TECHNICAL TRANSACTIONS 9/2017
CZASOPISMO TECHNICZNE 9/2017
ARCHITECTURE AND URBAN PLANNING
DOI: 10.4467/2353737XCT.17.147.7159

Wojciech Kujawski (wk.kujawski@gmail.com)
RAIC, LEED AP, iiSBE – Principal at Integrative Solutions Group Inc., at INPOL Consulting, lecturer at Building Science and Eco-Design at Algonquin College, Ottawa, Canada

New role of buildings as contributors to the infrastructure

Nowa rola budynków jako elementów współtworzących infrastrukturę

Abstract

Buildings can create a sense of community and add to the character of neighborhoods and cities. They can also support communities by either directly contributing to the infrastructure requirements of their neighbors, or by reducing their own demands and/or creating their own supply and treatment systems to create capacity for others in, for example, community energy and water systems. Buildings can also reduce wastage with its environmental and economic burdens by recapturing heat being lost through inefficient systems and by using municipal waste, especially bio-waste, as a fuel source. Building energy demands are a significant part of the challenge to reduce dependence on fossil fuels, save on resources, to cut emissions and mitigate the effects of climate change, while also representing opportunities to reduce the negative impacts on municipal infrastructure. This paper explains how buildings can mitigate such impacts while also acting as elements of infrastructure.

Keywords: energy, infrastructure, energy efficiency, environment, community, neighborhood

Streszczenie

Budynki mogą tworzyć poczucie wspólnoty i dodawać do charakteru dzielnic i miast. Mogą też wspierać społeczności poprzez bezpośredni wkład w wymagania infrastrukturalne sąsiadów lub poprzez zmniejszenie własnych potrzeb oraz/lub tworzenie systemów zaopatrzenia i oczyszczania w celu zwiększenia pojemności systemów, na przykład w odniesieniu do energii i wody. Budynki mogą również zmniejszyć marnotrawstwo w środowisku i obciążeniach ekonomicznych, odzyskując ciepło utracone przez nieefektywne systemy i wykorzystując odpady komunalne, zwłaszcza bioodpady, jako źródło paliwa. Zapotrzebowanie na energię w budynkach stanowi znaczną część wyzwania, aby zmniejszyć uzależnienie od paliw kopalnych, oszczędzać zasoby, zmniejszyć emisję i złagodzić skutki zmian klimatycznych, a jednocześnie przedstawiać możliwości zmniejszenia negatywnego wpływu na infrastrukturę komunalną. Niniejszy artykuł wyjaśnia, jak budynki mogą złagodzić takie oddziaływania, a jednocześnie działać jako elementy infrastruktury.

Słowa kluczowe: energia, infrastruktura, energooszczędność, środowisko, społeczność, ekologia, sąsiedztwo

1. Introduction

Buildings, besides their traditional roles as shelters and providers of services, can not only mitigate their impacts on surrounding infrastructure, be it neighbourhood, community or city itself, but also contribute to it by producing energy, clean water, food and converting waste to resources. Building energy demands were always a significant part of the challenge to reduce dependence on fossil fuels, to cut emissions, and save on natural resources, all the while representing potential opportunities to reduce the impacts on municipal infrastructure if properly designed. An integration of buildings and infrastructure represents a major change in coexistence of urban form, which is actually created by buildings, then neighborhoods, then communities; however, none of these entities can function well without an efficient infrastructure. Improving building performance by any degree would move the city system model closer to the sustainable community model.

"(...) Infrastructure matters because it represents the major capital outlay for the developer and a key accounting element in pricing the buildings, after land. (...) to be competitive, infrastructure costs have to be equal to or lower than what conventionally has been achieved in previous developments or by the industry at large" [2].

This paper describes the benefits of buildings as strategic contributors [1] to the city systems helping understand:

- The design implications of buildings as components of community infrastructure,
- Development, design and construction issues,
- Certain aspects of costs and savings incurred in sustainable buildings and communities in relation to infrastructure.

Building can be classified into well known "green", "sustainable," "living" or "regenerative". The very basic features for Green Buildings became a starting point from which the designers can measure their progress.

