considering synergy potential with surrounding properties *(as per Synergy Zones idea by N.Larsson).*

- Reduce water usage, thus costs, by 50 percent of the city average
- Construction of a green roof [Fig.24]

Figure 24. Green roof. Source: Hobin Architecture
https://www.hobinarc.com/projects/beaver-barracks-redevelopment/ accessed May 2018

Key features that were recommended for the design and construction:

Building envelope and balconies

To optimize the energy performance of the building envelope and the 'right-size' space conditioning systems, the integration of architectural, mechanical and cladding design was critical. The specific improvements to the building envelope included:

- enhanced window energy efficiency performance;
- enhanced building air leakage control measures;
- the elimination of balconies on the south side of the building, due to traffic noise from the highway, removed a source of thermal bridging impacting the thermal properties

HVAC and energy systems

The proposed energy system was a central, community geothermal system that would provide all of the buildings on the site with space heating, space cooling and domestic hot water. A study to determine the feasibility and cost of this option was conducted. The owner's experienced staff guided the decision to have central ventilation air delivery to the suites, noting the difficulty of servicing in-suite, stand-alone units, and the challenge of tenant participation for regular maintenance. To reduce ventilation-related energy costs, the system is equipped with an energy recovery system that transfers heat from the outgoing exhaust air (from the kitchen and bathrooms in each apartment) to the incoming fresh air.

Building services

A central geothermal heating system will be installed to meet space heating and cooling and domestic hot water needs. The inclusion of the geothermal system was a pivotal design decision. This choice was made after a feasibility study and test drilling carried out by a micro-utility company that confirmed the costs and benefits. Provisions for photovoltaic or solar thermal systems were included in the design of the building structure that would benefit the capacity of the required infrastructure.

Ventilation

To reduce energy consumption and costs, a central energy recovery ventilator (ERV) will capture the heat from the air exhaust from the kitchen and bathrooms in each unit and transfer it to the ventilation air that is delivered to each apartment. To ensure better indoor air quality, the airflow design will be 50 percent higher than the code minimum. The ERV system will operate at reduced speeds at night, based on a time-clock setting in order to reduce ventilation-related energy consumption and costs.

The suites will be compartmentalized (that is air-sealed from the outside, one another and the common areas) to reduce inter-zonal air movement, odor migration and noise transfer. Compartmentalization can also help reduce air leakage into, and out of, the building. Blower door testing will be performed on representative suites, to ensure that the airtightness objective is reached.

Figure 25. Townhouses. Source: W.Kujawski

Domestic hot water

Energy-saving, variable-speed domestic hot water booster pumps will supply hot water to the suites. To maintain an even flow rate, pressure tanks will be located in the mechanical penthouse. The washing machines in the laundry room will have a cold water supply with an option for hot water at an additional charge, while the dryers will be gas-fired to reduce electricity consumption and loads. Both the washers and dryers will be high-efficiency, front-loading commercial machines.

Other

Energy-conserving features include an energy management system that will control the overall heating system. The Metcalfe building garage will be kept at a minimum temperature sufficient to prevent freezing. Glycol fan coil units will temper incoming ventilation air. Additionally, as a lifecycle cost-saving feature, a glycol radiant heating system (as opposed to an electric system) will be installed at the garage entry ramp to prevent ice build-up.

Water

In line with the overall objective of reducing the water consumption to one-half the normal per-capita water consumption, water-efficient, dual-flush toilets will be installed in all units.

Waste management

There will be no garbage chute installed in the buildings. Although this means that the residents will have to take their garbage and recycling to the basement, this change provides more floor area for the apartments and reduces problems associated with noise and odors. Additionally, residents will become more aware of the waste they produce and will take some responsibility in dealing with its disposal besides participating in the composting system with their kitchen waste.

Conclusions 6

Figure 26. Catherine Street. Source: W.Kujawski

The Beaver Barracks charrette demonstrates the advantages of engaging a wide variety of stakeholders in the conceptual design of development projects. Through the consultative nature, a diversity of interests, opinions, concerns and solutions can be consulted and considered on the design of buildings and communities. In case of the Beaver Barracks, the charrette helped the project owners identify technologies and practices improving the overall sustainability of the project well-integrated into the existing neighborhood. Almost all aspects of the building design, as well as the neighborhood itself, play a role in the contribution to the required and operating infrastructure.

Thanks to the process every feature was well studied and the overall results showed that both energy and water consumption could be significantly reduced and directly contribute to the development's infrastructure. Parts such as the green roof are contributing to the stormwater services and indirectly to the transportation emissions with some vegetables growing there.

Summary

Water touches all aspects of our lives, and thus should touch all aspects of our design. The objective of the Water-Sensitive Urban Design (WSUD) is to integrate urban design with natural ecological processes and add value to the development of scale with its water infrastructure.

In other more scientific words:

to ***maintain or replicate the pre-development water cycle through the use of design techniques to create a functionally equivalent hydrological landscape*.**

Various positive approaches are mitigating the thermal deterioration of urban environments. Conserving existing green spaces in urban settings, using more appropriate materials in the built environment, opting for designs that address both the issues and their impacts, reducing impermeable surfaces and developing a better public transit policy should reduce the presence of urban heat islands and affect directly the infrastructure.

The impact of urban heat islands can cause temperature raising in cities by 2 degrees C stronger than in other, non-highly urbanized areas. That means a much higher demand for air conditioning, thus energy, and general problems such as, for example, lower productivity and high vacancy rates resulting from the lack of comfort satisfaction but affecting the operations and stability of the infrastructure systems.

To combat heat islands effectively, the simultaneous introduction of various mitigation measures is the most efficient approach with early adoption of measures and with specific attention paid to commercial and industrial sectors. Implemented measures produce benefits such as lower surface and felt temperatures, reduced mortality, better quality of life, less smog, smaller temperature variances, the longer useful life of materials, energy savings, higher property values and fewer floods.

Design of any infrastructure requires a thorough analysis that will directly affect the size of the piping network, layout and surfacing of the roads, the design of buildings, elevation of buildings (flood risk), nature of the landscaping and the density of the development. That is a direct impact on the infrastructure of any building, be it a single one or a cluster of them, or the entire neighborhood.

The Canadian NZE Healthy Housing Initiative's approach protects and conserves natural resources through the planning densities and design goals promoting solutions that adequately balance occupant's needs and desired activities with community needs and functions. Building materials are specified from local renewable resources; construction waste is reduced and well managed, construction impact on the surrounding area and watershed is reduced through reduced erosion and durability of building components is emphasized. NZE Healthy Housing uses efficient water and wastewater systems, and site design and landscaping provide for on-site rainwater use, stormwater retention and reduced infrastructure costs.

Alternative designs can minimize the need for raw materials extraction — be it forest based, petroleum based or water related resources. More efficient construction processes can reduce wastage on the site. Minimizing the environmental impact of housing will require new approaches to community planning, housing design, materials selection, construction techniques and the regulatory approvals process as well as in how these processes are integrated.

Sustainable community is a community that supports healthy ecosystems and healthy living conditions, and offers a variety of types and sizes of buildings, social, educational and cultural facilities. Full diversity of land use, commercial and service opportunities along with public space, and easily accessible, connected and affordable communication systems.

Designing it requires an interdisciplinary design team working as part of an integrated design process that involves a broad involvement of the community and stakeholders. Designing on the neighborhood scale gives the opportunity of integrating various systems in micro- and macro-scales.

Responsibility should be borne by designers who also have a great opportunity to discover new ways of creating architecture and urban planning.

Integrated planning on a scale of sustainable neighborhood or community can provide significant benefits including costs. Analyses with the optimization of buildings and the area around can create opportunities for energy and water integration as well as the use of renewable energy and waste within the community systems. District-scale development planning can also facilitate pedestrian-friendly alternatives such as walking and cycling routes as well as better developed public transportation.

At the scale of a community, it is necessary to include social aspects that are reflected by the satisfaction of translating into a better understanding of the environment that leads inhabitants to better, healthier life. Such an approach goes than to the infrastructure as a direct impact of buildings in which people save energy and water energy and care about waste while biking to their workplace

The design requires extensive community engagement and stakeholder involvement with a thorough understanding of the relationships between the diverse elements and functions of the built environment and seeks to capitalize on the interconnections between elements and systems (e.g., waste from one area providing fuel for another).

Designing at the neighborhood/community scale provides opportunities to integrate systems (such as water and energy systems) across multiple buildings and land uses. The infrastructure always benefits from such actions, and sustainable community projects in Canada and elsewhere demonstrate that specific, mentioned above, principles apply universally, although they are, or should be, interpreted locally to suit the particular context of the neighborhood or community. Communities that are designed with these principles can, in relation to the impacts on infrastructure significantly reduce energy and waste, reduce demand for urban resources and preserve ecosystems.

Minimizing the environmental impact of housing requires new approaches to community planning, housing design, materials selection, construction techniques and the regulatory approvals process as well as in how these processes are integrated.

Many municipalities are finding increasingly difficult and expensive to keep up with the growing requirements for fresh water and sewage treatment facilities and each measure that reduces water demand, also reduces infrastructure needs.

The Angus Technopole project in Montreal, the result of collaboration between governments, the private sector, associations, and experts, is the first industrial redevelopment with a green building approach in Canada. Main development criteria included marketing the Locoshop as the flagship of the Technopole, planned with the principles of sustainable community development sensitive to the existing urban context and to develop a building concept within its economic, historical and social contexts, at a competitive cost.