Table 1. Characteristics of Green Buildings [1]

Issue within	Related systems/features
Location	Not on fragile landscapes Doesn't contribute to urban sprawl Close to mass transit systems
Site	Focuses on surface water management and retention (holding ponds, porous paving) Xeriscaping Minimal or zero impact on local ecology Increased green space
Exterior	Renewable energy systems (geothermal, wind, solar, etc.) Window canopies or light shelves Green roofs Active transportation infrastructure (bicycle parking, etc.) Efficient, targeted exterior lighting, mitigation /elimination of light pollution

Interior	Minimal use of materials (e.g., leaving exposed structures, where possible and/or appropriate) Flexible layouts (movable walls, raised floors for services) Occupant controls of heat and light (as opposed to large zone thermostats or light switches) Abundant natural light and access to views Air quality better than in conventional buildings Low-flow water fixtures Supports sustainable practices (such as built-in recycling and composting bins)
Hidden features or attributes	High-performance building envelopes Materials selected to meet building goals (minimal environmental effects, low VOCs) High-efficiency mechanical systems integrated with electrical, structural, and architectural elements Energy-efficient lighting systems The use of maintenance materials (e.g., detergents) that also meet sustainability goals Continued monitoring and optimization of system performance over time.

The terms "green," "sustainable," "living" and "regenerative" can be confusing as they are often used interchangeably when, in fact, there are substantial differences.

- **Green buildings** follow a pre-design, design, construction and commissioning, and operations model, and performance is measured based on energy and resource consumption, environmental loading and indoor environmental quality.
- **Sustainable buildings** follow the same principles but with added economic, social and cultural aspects.
- **Living buildings** add to the urban environment by acting like ecosystems, maximizing the health of animals, plants and people. Like an ecosystem, methods of creating a living building are specific to the area where it is built.
- **Regenerative building** projects repair damaged ecosystems, replace agricultural opportunities, add to community energy and water supplies, etc., and, in essence, become critical components of community infrastructure. They are basically Energy Positive buildings (producing, on top of the energy for their own needs, a surplus energy that is used by other buildings or sold to the grid) that free up capacity within local utilities, reduce or eliminate impacts to water, road and energy infrastructure, treat water and wastewater on site, produce some food, while providing greenspaces and other community social areas, giving people opportunities to drive less and to walk, cycle or take public transit more often.

Sustainable buildings can incorporate high performance water conservation techniques (apart from water-efficient fixtures), such as on-site water and wastewater treatment, rainwater collection, xeriscaping and green roofs, can reduce the impact to municipal water, wastewater and stormwater systems. However, if a building treats local wastewater, it would be considered a regenerative building (with other criteria fulfilled as well).

The Integrative Design Collaborative of Arlington, Massachusetts helps builders understand the connections between buildings, the environment and people by employing a "regenerative design" model, as shown (Fig. 1).

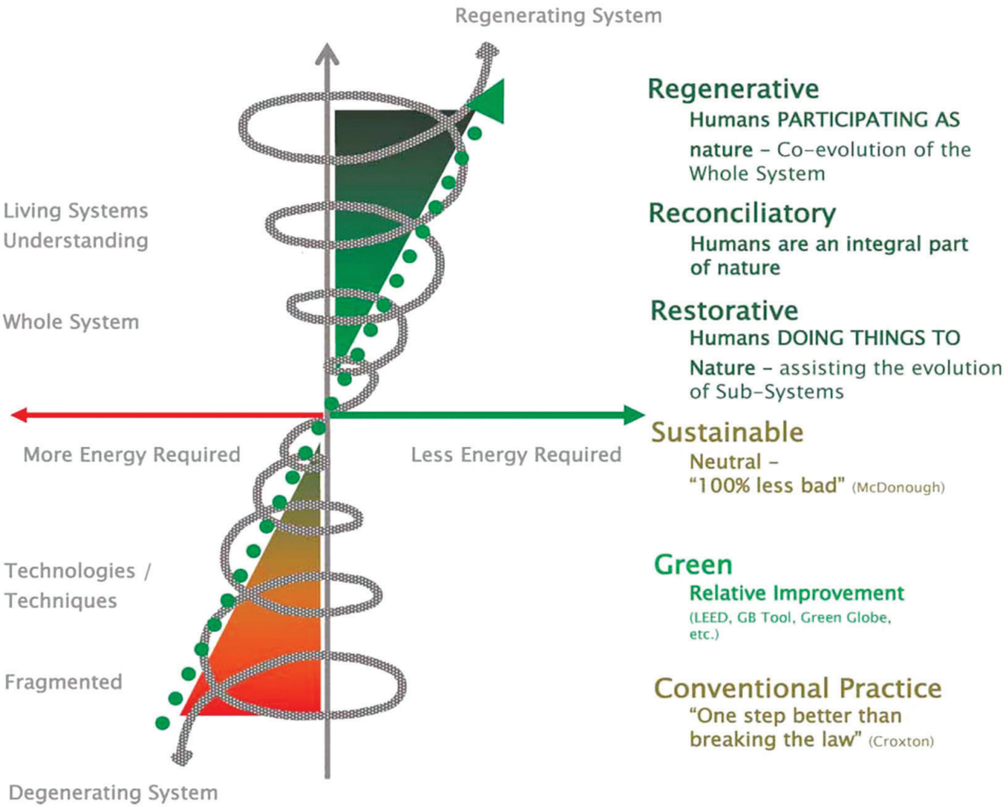

Fig. 1. Regenerative Design Model. Courtesy of the Integrative Design Collaborative

In both the developed and developing worlds the possible solutions lie in a mitigation of the infrastructure construction and its expansion [3]; however, only the most obvious aspects of building's contributions are shown in a more detailed way in this paper. Some are only mentioned; all should give a reader the idea that we are at the brink of a new vision of how we should prepare ourselves for the future.

2. Eco-industrial networks

So called eco-industrial networks (EIN) and eco-industrial parks [13] are structured around both energy and waste sharing between producers and consumers (Fig. 2) and while networks usually supply entire communities, the parks, generally, share within themselves, and then almost nothing is wasted and everything is used.

A good, but quite old, example of such EIN is Kalundborg (Fig. 3) in Denmark (a city first settled in 1167). It started their network in 1961 with a single power station project and have expanded it over time into a cluster of companies that rely on each other for material inputs and supply of energy to the entire community while reducing waste and improving

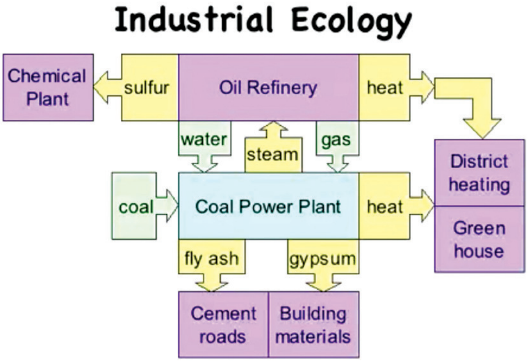

Fig. 2. Idea of EIN (source: [14])

Fig. 3. View of Kalundborg (source: [15])

its economics and environment. They do it for mutual benefit, on the basis that by-products from one business can be used as low-cost inputs by the others [4].

For example, treated wastewater from one place is used as cooling water by the adjacent power station. Others purchase 'waste' process steam from the power station for their operations. Surplus heat from the power station is used for heating adjacent homes, and warm a local fish farm. Other by-product, such as fly ash, is used in cement work and roadbuilding and to obtain gypsum; such purchases meet almost two-thirds of needs. Surplus gas from the refinery, a low-cost energy source, instead of being flared off, is delivered to others. The use for household heating of the excess heat from its producer has eliminated about 3,500 oil-burning domestic heating systems [16].

Original motivation behind the clustering of "park stakeholders" was to reduce costs by using unwanted by-products; but soon it was complemented by a vision of environmental benefits shared by everybody.

Larsson et al [3] synthetized two important ideas: **Smart Grids** – optimization of supply and demand of electrical power at a regional level, and a **Synergy Zone** dealing with the interaction of other issues such as:

- Thermal energy for space heating or cooling;
- Domestic hot water;
- Grey water;
- DC power at the zone and building level;
- Solid waste generated by building operations.

Each of these urban sub-systems could benefit from appropriate storage systems, methodology for optimization of supply and demand, and distribution networks.

Tillie et al. [5] developed an inventory of a wide range of buildings, with different cooling/heating needs patterns changing throughout the day and the year. With an appropriate mix of buildings (a heat/cold ratio close to one) and heat/cold storage facilities at the neighborhood scale, the waste streams could be reused, thus this process could theoretically lead to almost 50% reduction in energy consumption for heating and cooling: as all the heat usually wasted by cooling systems is reused, heating could be "free".

Such strategies could be implemented to building, neighborhood, district/community and even the whole city itself while reducing energy consumption, applying reuse and exchange of waste energy and production of renewable energy (Fig. 4).