All measures applied to Angus Technopole Locoshop directly affected the entire site and its infrastructure. With the pressure of the community, all objectives were achieved including energy-efficient green building, optimized environmental aspects, water use, treatment, recycling and reuse of most materials, saving on resources, and indirectly on production and transportation of materials. Most of these aspects directly influence the capacity and operations of the infrastructure by contributing to it

The Beaver Barracks charrette, another example of an integrated approach, demonstrates the benefits of engaging diverse stakeholders in the conceptual design of the development project. Through the consultative nature, different interests, opinions, concerns, and solutions can be discussed and considered in the design of buildings and communities. The charrette helped the owners identify technologies and practices improving the overall sustainability of the project well-integrated into the existing neighborhood. The example of such process is proposed energy system -a central, community geothermal system that would provide all of the buildings on the site with space heating, space cooling, and domestic hot water. The decision was taken after a thorough analysis of the feasibility study and test drilling carried out by a micro-utility company that confirmed the costs and benefits.

Almost all aspects of the building design, as well as the neighborhood itself, play a role in the contribution to the required and operating infrastructure. Thanks to the process every feature was well studied and the overall results showed that both energy and water consumption could be significantly reduced and directly contribute to the development’s infrastructure. Parts such as the green roof are contributing to the stormwater services and indirectly to the transportation emissions with some vegetables growing there.

In the urban context, the site plan determines how the building interacts with the surrounding neighborhood and environment. Careful site planning can contribute to the efficiency of the individual building (including optimization of its location, orientation, and landscaping), minimize the impact of it on the surrounding environment including its infrastructure and contribute to a ‘healthy’ social environment.

Table of figures

Wojciech Kujawski, M. Arch, MRAIC

Other potential influencers

Module 5

Table of Contents

Introduction to the topic

Motto: "We shape cities and cities shape us." – *Winston Churchill*

This part describes research and publications by other researchers and professionals that support the thesis by complementing or by extending the existing studies to new borders. The main difference between this module and other ones is that it also contains analyses (as opposed to advice in guidelines) of detached buildings and their performance and also both buildings and their interacting urban fabric with specific characteristics. Such descriptions are in several parts that complement themselves; however, some research and conclusions may overlap in details; that was unavoidable considering the "presentational rather than research-oriented" aspect of this dissertation.

Module 5 consists of mostly urban issues that do not belong to other parts, due to the fact of not being written or managed by the author, and serving instead as updates and research support to the thesis. Those issues are the Urban Morphology, Synergy Zones, urban canyons, hybrid infrastructure, climatic design, urban agriculture, insurance issues, costing idea and the Big Data involvement in all aspects of a global image of the built environment that cannot exist without its bloodstream - the infrastructure. Most of them, however, have already been used by the author in his earlier publications.

1. Urban Morphology

"Urban" means a planning pattern, characteristic of the highly populated area with infrastructure; however, it may be applied from a specifically oriented building to a block, neighborhood, community, district, city, and agglomeration. In other words, it can be considered as a part of a fractal theory of the human-created space from micro to macro scale. Salat [2011] reiterates the presence of fractal order in organisms and postulates that such order is a fundamental prerequisite for a well-functioning city thus unquestionably related to the urban issues [after Salat, 2011].

The fractality could be recognized and measured in all aspects of living city be it an activity (from selling one egg to selling thousands of chickens) or a physical presence. Example: from a bookseller stand to a megastore or from a luxury 500 m2 apartment with ten rooms for two occupants to a suburban apartment of 80 m2 with three rooms occupied by ten and "functional administrative fractals": from a village /borough made up of few "elders" to the city, provincial, or national governments numbering thousands of "servants" [after Grammenos, Kujawski, 2012].

An example of another aspect of a fractality more in line with the support of the thesis: a starting point (resulting from aspects of the fractal theory) could be any energy-related feature, then a cluster of such features in a building, arrangement of buildings, streets and open spaces that can preserve or block access to the sun, wind and light resources. The energy consumption (and carbon emissions) of the building result from many factors: the isolation of the building, the types of systems used for heating/ cooling/lightning, the behaviorof the inhabitants and the urban morphology [after Salat, 2008].

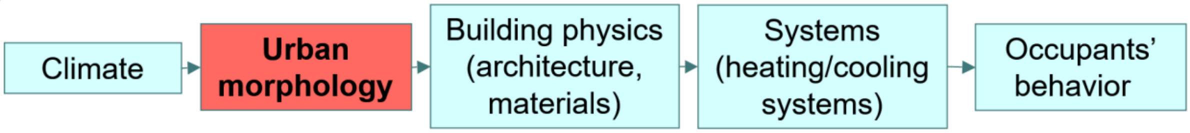

Figure 1. Place of Urban Morphology. Source: S.Salat, 2008

Salat in his "Urban Morphology"[1] [Salat, 2008] performed a study of urban fabric by analyzing those aspects with a range of parameters such as building sizes and shapes, street patterns and shapes, the urban design itself and a population density. Indeed the organization of an urban fabric has impacts on the availability of sunshine and the thermal losses through theexterior walls.

Four axes of comparison were taken into accounts such as building mass organization (built-up area, proximity, height, compactness), openness to the sky (solar admittance), passive volume and street networks. Unobstructed passive volume uses two times less energy than the non-passive volume. The

[1] http://www.unepfi.org/fileadmin/events/2008/seoul/Alice_Morterol.pdf accessed March 2018

buildings' physics and urban space: an efficient building in an efficient urban fabric can consume four times less energy than a non-efficient one. The urban morphologies depend on density, streets network, and energy consumption to the point.

Figure 2. Look of morphologies. Source: S. Salat

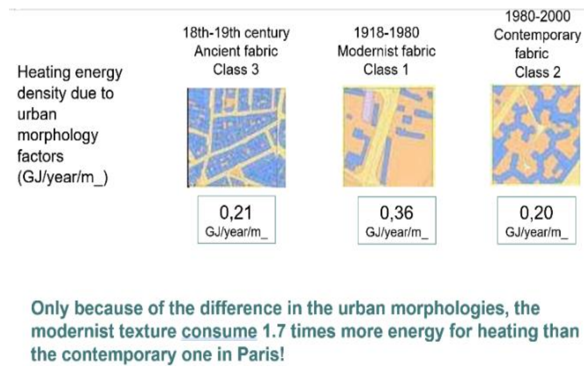

Figure 3. Energy intensity in different morphologies. Source: S. Salat

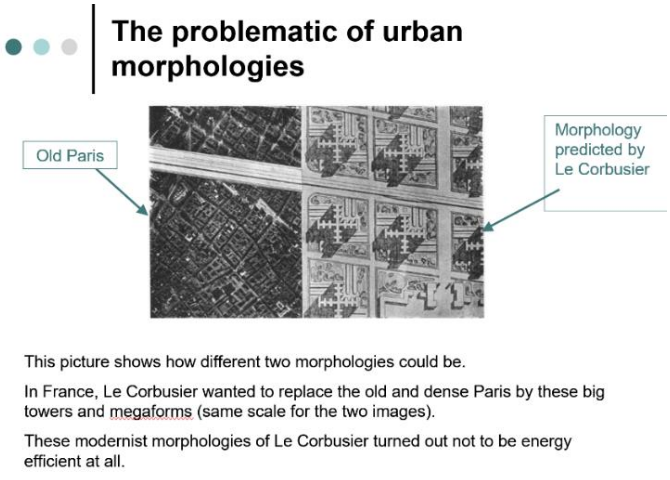

Figure 4. Energy efficiency in morphologies. Source: S. Salat

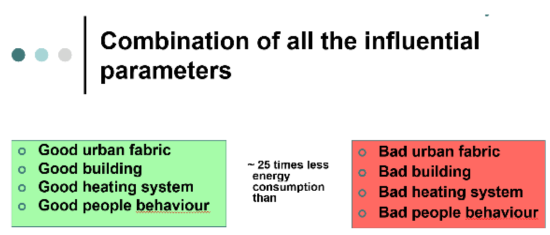

Figure 5. Parameters of Urban Methodology. Source: S. Salat

2. Street Patterns with the building as infrastructure contributor

Main road network within any community is created by local streets (more than 70% in some cases) and usually up to 20% of a municipality's infrastructure budget is used there, quadrupling their initial cost over their lifetime for maintenance and replacement. Reducing such road costs is another way of finding funds for building performance improvements that, in turn, will have an impact on infrastructure.

Paved streets add to the impermeable surface area forcing an increase of stormwater systems, affecting water quality and contributing to the urban heat island effect rising the demand for cooling. Well-designed streets can also mitigate traffic and enable active transportation (walking, cycling), which can reduce the energy required for transportation and related GHG emissions.

Several CMHC studies [Grammenos, 2009] show how even minor adjustments to street patterns can create opportunities to build higher density developments and reduce the impacts on municipal infrastructure while raising the viability of shared energy systems. One such road pattern is the "Fused Grid."

2.1. Fused Grid

Figure 6. Modelling fused grid.
Source: F. Grammenos

This concept blends the best parts of conventional and grid-based street layouts, encourages optimal use of land, requires less hard surfaces, allows for higher densities and more open space than conventional suburbs, and can be more cost effective to service and maintain (Table 2).

Table.2 Fused Grid elements with their potential effects

Fused grid elements	Potential
Traffic calming and control	Reduces noise and air pollution. Less stress for all users (drivers, pedestrians, and cyclists). Fewer cars can reduce wear and tear on roads.
Street design	Pedestrian and cyclist safety Reduces noise and air pollution. Promotes better water quality through stormwater management techniques and more permeable surfaces. Creates social opportunities that can lead to a safer neighborhood.
Greenspace and water retention	Promotes better water quality Improves local air quality. Provides habitat for plants and animals Reintroduces local flora.
Optimal development density and mixed-use	Encourages active transportation and discourages car trips. Higher density can create a higher tax base for the municipality and greater revenues for developers. Supports mass transit systems.
Active transportation infrastructure (cycling lanes, sidewalks)	Encourages active transportation Safer roads. Promotes greater physical activity among residents.

Fused grid neighborhoods encourage greenspaces throughout development, and these green spaces can be utilized to meet goals other than merely community or recreation areas. For instance, they can provide connections between neighborhood elements, snow storage and food production locations, function as storm and wastewater management components, make higher density more acceptable, etc. (it was determined that higher densities be far more acceptable when developed in conjunction with open space).

Higher density buildings also offer greater viability for locating co-generation and shared energy systems. If such buildings are strategically located, they can share surplus energy with other lower density buildings nearby and, together, service the entire neighborhood (*refer to Synergy Zones*).

Fused Grid in Works

Saddleton, Calgary, Alberta, Canada is an example of how the specifically targeted urban planning can mitigate the potential traffic areas together with implications on their required infrastructure.

Additionally, due to buildings design features, they may become direct contributors thanks to the Fused Grid principles of consistent orientation and specific density. This building project places higher density buildings along planned light rail corridors and incorporates sustainable infrastructure while also reduces the cost. Wherever possible uses, open, permeable spaces are instead of hard surfaces. The proposed density is between 25 and 30 units per hectare, 50% higher than conventional subdivisions.. The 63-hectare development shifts most traffic to its perimeter and introduces smaller collector streets around the neighborhood that lead to major roads.

Using the fused grid model, Saddleton is laid out as four distinct quadrants, all of which contain a central green space. Pedestrian access between the quadrants will create a walkable community, with the central core just a five-minute walk from any corner of the development. Saddleton also includes a mix of local commercial properties, a storm pond, a rain garden (filters rain, provides recreational areas and is part of the pathway network) and a children’s playground.

Figure 7. Saddleton street network and land use planning. Source: CMHC

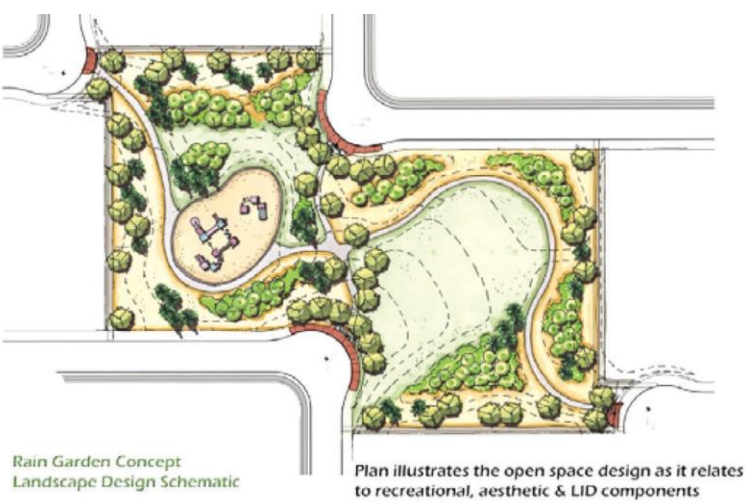

Figure 8. The rainwater garden space – recreation, pathway node and rainwater filtration. Source: CMHC

When compared to the conventional suburb design of almost identical sites, the fused grid pattern will cut road space significantly, and the “freed” street space may now be used as stormwater collection routes (if not built as permeable), greywater gardens, and linear, vegetated parks that cool and improve air, and provide habitat and pleasure [Fig. 6], [Fig.7], [Fig.8]. The sheltered courtyards are ideal for food production, rainwater storage, grey water purification and some of them may function as greenhouses [after F.Grammenos, 2009].

3. Urban canyon and building energy use

- Urban density versus daylight and passive solar gains[2]

One of the most fundamental questions in urban master planning and building regulations is how to secure universal access to sun, light and fresh air, all affecting the energy use of buildings and related infrastructure. Optimization of energy in the building and urban designs thus improvement of the situation in ever-growing cities requires a detailed understanding of all aspects of the complex interrelations between both [after J.Stroemann, P. Sattrup, 2011] and the general conclusions strongly support the thesis that buildings, if adequately designed within equally well thought off urban context, are major contributors to the infrastructure. The link between urban density and building energy use is an intricate balance between climatic and spatial factors, material and urban use patterns with buildings that constitute them and the concept of the urban canyon is used to investigate the ways it may affect the energy performance of low-energy buildings.

The name - urban canyon - has been used in urban climatology describing, in geometric terms, the height to width ratio of the space between adjacent buildings.

It was found that the geometry of urban canyons plays a crucial role in impacts on total energy consumption in the range of up to 30% for offices and 19% for residential buildings. Canyon's reflectivity also plays a vital role, especially in dense cities [after J.Stroemann, P. Sattrup, 2011]; however, urban densification is one strategy for sustainable development focusing on energy savings through efficient transit, shared infrastructure, and optimized energy. The solar access of the already built cities on high latitudes and with related low solar inclinations is affected much more than in other parts of the world, primarily by overshadowing.

Knowledge of the relative impacts of urban geometry is an essential asset for energy-optimized architecture because energy savings from design choices on the urban scale are very long-term and lessen the need for technologies with high cost and shorter lifetime. One of the main deficiencies is focusing on individual building performance while neglecting its urban context, especially overshadowing and reflectivity. If the context around the building with energy consumption of 50kW/m2/yr, transforms into a dense area, the energy will increase up to 70kW/m2/yr, thus about 30%.

As a consequence, it becomes critical to define ways to control solar access, and new developments should be screened for their impacts on neighboring buildings and public spaces. The reflected light makes an essential contribution to the building energy demand and is the highest fraction of daylight available on lowest floors in buildings in high urban densities. It is important to note that it is not only light but also the

[2] http://orbit.dtu.dk/en/publications/the-urban-canyon-and-building-energy-use-urban-density-versus-daylight-and-passive-solar-gains(3bd0b537-790a-45c6-a71e-e89a151b1b5b).html

heat that is carried and distributed; however, depending on the level of reflectivity of the neighboring facades [after J.Stroemann, P. Sattrup, 2011].

4. Climatic Design[3]

Both Synergy Zones and Urban Morphology studies fit well with another method of optimization of buildings. R. DeKay [DeKay, 2017] provided the guidelines of what to observe in an existing urban setting and how to adjust the parameters of existing buildings to fulfill the requirements affecting almost all aspects of the infrastructure that is being proposed, designed and implemented in buildings being subjects of urban creation.

The design of a city can make the outdoor climate more intense and uncomfortable or more moderate and comfortable. It can make air quality worse and buildings more expensive to operate—or it can help clean the air and help buildings to be more energy efficient. Cooling the city can happen by increasing scattered vegetation and dispersing wind by creating breeze channels throughout the mentioned urban elements. Simple design patterns can be incorporated into urban development planning and regulations providing the site-based energy resources for buildings- soon to be contributors to their built environment- the infrastructure.

Access to site-based energy resources is a pre-requisite for natural lighting, solar heating, and natural ventilation in buildings. The organization of buildings, streets and open spaces in higher density areas can either preserve or block access to sun, wind, and light resources. A composite technique, called 'Climatic Envelopes,' was developed which regulates the shape of buildings on a block or site to protect access to both daylight from the sky and direct radiation from the sun.

Figure 9. Urban Cooling method 1. Source: M. DeKay

It combines the 'Daylight Envelope' with the 'Solar Envelope' that satisfy the criteria for composite climatic envelopes and follow several design patterns for daylighting while maximizing development potential. The modifications were developed to cool the city ('Downtown Cooling Plan) by creating additional shade, channeling winds to bring ventilation to more buildings, and working with the existing or creating a new topography.

[3] Climatic Urban Design: Configuring The Urban Fabric To .., https://www.witpress.com/Secure/elibrary/papers/SC12/SC12052FU2.pdf (accessed June 21, 2018).

The following patterns can create the cooling plan:

Distributed Vegetation: with temperature reduction proportional to vegetation cover.

Up-slope Forest Drainage: Green ventilation corridors direct cool air from up-slope into the hot urban core. Protecting these slopes from development is critical.

Breeze Channels: Spaces between buildings can be organized to create Greater block permeability increases east-west air movement.