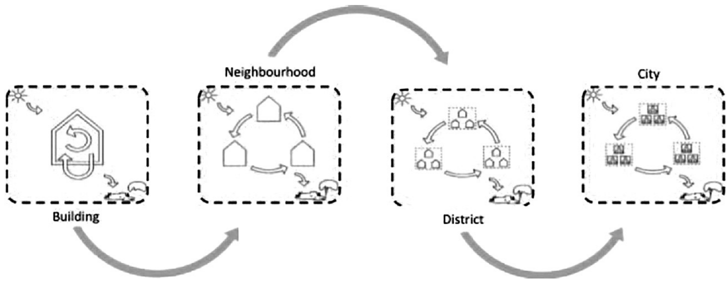

Fig. 4. Knotting the flows at every scale (adapted from [5])

Since heat is a natural byproduct of many manufacturing processes, some developers preferred to locate residential, office or other types of buildings close to industrial or manufacturing plants to take advantage of all potential benefits possible within, district heating including.

Buildings that supply their own energy and produce it also for others nearby, are often the most cost- effective. Combined Heat and Power (CHP) systems achieve peak efficiency when they run continuously on full time loads in their own neighbourhood or a community. Having also its own water treatment facility, and greenhouses etc. they can remain functional even in times of emergency.

Scaling from the building up determines if energy can be exchanged or stored especially between buildings in the neighborhood where the diversity of uses and configurations affect the efficiencies of most systems. They usually work much better on a neighbourhood, than a single building, scale, thus came the logical necessity of a creation of community as a system, rather than a community of separate buildings. The benefits available through different building sites go beyond the traditional infrastructure and now, even a food production of a scale, can be considered.

With the advances in renewable energy technologies such as photovoltaics (PVs), geothermal and in heating and cooling systems, combined heat and power (CHP), the viability of local energy production has improved significantly. Local and individual production can also reduce the peak energy demand and stresses it gives into a community system. When individual buildings take on this role, then retrofitting and expansion of existing grids is avoided. That is the main reason for strong push from utilities for energy efficiency, which could be seen as against their interest, until the cost of a new infrastructure comes to the light.

Also many communities became stronger and more resilient by implementing decentralized systems in which neighbourhoods could still remain functional during and after an event, be it climatic, weather related, natural disaster etc. Table 1 and Fig. 5 show the range of building supported infrastructure features.

Table 2. What types of infrastructure can buildings support? [1]

Infrastructure Component	Sustainable Building Element(s)	Potential Benefits to the developer, occupants, municipality, and/or the community
Energy (heating, cooling, electricity, ventilation, humidification)	▸ District heating (renewable or fossil fuels) ▸ Renewable energy (wind, micro-hydro, solar thermal, PV, geothermal) ▸ High-performance building envelope ▸ use of thermal mass (passive solar design) ▸ Natural light (solar, light tubes, etc.) ▸ Energy-efficient lighting ▸ Controls (sensors, timers, etc.) ▸ Natural, no- or low-VOC finishes (related to indoor air quality)	▸ Reduced energy demands on municipal or provincial utilities ▸ Reduced equipment sizing requirements ▸ Improved indoor and outdoor air quality ▸ Reduced GHG emissions through energy efficiency and reduction of fossil fuel use ▸ Reduced operating and maintenance costs for owners and occupants ▸ Growth of renewable energy and sustainable building technology sectors ▸ Revenue opportunities to sell surplus energy or carbon credits
Roads & Transportation	▸ Optimal street design (e.g., fused grid) ▸ Transit-oriented development ▸ Limited parking spaces ▸ Active transportation infrastructure, (bike paths, racks and storage, sidewalks, etc.)	▸ Reduced urban heat island effect ▸ Reduced GHG .emissions and improvement of air quality with fewer cars on roads ▸ Reduced costs to developers with fewer parking spaces and freed up land
Water/ Wastewater/ Storm water	▸ Permeable surfaces ▸ On-site water reuse ▸ Stormwater management techniques ▸ Green roofs ▸ Rain capture systems ▸ Water efficient appliances (low-flow fixtures, etc.)	▸ Reduced impacts, size and cost to municipal water, wastewater and stormwater systems ▸ Reduced stormwater runoff ▸ Reduced water costs for occupants ▸ Green roofs may reduce cooling requirements and the urban heat island effect
Waste (garbage, recycling, composting)	▸ On-site composting and/or recycling facilities ▸ Reusable/recycled/recyclable building materials ▸ On-site waste reduction during construction and demolition	▸ Extended lifespan of municipal landfill sites ▸ Reduced GHG emissions from landfills (methane = 20x the global warming of CO_2) ▸ Reduced landfill tipping costs by limiting waste during construction and creating revenue from selling useable construction materials
Greenspace	▸ Site location ▸ Community gardening spaces (including green walls and roofs)	▸ Avoidance of disturbing sensitive natural areas ▸ Increased native or drought-resistant flora ▸ Reduced maintenance and remediation costs ▸ Provision of social, recreation and fitness opportunities for residents