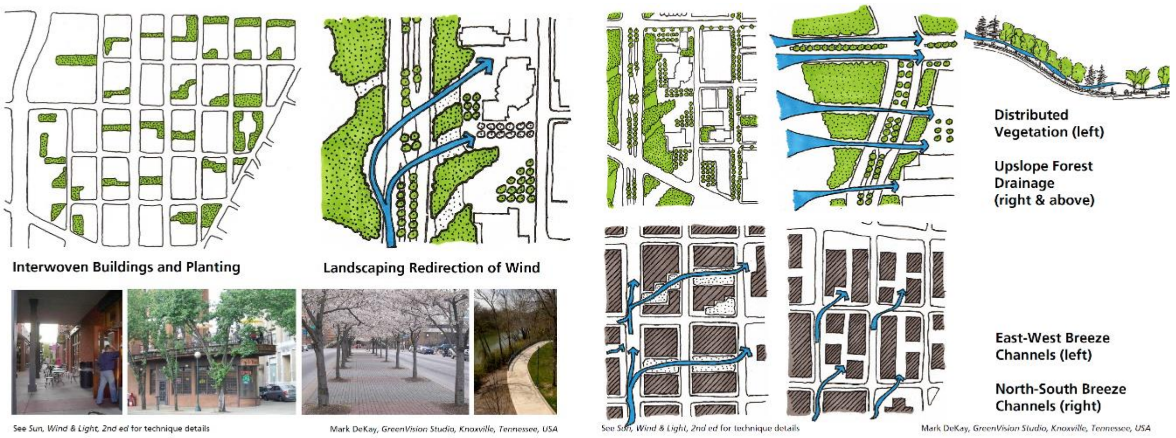

Figure 10. Urban Cooling Method Details. Source: M. DeKay

Climatic Envelopes

Climatic Envelopes regulate the shape of buildings on site to protect access to both direct beam radiation (sun) and the diffuse sky (light) as a pre-requisite for natural lighting and solar heating of buildings. In urban situations, as the height of buildings along streets increases, the daylight available to buildings, especially on lower floors, is decreased. If a building to the south of another is too tall, it will block the winter sun.

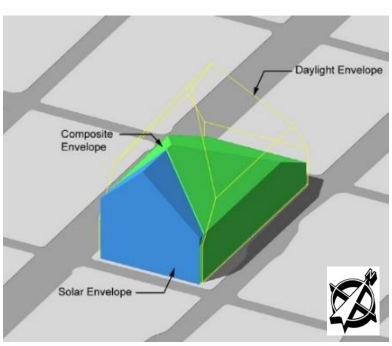

Figure 11. Forming the climatic envelope Step 1 . Source: DeKay

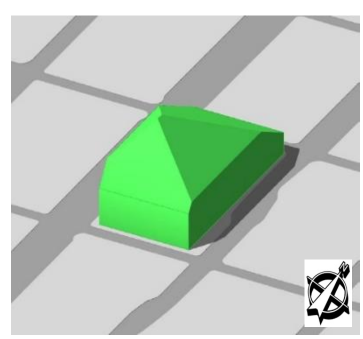

Figure 12. Forming the climatic envelope Step 2. Source: DeKay

Climatic envelopes: urban pattern

The most important factors besides the local climate, affecting the amount of available daylight are the ratio between the building heights and the street width between buildings, a reflectance of the exterior building materials and ground surfaces, and the area of windows.

The overall energy consumption of buildings depends in part on available daylight to provide required level of light, thus directly affects the infrastructure loads.

Urban cooling and buildings

The effect of city design on microclimate can help clean the air and help buildings to be more energy efficient. Urban development can replace asphalt with vegetation. Heat-absorbing dark surfaces, such as black roofs and heat-storing massive surfaces, such as concrete, can be replaced by cool, transpiring green surfaces. Taller buildings in the inner city should be avoided in groups because they block the wind, create more friction for it, and reduce the ability of other buildings to lose heat causing the urban heat island effect thus to increase of the infrastructure energy demand, costs and health risks. If buildings and outdoor spaces do not have access to breezes, they cannot be cooled by the wind.

Streets will not be well ventilated without their proper orientation to the prevailing winds. When the air of the city is not vented out, heat and pollutants build up, especially at the street level. Because the buildings do not have wind access, air-conditioning is often used when natural cross-ventilation would do the job. Air-conditioners simply move the heat from inside, along with their own waste heat, to the outside, where it is rejected to the atmosphere, thus further warming the outdoor climate and contributing to the heat island effects and directly to the energy load of the infrastructure [DeKay].

Conclusions 1 – a compilation of research 1, 2, 3 and 4

"Urban" means a planning pattern, characteristic of the highly populated area with infrastructure; however, it may be applied from a specifically oriented building to a block, neighborhood, community, district, city, and agglomeration. In other words, it can be considered as a part of a fractal theory of the human-created space from micro to macro scale [Salat, 2008]. The urban morphologies depend on density, street network and the energy consumption of the built environment- buildings and infrastructure.

The organization of an urban fabric has impacts on the availability of sunshine (solar admittance) and on the resulting thermal losses or gains through the exterior walls. Analyses were taking into account building form and orientation, openness to the sky, passive volume and street networks. Unobstructed passive volume uses two times less energy than the non-passive volume and an efficient building in an efficient urban fabric can consume four times less energy than a non-efficient one.

All authors in this section: Salat, Stroemann, Sattrup, and DeKay write about the necessity of considering site-based resources: solar, wind and light and the conclusions go into the same direction of synergies between urban and building design with the same goal of achieving the best efficiency in all aspects of the performance including comfort of occupants and users.

The overall energy consumption of buildings depends in part on available daylight to provide the required level of light, thus directly affecting the infrastructure loads [after DeKay, 2017].

Local streets create main road network within any community, and a reduction of their possible construction and maintenance costs can switch funding towards building performance improvements impacting, in turn, on infrastructure. Well-designed streets can also mitigate traffic and enable active transportation (walking, cycling), which can reduce the energy required for transportation and related GHG emissions. Even minor adjustments to street patterns can create opportunities to build higher density developments and reduce the impacts on municipal infrastructure while raising the viability of shared energy systems.

The design of a city can make the outdoor climate more intense and uncomfortable or more moderate and comfortable. It can make air quality worse and buildings more expensive to operate—or it can help clean the air and help buildings to be more energy efficient. Increasing scattered vegetation and dispersing wind by creating breeze channels can cool the city [after DeKay, 2017]. The design of permeable areas decreases stormwater systems, affecting water quality and contributes positively to the urban heat island effect by lessening the energy demand for cooling and increases urban comfort. Simple design patterns can be incorporated into urban development planning and regulations providing the site-based energy resources for buildings- soon to be contributors to their built environment- the infrastructure.

The most important factors besides the local climate, affecting the amount of available daylight are the ratio between the building heights and the street width between buildings, a reflectance of the exterior building materials and ground surfaces, and the area of windows.

The organization of buildings, streets and open spaces in higher density areas can either preserve or block access to sun, wind, and light resources. A composite technique, called ‘Climatic Envelopes,’ was developed which regulates the shape of buildings on a block or site to protect access to both daylight from the sky and direct radiation from the sun [after DeKay, 2017].

The name- urban canyon- has been used in urban climatology describing, in geometric terms, the height to width ratio of the space between adjacent buildings. The link between urban density and building energy use is an intricate balance between climatic and spatial factors, material and urban use patterns with buildings that constitute them and the concept of the urban canyon is used to investigate the ways it may affect the energy performance of low-energy buildings [after J.Stroemann, P. Sattrup, 2011].

One of the most fundamental questions in urban master planning and building regulations is how to secure universal access to sun, light and fresh air, all affecting the energy use of buildings and related infrastructure. Optimization of energy in the building and urban designs in ever-growing cities requires an understanding of all interrelations between them, and the general conclusions strongly support the thesis that buildings, if designed adequately within equally well thought off urban context, are the major contributors to the infrastructure.

Urban geometry is an important factor in energy-optimized architecture as energy savings from design choices on the urban scale are very long-term and lessen the need for technologies with high cost and shorter lifetime. Urban context, especially overshadowing and reflectivity, an essential contribution to the building energy demand, is often overlooked in favor of individual building performance. If the context around the building with energy consumption of 50kW/m^2/yr, transforms into a dense area, the energy will increase up to 70kW/m^2/yr, thus about 30%, thus it becomes critical to define ways to control solar access and new developments should be screened for their impacts on neighbouring buildings and public spaces [after J.Stroemann, P. Sattrup, 2011].

5. Synergy Zones and Microgrids[4]

N. Larsson, 2012

The pressure to become much more sustainable is applied to communities in both developed and developing worlds, and the issues of either new or aging infrastructure are introduced together with their huge costs related to traditional infrastructure models.

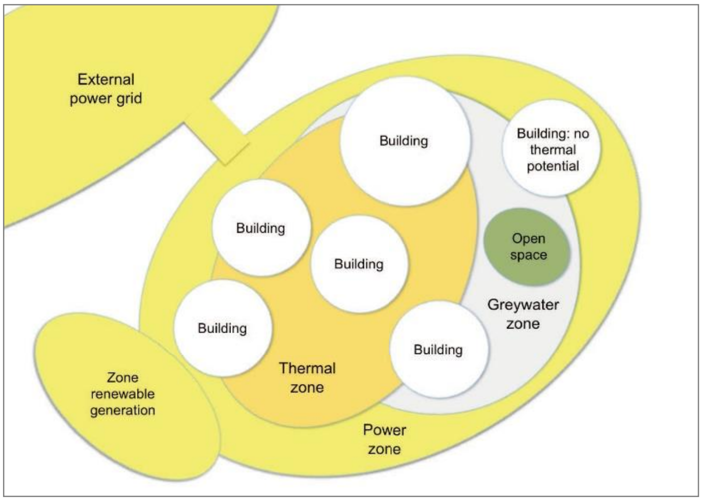

Figure 13. Schematic representation of possible differences in sub-zone areas in a Synergy Zone. Source: N.Larsson, iiSBE http://www.iisbe.org/files/Synergy%20Zones%2029Nov12.pdf (accessed March 2018)

Focusing more on the potential role of very small urban areas offers possibilities to improve the aggregate performance of buildings. A concept model that builds on the form of synergistic performance in energy, emissions and water and other less critical issues, is called a Synergy Zone, which is an equivalent for Synergy Neighborhood.

With the Smart Grid concept being developed at such a small scale, a more extensive range of issues and more in-depth is considered, providing an appropriate framework for developing strategies for neighborhood infill and renovation programs that must reach very high levels of performance. They include the use of renewable DC power on site with no conversion losses, the distribution of thermal energy from buildings with surpluses to those with deficits, and similarly more efficient use of surplus greywater. Some of the neighborhood-scale (zone) systems that could benefit from optimization of storage, supply, and demand, and a reduction in wasted energy and material flows [Pollard, 2016[5]] include:

- **passive solar performance** potential of the buildings individually and collectively
- **rainwater capture and greywater use** through the provisions for rainwater capture by low-rise buildings - other (e.g., highrise) could contribute only relatively minimal amounts. It can come with zone-wide greywater treatment, storage and redistribution system for all buildings within the zone before storage.
- **domestic hot water systems** through the optimization of supply and demand, given that some occupancies such as residential, hotels, restaurants have much higher demand than commercial or pub Performance Synergies In Small Urban Zones - Hkgbc. (n.d.). Retrieved from lic occupancies, but offer the possibility of DHW production through waste heat produced in combined heat and power

[4] https://www.hkgbc.org.hk/sb13-upload/PresentationPDF/7.-Mr-Nils-Larrson.pdf

[5] https://www.audiosolutionz.com/land-use-zoning-law/urban-resilience.html accessed March 2018

(CHP) systems or (for DHW pre-heating) recapture of thermal energy from HRVs.

- **solid waste capture and storage -** a system for all buildings in the zone, such as provided by central vacuum systems. Such a system could be linked to a local zone bio-generation plant.
- **DC (Direct Current) power** can be produced from CHP, PV, wind power, bio-mass or other common renewable source in the zone. The use of DC would increase operating efficiencies by reducing conversion losses AC (Alternate Current) to DC.
- A zone-wide **greywater supply, storage and redistribution system** for all buildings filtering and treating grey and black-water within the zone before storage. \
- **DC power distribution systems** to parallel AC systems in commercial buildings, to maximize use of DC systems and to minimize conversion losses to AC, along with mid-term storage and control systems. The storage of DC power generated in the zone, as well as off-peak power from outside sources, will contribute in redistribution to other buildings with a DC deficit or to the grid.

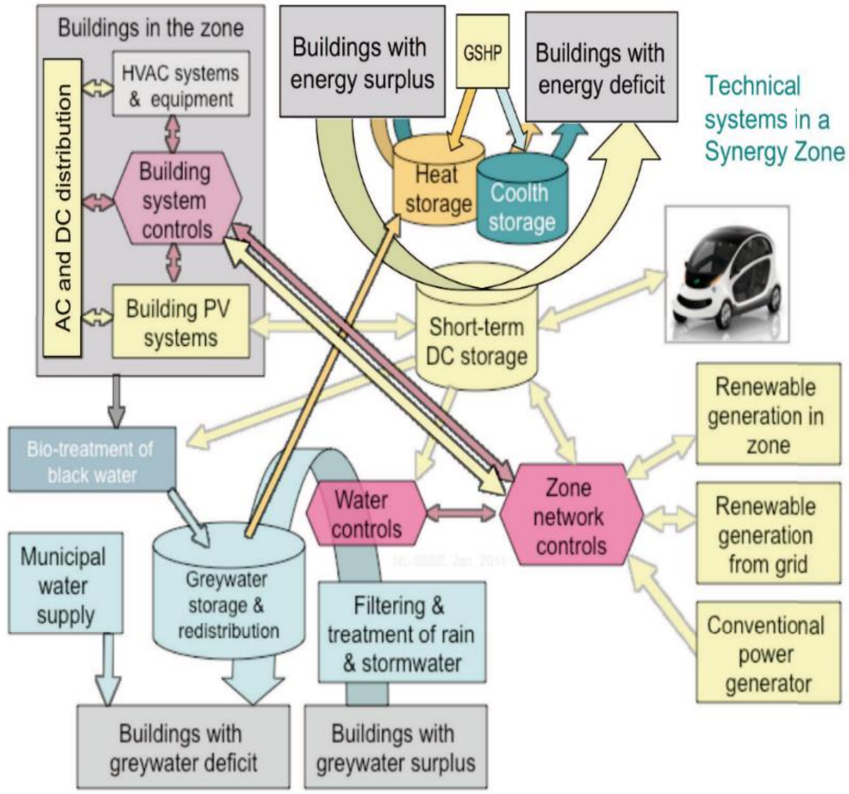

Figure 14. Schematic representation of a Synergy Zone. Source: N. Larsson

A Synergy Zone itself should also be more resilient in cases of power outages due to extreme events. It is a systems model for the development or redevelopment of neighborhoods, and it is almost perfect support of the thesis by underlining most of the possibilities of the building's contribution;

however, with much better control. Table 1 shows the fit between generic building type and system types. It indicates that, in many cases, buildings with deficits in energy, water, or even parking spaces, could be supplied by other buildings with surpluses [after Larsson, 2012- 2018].

Table 1. Overview of relationship between generic building types.Source: N.Larsson

Issue / System	Residential	Office w. interior zone	School
Space to install PV or thermal solar collectors (orientation issue not considered)	In low-rise, space for large arrays on roofs.	Roof or ground installation is problematic, and spandrel panel types are expensive.	Space for large arrays on roofs.
Space heating (heating season)	Energy deficit for space heating	Thermal surplus from interior zones	Variable, depending on student density
Domestic hot water	High constant demand	Low demand	Low and intermittent demand
Rainwater collection for use as greywater (if there is storage and more than 500 mm/yr. rain)	Good possibilities in low-rise family projects with open landscaped areas and flat roofs	Could have surplus in low-rise projects, but deficit in high-rise.	Surplus is likely due to large collection area on roof and grounds.
Vehicle parking	Night-time peak demand	Day-time peak emand	Day-time peak demand

Moving from Buildings to Building Clusters

Most architects and engineers are aware of the performance synergies that can be achieved within mixed-use buildings in urban settings, such as different schedules within each occupancy for peak electrical or space heating or cooling demand. The principle of inter-system synergies can be applied if the scope is extended from a single building to small clusters of buildings, where the area of a cluster to be small enough to allow economical active thermal transfer between buildings and to allow direct use of DC power to buildings in the cluster [based on Larsson, 2009]. As mentioned earlier, the Synergy Zones come from a small-scale Smart Grids; however, the more precise description will set them out as small-scale, self-sustaining power networks not supplied by a centralized power plant but still, in many cases, connected to it for the emergency backup.

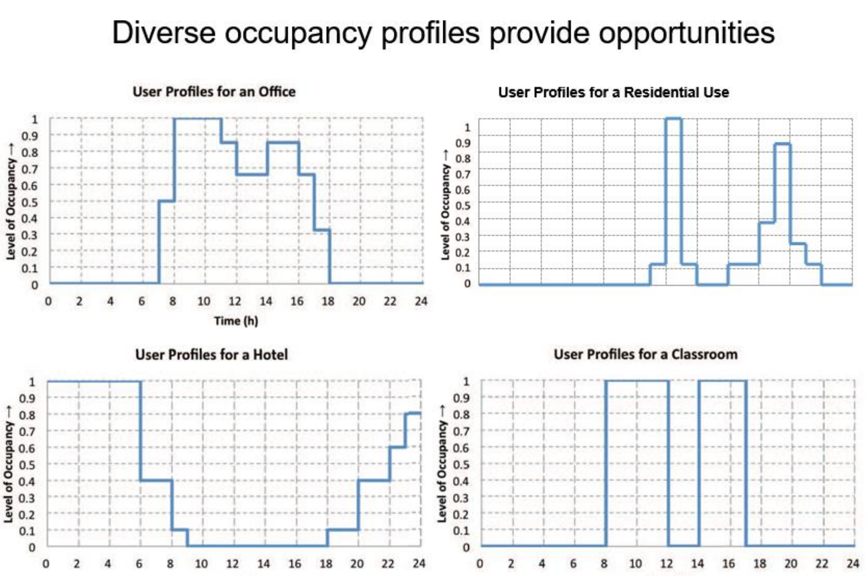

Figure 15. Schematic representation of possible differences in sub-zone areas in a Synergy Zone. Source: N. Larsson

A modern microgrid may contain energy storage, renewables, and diesel backup, to ensure consistent reliability and take advantage of continually evolving pricing scenarios [based on REW, 2018].

Between the hurricane-induced power outages and the rise of small-scale energy resources such as solar arrays and batteries, people are planning for transformations in the production and consumption of energy and the microgrid can be considered as a critical factor in that process, which uses both aspects together during analyses of causes of the infrastructure successes or failures [Larsson, 2009].

A significant aspect of the microgrids related to the optimization of buildings contribution to the infrastructure is the end user control over the energy mix and new cost-saving opportunities available with the help of specialized energy management systems. They continuously analyze energy prices, demand and weather conditions to determine the optimized energy mix - energy sources used at that moment. It can, for example, switch instantaneously from solar to gaz and back when market energy prices justify it.

6. Hybrid infrastructure

It is defined as infrastructure systems that are integrated within buildings and landscapes that also provide non-infrastructure uses. The performance assessment results of the hybrid infrastructure show that refocusing building performance goals and assessment methods to the urban scale can be more effective than current building performance ones [based on Mangone, 2015].

The development of hybrid infrastructure can provide a diverse range of benefits to local municipalities, building owners, occupants, and local and global natural ecosystems. However, in a typical example of potential confusion between correlation and causation, it would be a different kind of a contribution, the one opposite to the production of the energy that results in a reduction of the infrastructure. District heating and cooling systems (DHC), particularly when combined with district energy systems (DES), can be more effective than individual building mechanical systems. That may happen with regards to cost, energy performance, and emissions, as well as reduction of the building floor area dedicated to building systems, thus contributing directly and indirectly to the reduced required capacity of the infrastructure that serves the construction and operation of the smaller building [after Mangone, 2015].

Hybrid infrastructure can improve the economic performance of municipal infrastructure.

Hybrid infrastructure can be incorporated into buildings in a manner that allows the building systems, occupants, and owners to benefit from the physical system components, spaces, surfaces, materials, and process by-products, such as waste heat. For instance, the design of a decentralized wastewater system within a suburban low-rise social housing block in Kolding, Denmark provided rentable space for a local horticulturalist to grow 15,000 plants within the infrastructure system, as well as provided wastewater for cost-effective irrigation. In Helsinki, the harvesting of waste heat from computer servers within a building has been found to be a cost-effective means for heating and extending the growing season of rooftop greenhouses. Thus, the integration of municipal infrastructure into buildings and landscapes can generate diverse economic opportunities for local communities.

Specific technical infrastructure processes can be designed to interact with occupants in ways that improve their well-being, such as designing part of a neighborhood rainwater storage system as a falling water feature with sounds of cascading water and light - all found to reduce stress and anxiety. Water tanks can also function as thermal mass and shading for a building. Depending on the design and context, this can substantially improve the thermal comfort of a building space, optimizing occupants satisfaction and from the other side, energy use, thus infrastructure size and use [after

Mangone, 2015], which includes a more cautious approach to resource consumption, generally, translating into reduced use of energy.

Conclusions 2 – compilation of research 5 and 6

The potential role of very small urban areas offers possibilities to improve the aggregate performance of buildings. A concept model that builds on the form of synergistic performance in energy, emissions and water and other less critical issues, is called a Synergy Zone. A more extensive range of issues provides an appropriate framework for neighborhood infill and renovation programs strategies with very high levels of performance. They include the use of renewable DC power with minimized conversion losses, the distribution of thermal energy from buildings with surpluses to those with deficits, and similarly more efficient use of surplus greywater.

The performance synergies can be achieved within mixed-use buildings in urban settings, such as different schedules within each occupancy for peak electrical or space heating or cooling demand. It is especially valid if the scope is extended from a single building to small clusters of buildings, where the area of a cluster can be small enough to allow economical active thermal transfer between buildings as well as the direct use of DC power in buildings within the cluster.

Hybrid infrastructure is defined as systems that are integrated within buildings and landscapes that also provide non-infrastructure uses [after Mangone].

District heating and cooling systems (DHC), particularly when combined with district energy systems (DES), can be more effective than individual building mechanical systems. That may happen with regards to cost, energy performance, and emissions, as well as reduction of the building floor area dedicated to building systems, thus contributing directly and indirectly to the reduced required capacity of the infrastructure that serves the construction and operation of the smaller building [after Mangone, 2015]. However, it would not result in the reduction of the overall neighborhood infrastructure size.

Hybrid infrastructure can improve the economic performance of municipal infrastructure.

Specific technical infrastructure processes can be designed to improve occupant's well-being, such as designing part of a neighborhood rainwater storage system as a falling water feature with sounds of cascading water and light - all found to reduce stress and anxiety. Water tanks can also function as thermal mass and shading for a building and, depending on a context, substantially improve the thermal comfort of a building space, optimize occupant satisfaction and result in much more cautious approach to the use of energy, thus positively affecting an infrastructure size and usage [after Mangone, 2015], For the functioning of any modern urban area, critical infrastructure is necessary, such as hospitals, public transport, food supplies, water and sewage facilities which should operate at a basic level in all extreme conditions. The Synergy Zones concept can meet the emergency supplies; the hybrid infrastructure shows that it can be resilient, redundant and modular providing the same, similar, or backup functions. Using both concepts can result in a significant victory over climatic or unexpected events.

7. EQ^{tm} Insight Green Infrastructure

At the community scale, green infrastructure refers to stormwater management solutions that mimic natural hydrologic processes, also known as Low-Impact Development (LID). It also refers to landscape best practices, which, in combination with LID, aim to improve stormwater management, protect natural hydrology and habitat, as well as maximize diverse, low-maintenance plantings that make communities attractive and pedestrian-friendly. Much of the feasibility and technical analysis as well as consultation and design work described below was funded through the EQuilibrium Communities Initiative.

The conventional approach to **stormwater management** has focused on large-scale engineered systems, such as storm sewers and detention ponds. However, this approach alone has negative impacts at the watershed level, such as downstream flooding, stream bank erosion, degradation of aquatic habitats and adverse effects on water quality due to contaminants in the stormwater, such as metals and de-icing salt, as well as increased water temperatures.

It also places stress and costs on municipal sewer and treatment infrastructure. Instead, a more recent approach emphasizes small-scale, decentralized solutions that mimic the natural hydrologic cycle or predevelopment hydrology of the site, managing stormwater close to its source. The goal is to minimize runoff and maximize permeability, while ensuring flood protection, through a system of distributed, small-scale design practices that infiltrate, intercept, evapotranspire, harvest, filter, detain and remove pollutants from stormwater.

Stormwater runoff volumes. Practices often include a perforated underdrain linked to a detention pond or storm sewer. Bioretention is designed to capture small storm events, ensuring no water standing for over 72 hours. An overflow or bypass is necessary to pass large storm event flows. Above all, bioretention practices should be designed as attractive landscape amenities. Examples include:

- **bioretention cells and rain gardens**, which are planted shallow depressions that capture roof, lawn and pavement runoff;
- **bioswales**, which are shallow, linear planted swales generally along the road or parking lot edges; and
- **stormwater planters**, which have hard edges and are typically used in dense areas adjacent to buildings, along streets and hardscaped spaces

Green roofs help to reduce the impact of hard impermeable surfaces, including the urban heat island effect. This occurs when dark unplanted surfaces absorb solar radiation and, when combined, raise the temperature of urban areas in summer. Through the evaporation and transpiration of water by the plants on their surfaces, green roofs help cool cities. They also reduce stormwater runoff and have other social and environmental benefits, including habitat creation.

Permeable pavements allow stormwater to infiltrate into a granular reservoir under the pavers, allowing it to infiltrate further into the underlying soil or they may be temporarily detained. Such pavements can be used on low traffic roads, parking lots, driveways, walkways, and plazas. Examples include permeable interlocking concrete pavers, pervious concrete, and porous asphalt.

Soakaways are underground pits filled with void-forming material, such as clean granular stone, that receive runoff, for example, from roofs through a perforated pipe inlet, and allow it to infiltrate into the surrounding soil. Infiltration galleries perform a similar function.

In addition to Low-Impact Development (LID) practices, landscape best practices that are part of a green infrastructure system include other infrastructure related measures like design that minimizes the need for irrigation- up to elimination of the water pipe network, maximization of tree canopy-shading leading to energy savings, pedestrian-oriented routes, streetscapes and open spaces – minimization of car traffic.

8. Urban Farming

Design principles for urban agriculture provide a framework and context to guide more detailed design strategies aiming to create an infrastructure that celebrates food production, preparation and consumption and leads to diverse, productive landscapes. The technical considerations, such as structural implications for planters connected to buildings and green roofs, the need for irrigation systems, the balancing of rain and stormwater systems regular needs with a natural capability of urban farming to absorb part, if not all of it, are taken into the account when buildings- future contributors are designed [after Gorgolewski et al., 2011].

Transformation of "lost", or merely underused, urban space containing buildings [Rovers, 2006] can show the new ways of creation of urban areas by linking spaces like riverbanks, median strips, public parks, schoolyards and boulevards with urban agriculture- in other words, a food production. The potential contribution of such designs of buildings and communities could have a considerable impact on the infrastructure. When features, such as farmer's markets, greenhouses, edible landscapes, living walls, permeable pavings, green roofs, and community gardens can be incorporated into a design, it may change the basics directing any urban design [based on D-L. Smith, 2010]. Urban farming can become the remedy for increasing food demand, a solution to the increasing urban areas with no green spaces and a relief in the age of global warming.

Considering the aspect of the thesis that buildings in such cases can provide benefits such as, for example, an improved thermal performance due to green roofs and green walls acting as insulation buffers, they act as an infrastructure contributor. Furthermore, the significant advantage of rooftop gardens is that they cut on the energy consumed for transportation as they are not generally used on a commercial scale. Rooftop farming also has advantages other than providing with food which includes maintaining the temperature of the house or structure, attracting birds(ecology) to urban spaces and providing with an overall cooler environment.

Figure 16. The first urban rooftop farm in Denmark. Source: S.Patel, S. Nair.

It is important to mention that the main areas of the implementation of urban agriculture are within building itself or its premises, and in landscaping with the following recommendations/requirements having the impact on the infrastructure:

- Integration with existing structures – impact on shading/cooling/(over) heating
- Artificial environment (light, temperature, humidity) – impact on most building systems
- Techniques of greenhouse – impact on mechanical systems
- Rooftop Farming - perfect for high-density areas – impact on mechanical systems, stormwater management
- Countering climate change through a reduction of GHG emissions,
- Reduction of heat island effect and
- Creation of an ecologically welcoming environment.

Conclusions 3 – a compilation of research 7 and 8

Part of a green infrastructure system consists of Low-Impact Development (LID) practices (such as **stormwater management**, **stormwater runoff volumes, green roofs, permeable pavements, soakaways).** Landscape best practices include other infrastructure related measures like design that minimizes the need for irrigation- up to elimination of the water pipe network, maximization of tree canopy- shading leading to energy savings, pedestrian-oriented routes, streetscapes and open spaces – minimization of car traffic.

Design principles for urban agriculture provide a framework and context to guide more detailed design strategies aiming to create an infrastructure that celebrates food production, preparation and consumption and leads to diverse, productive landscapes. The technical considerations, such as structural implications for planters connected to buildings and green roofs, the need for irrigation systems, the balancing of rain and stormwater systems regular needs with a natural capability of urban farming to absorb part, if not all of it, are taken into the account when buildings- future contributors are designed [after Gorgolewski et al., 2011].

The potential contribution of designs linking spaces like riverbanks, median strips, public parks, schoolyards and boulevards with the urban agriculture of buildings and communities - the transformation of “lost,” or merely underused, urban space containing buildings [Rovers, 2006] could have a considerable impact on the infrastructure. When features, such as farmer’s markets, greenhouses, edible landscapes, living walls, permeable pavings, green roofs, and community gardens can be incorporated into a design, it may change the foundations directing any urban landscape [based on D-L. Smith, 2010]. Urban farming can become the remedy for increasing food demand, a solution to the increasing urban areas with no green spaces and a relief in the age of global warming. Buildings in such cases can provide direct benefits such as, for example, an improved thermal performance due to green roofs and green walls acting as insulation buffers, all of which contribute to infrastructure. Furthermore, the primary advantage of rooftop gardens is that they cut on the transportation of energy since they are not generally used on a commercial scale.

9. Insurance Problems

Insurers count mounting costs of climate change and lobby to reduce the damage [Noakes, CBC, 2015]i In the past decade the insurance industry has been hit by mounting claims from extreme weather. "The property and casualty insurance industry has been on the front lines of this " and …" for the industry, climate change is a priority. We are working with every level of government to try to impress preparedness." [Craig Stewart, Insurance Bureau of Canada].

Figure 17. The High River area of Hampton Hills - 2013 floods in Alberta. Source: Jeff McIntosh/Canadian Press)

Urban flooding likely to worsen, say experts

2013 is the year the Canadian government had to write a cheque to Alberta for $2.8 billion (*milliards in Europe*) for flood damage, to partly compensate for damage of more than $6 billion, while claims in southern Ontario from severe weather totalled $1.1 billion — a total of $3.4 billion in claims from catastrophic weather events for the year.

Improvements of urban infrastructure against flooding from extreme weather

The primary infrastructure related climate events are overwhelmingly floodings, as storms bring higher levels of rainfall and rivers to overflow from sudden spring melts and heavy rain. The area of the potential mitigating action or avoidance of disasters for the infrastructure is related to the way we plan the urban settings and design the buildings within. Cities have to identify which parts of their system are at highest risk for flooding and what to finance while upgrading sewers and storm-water infrastructure. However, the outcome is related to the design of buildings and thus inherently the built environment -urban tissue that results in better planned and built infrastructure while creating another aspect of buildings and community performance. The Institute for Catastrophic Loss Reduction (ICLR) at the University of Western Ontario in London, Ontario, identifies effective practices for protecting buildings as a part of the planned resilience protecting and mitigating the needs of existing infrastructure. [Todd Korol/Reuters].

"Cities are going out to engage their citizens. It is not just infrastructure; homeowners also have to take measures to protect their property."

Some simple examples applied to buildings and to their indirect contribution: the incentives to install sewer back-valves, which prevent floodwaters from coming up through the sewer, disconnection of downspouts from the sewer system or the installation of wet and dry ponds to retain stormwater in new subdivisions.

10. Life Cycle Costing

Life cycle costing (LCC) helps municipalities look beyond initial capital costs and assess infrastructure strategically over its entire life. LCC can strengthen fiscal performance as well as contribute to GHG reductions and evaluate the efficiency of infrastructure and renewable energy since their initial costs are often higher but operating, and maintenance costs over the life cycle of a project are lower.

Barrier: First Cost Orientation

A significant barrier to advancing premium efficiency infrastructure and renewable energy is that consumers focus on the initial capital cost and simple payback.

Looking Long Term

LCC considers the total cost of owning, operating and maintaining infrastructure over its useful life (including fuel, energy, labor, and replacement components). LCC analysis has made some of the most significant contributions to advancing local government climate change programs. LCC has applications across a wide range of sectors with the following related to the infrastructure

- Civic Buildings, relevant for premium efficiency targets for new and existing stock
- Equipment, relevant for office equipment and machinery
- Infrastructure, relevant for transportation and energy systems
- Land use planning, notably as it pertains to infrastructure costs
- Residential and Commercial Buildings

CMHC created its Life Cycle Costing Tool for Community Infrastructure Planning[6] to help owners and developers estimate the approximate costs of development and **to compare alternative development scenarios** (currency may not matter). It allows to consider the life-cycle costs of development, (over a 75-years) and can be used for a variety of project sizes, from infill to subdivisions, and looks at
some different costs such as:

- Hard infrastructure such as roads, sewers
- Municipal services such as transit and waste management
- Private user costs, including driving and home heating costs
- External costs such as air pollution and climate change

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6 Due to the reorganization of CMHC within the switch of priorities in the Canadian Government, the tool has been transferred to the Government of British Columbia and is available for free at the address:
http://www.cscd.gov.bc.ca/lgd/greencommunities/sustainable_development.htm,
http://www.toolkit.bc.ca/tool/life-cycle-costing accessed March 2018, accessed March 2018

11. Big Data[7]

Nothing can be seriously analyzed today without the use of the Big Data**,** which is everything sourced from sensors, digital satellites, digital pictures and videos, banking records, cell phones, GPS signals, climate data, wireless networks; every bit of data that we exchange in our daily lives is part of analytics.

Transforming the kind of cities and buildings

- Monitored control.
- Data mapping to manage city's assets and systems. Building operations management
- Resolve the environmental issues
- Improve quality through market competitiveness.
- Address bottom line concerns of our cities, management, and governance.

BIM oriented performance

- Quantitative assessment of the buildings & systems.
- Operational statistical analysis & investment planning.
- Retrofit for older buildings.
- Digital warehouses are built to store the enormous amount of data being produced, for further analytics. These are the big-data induced architecture, slowly pocketing into our neighborhoods.

One of the first examples: The Smart Nation Initiative that is planning to turn Singapore into a "living laboratory" and to make the city energy efficient, improving the transportation and making the city safer. The Smart Nation is concentrating on three components: *home, health and on the road.*

- "Go Smart" program for the homes with thousands of sensors installed to recover data from individual apartments giving feedback to the residents on their electricity and water usage.
- "Elderly Monitoring System" (EMS) collecting information from sensors on doors and movement in the rooms. A lack of movement will trigger notifications to the family/ caregiver.
- Monitoring of transports - a program with self-driving car and buses to reduce the crowdedness of the city thus help the infrastructure to function properly.

Leaders and designers are more likely to base the policies and designs on a holistic mapping of past and present conditions to render more sustainable solutions, touching the environmental and social aspects, along with economic improvements.

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[7] S.Sood Joshi, C. Desormaux, "How has the Big-data altered our built environment?", students of Eco Design, Green Architecture, Algonquin College, Ottawa, Canada, 2018, *W.Kujawski, course professor*

Conclusions 4 – a compilation of research 9, 10 and 11

Parts of the sewers and storm-water infrastructure systems that are at the highest risk have to be identified. The outcome is related to the design of buildings and thus inherently the built environment - urban tissue that results in better planned and built infrastructure while creating another aspect of buildings and community performance.

"Cities are going out to engage their citizens. It is not just infrastructure; homeowners also have to take measures to protect their property."

Life cycle costing (LCC) helps local governments look beyond initial capital costs and can assess infrastructure strategically over its entire life significantly strengthening fiscal performance. It is especially useful for evaluating premium efficiency infrastructure and renewable energy opportunities since their initial costs are often higher, but they tend to have lower operating and maintenance costs over the life of the project. A major barrier is that consumers focus on the initial capital cost and simple payback and LCC, rather than evaluating projects on the first cost, considers the total cost of owning, operating and maintaining infrastructure over its useful life. LCC has applications across a wide range of sectors with the following related to the infrastructure

- Civic Buildings, relevant for premium efficiency targets for new and existing stock
- Equipment, relevant for office equipment and machinery
- Infrastructure, relevant for transportation and energy systems
- Land use planning, notably as it pertains to infrastructure costs
- Residential and Commercial Buildings

CMHC created its Life Cycle Costing Tool for Community Infrastructure Planning to help owners and developers estimate the approximate costs of development and **to compare alternative development-different options for types of infrastructure[8].**

Every aspect of life analyzed today is with the use of the Big Data9 - sourced from sensors, satellites, digital pictures and videos, banking records, cell phones, GPS signals, climate data, wireless networks; every bit of exchanged data in our daily lives is part of analytics. It also applies to the aspect of buildings and their operations affecting the infrastructure from monitoring controls through an operation to management on all levels. Control goes to continuous performance assessment of the building, market conditions, operational statistics- all to improve the overall performance of the built environment.

[8] It is available at http://www.cscd.gov.bc.ca/lgd/greencommunities/sustainable_development.htm
Accessed in March 2018

[9] S.Sood Joshi, C. Desormaux, "How has the Big-data altered our built environment?", students of Eco Design, Green Architecture, Algonquin College, Ottawa, Canada, 2018, *W.Kujawski, course professor*

12. Summary

"Urban" means a planning pattern, characteristic of the highly populated area with infrastructure; however, it may be applied from a specifically oriented building to a block, neighborhood, community, district, city, and agglomeration.

One of the most fundamental questions in urban planning and building regulations is how to secure universal access to sun, light and fresh air, all affecting the energy use of buildings and related infrastructure. Optimization of energy in the building and urban designs in ever-growing cities requires an understanding of all interrelations between them, and the conclusions strongly support the thesis that buildings, if adequately designed within equally well thought off urban context, are major contributors to the infrastructure.

Urban geometry is an essential factor in energy-optimized architecture as energy savings from an urban design are very long-term while reducing the need for costly but not durable technologies. Urban context, an important contribution to the building energy demand, is often overlooked in favor of individual building performance [after DeKay, 2017].

A study of urban fabric was performed by analyzing those aspects of spaces with a range of parameters such as building sizes and shapes, street patterns and shapes, the urban design itself and a population density. Unobstructed passive volume uses two times less energy than the non-passive volume and an efficient building in an efficient urban fabric can consume four times less energy than a non-efficient one [after Salat, 2008].

The overall energy consumption of buildings depends in part on available daylight to provide the required level of light, thus directly affecting the infrastructure loads [after DeKay, 2017].

The most important factors besides the local climate, affecting the amount of available daylight are the ratio between the building heights and the street width between buildings, a reflectance of the exterior building materials and ground surfaces, and the area of windows [DeKay, 2017]

The name - urban canyon- has been used in urban climatology describing, in geometric terms, the height to width ratio of the space between adjacent buildings. The link between urban density and building energy use is an intricate balance between climatic and spatial factors, material and urban use patterns with buildings that constitute them [after J.Stroemann, P. Sattrup, 2011].

Local streets create main road network within a community and become a major determinant of the designer's input in buildings and infrastructure in any urban development. The outcomes of other presented studies only confirm such relations as, for example, the design of permeable areas that decrease stormwater systems, contributing positively to the urban heat island effect by lessening the energy demand for cooling and increases urban comfort.

Well-designed streets can also mitigate traffic and enable active transportation (walking, cycling), which can reduce the energy required for transportation and related GHG emissions. Even minor adjustments to street patterns can create opportunities to build higher density developments and reduce the impacts on municipal infrastructure while raising the viability of shared energy systems.

The potential role of small urban areas offers possibilities to improve the aggregate performance of buildings. A concept model that builds on the form of synergistic performance in energy, emissions and water and other less critical issues, is called a Synergy Zone. A more extensive range of issues provides an appropriate framework for neighborhood infill and renovation programs strategies with very high levels of performance. They include the use of renewable DC power with minimized conversion losses, the distribution of thermal energy from buildings with a surplus to those with deficits, and similarly more efficient use of surplus greywater. [Larsson, 2012]

The performance synergies can be achieved within mixed-use buildings in urban settings, such as different schedules within each occupancy for peak electrical or space heating or cooling demand. It is especially valid if the scope extends from a single building to small clusters of buildings, where the area of a cluster to be small enough to allow economical active thermal transfer between buildings and to allow direct use of DC power to buildings in the cluster.

Hybrid infrastructure is defined as systems that are integrated within buildings and landscapes that also provide non-infrastructure uses [after Mangone].

Hybrid infrastructure can improve the economic performance of municipal infrastructure.

District heating and cooling systems (DHC), particularly when combined with district energy systems (DES), can be more effective than individual building mechanical systems. That may happen with regards to cost, energy performance, and emissions, as well as reduction of the building floor area dedicated to building systems, thus contributing directly and indirectly to the reduced required capacity of the infrastructure that serves the construction and operation of the smaller building [after Mangone, 2015]. However, it would not result in the reduction of the overall neighborhood infrastructure size.

Specific technical infrastructure features can be designed to improve occupants well-being, such as, for example, designing part of a neighborhood rainwater storage system as a falling water feature with sounds and light - both stress and anxiety relievers. Water tanks can also function as thermal mass and shade for a building and, depending on a context, can substantially improve the thermal comfort of a building space, optimize occupant's satisfaction resulting in much more cautious approach to the use of energy, thus positively affecting infrastructure's size and usage [after Mangone, 2015],

For the functioning of any modern urban area, critical infrastructure is necessary, such as hospitals, public transport, food supplies, water and sewage facilities which should operate at a basic level in all extreme conditions.

The Synergy Zones concept can meet the emergency supplies; the hybrid infrastructure shows that it can be resilient, redundant and modular providing the same, similar, or backup functions. Using both concepts can result in a significant victory over the climatic or other unexpected events.

Part of a green infrastructure system consists of Low-Impact Development (LID) practices (such as **stormwater management**, **stormwater runoff volumes, green roofs, permeable pavements, soakaways).** Landscape best practices include other infrastructure related measures such as design which minimizes the need for irrigation- up to the elimination of the water pipe network, maximization of tree canopy- shading leading to energy savings, pedestrian-oriented routes, streetscapes and open spaces – minimization of car traffic.

Design principles for urban agriculture provide a framework and context to guide more detailed design strategies aiming to create an infrastructure that celebrates food production, preparation, and consumption and leads to diverse, productive landscapes. The technical considerations, such as structural implications for planters connected to buildings and green roofs, the need for irrigation systems, the balancing of rain and stormwater systems regular needs with a natural capability of urban farming to absorb part, if not all of it, are taken into the account when buildings- future contributors are designed [after Gorgolewski et al., 2011].

The potential contribution of designs linking spaces like riverbanks, median strips, public parks, schoolyards and boulevards with the urban agriculture of buildings and communities - the transformation of "lost," or simply underused, urban space containing buildings [Rovers, 2006] could have a huge impact on the infrastructure. Urban farming can become the remedy for increasing food demand, a solution to the increasing urban areas with no green spaces and a relief in the age of global warming. Buildings in such cases can provide direct benefits such as, for example, an improved thermal performance due to green roofs and green walls acting as insulation buffers, so acting as an infrastructure contributor. Furthermore, the major advantage of rooftop gardens is that they cut on the transportation energy as they are not generally used on a commercial scale.

During upgrading sewers and storm-water infrastructure parts of their systems that are at the highest risk have to be identified. The outcome is related to the design of buildings and thus inherently the built environment -urban tissue that results in better planned and built infrastructure while creating another aspect of buildings and community performance.

"Cities are going out to engage their citizens. It is not just infrastructure; homeowners also have to take measures to protect their property."

Life cycle costing (LCC) helps local governments look beyond initial capital costs and can assess infrastructure strategically over its entire life, significantly strengthening fiscal performance. It is especially useful for evaluating premium efficiency infrastructure and renewable energy opportunities since their initial costs are often higher, but they tend to have lower operating and maintenance costs over the life of the project. A major barrier is that consumers focus on the initial capital cost and simple payback and LCC, rather than evaluating projects on the first cost, considering the total cost of owning, operating and maintaining infrastructure over its utilitarian lifecycle. LCC has applications across a wide range of sectors with the following related to the infrastructure

- Civic Buildings, relevant for premium efficiency targets for new and existing stock
- Equipment, relevant for office equipment and machinery
- Infrastructure, relevant for transportation and energy systems
- Land use planning, notably as it pertains to infrastructure costs
- Residential and Commercial Buildings

CMHC created its Life Cycle Costing Tool for Community Infrastructure Planning to help owners and developers estimate the approximate costs of development and **to compare alternative development- different options for types of infrastructure[10].** Reduction of potential costs of a road network can switch funding towards building performance improvements impacting on infrastructure. Every aspect of life analyzed today is with the use of the Big Data[11] - sourced from sensors, satellites, digital pictures and videos, banking records, cell phones, GPS signals, climate data, wireless networks; every bit of exchanged data in our daily lives is part of analytics. It also applies to the aspect of buildings and their operations affecting the infrastructure from monitoring controls through management on all levels. Control strategies include the continuous performance assessment of the building, market conditions, operational statistics- all to improve the overall performance of the built environment [Sood Joshi, Desormaux, 2018].

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[10] It is available at http://www.cscd.gov.bc.ca/lgd/greencommunities/sustainable_development.htm Accessed in March 2018
[11] S.Sood Joshi, C. Desormaux, "How has the Big-data altered our built environment?", students of Eco Design, Green Architecture, Algonquin College, Ottawa, Canada, 2018, *W.Kujawski, course professor*

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