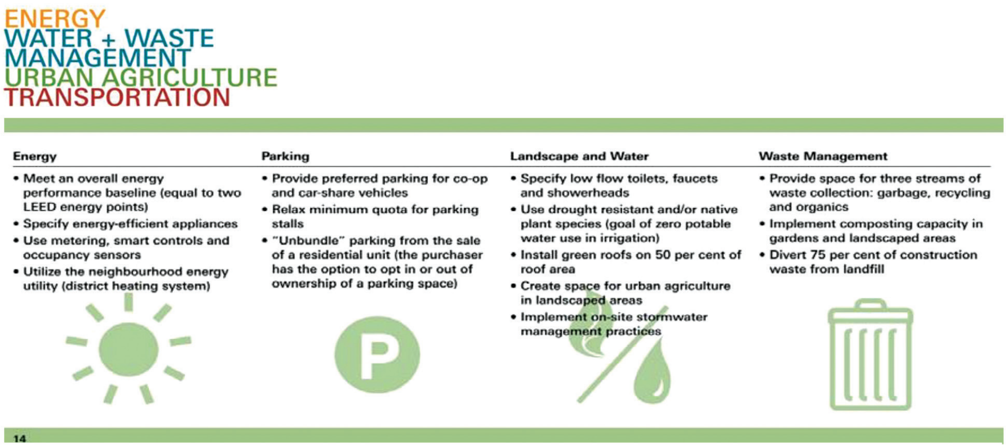

Fig. 5. Courtesy of R. Bailey, 2010, Vancouver

3. Buildings at Work

Many of the building developments, while acting as infrastructure, can either reduce their impact on community infrastructure, or eliminate entirely the need to connect to its elements such as electricity grids or municipal, waste and storm water systems.

Brownfield Redevelopments

Building on brownfields can often be challenging due to the need for very costly site remediation. However, it can easily be outbalanced by potential benefits such as prime location, usually the urban core, and reduced construction and operating costs, because most of the infrastructure is already in place.

BO01, Malmö, Sweden. Well known project that contributes to the municipal infrastructure capacity by, among other features, producing on-site renewable energy and reducing stormwater runoff.

BO01 ("Living 2001") is a mixed-use development on a brownfield site in Malmö, Sweden (Fig. 6) with close to 10,000 residents – one of the most important and already symbolic examples, because it works on a big scale while contributing to most of the infrastructure elements.

Built on a former industrial site, taller buildings were located on the edges of the development to shelter smaller blocks and courtyards from winds coming off the Baltic Sea. A nearby 2 MW wind facility, supplemented by photovoltaics (PVs) provides almost all electricity needs; however, a part of energy for homes and cars is provided by a methane from household waste, captured through vacuum garbage collection system. All garbage, organic waste and recyclables are connected to the underground pipeline system sucking material to a central storage area where it is picked up by municipal trucks, reducing GHG

Fig. 6. Aerial view of BO01. Courtesy of the City of Malmö

emissions and the traffic areas. Energy for water heating comes from seawater and solar and the heat is distributed through municipal sewage and waste infrastructure. Green roofs were installed on most buildings to absorb rainwater, cool the buildings, mitigate heat island effects and provide gardening space for residents. The roofs also delay stormwater runoff, lowering the risk of sewer overflows and overloads at the municipal treatment plant.

Southeast False Creek, Vancouver, British Columbia, Canada

This project contributes to the municipal infrastructure capacity by using a district heating system with sewer heat recovery [17] and providing space for urban agriculture.

Historically, Southeast False Creek (SEFC) was used for industrial and commercial purposes. In 1991, the City of Vancouver decided to transform the site into a model sustainable development.

This residential development, which was also home to the 2010 Winter Olympics Village, includes space for wildlife habitat, playgrounds and urban agriculture. At the heart of it is the city-owned Neighbourhood Energy Utility (NEU), a community energy system (Fig. 7) that provides space heating and domestic hot water.

The system uses several sources for heating, including waste heat from the municipal sewer system and rooftop solar thermal modules.

A Seniors Residency, designed as NetZero building, had waste heat planned to be delivered to its occupants from refrigeration equipment in retail spaces. Interestingly, the new equipment was so energy efficient that there was not enough waste heat, the possibility unthinkable only few years earlier.

SEFC Neighbourhood Energy Utility Schematic

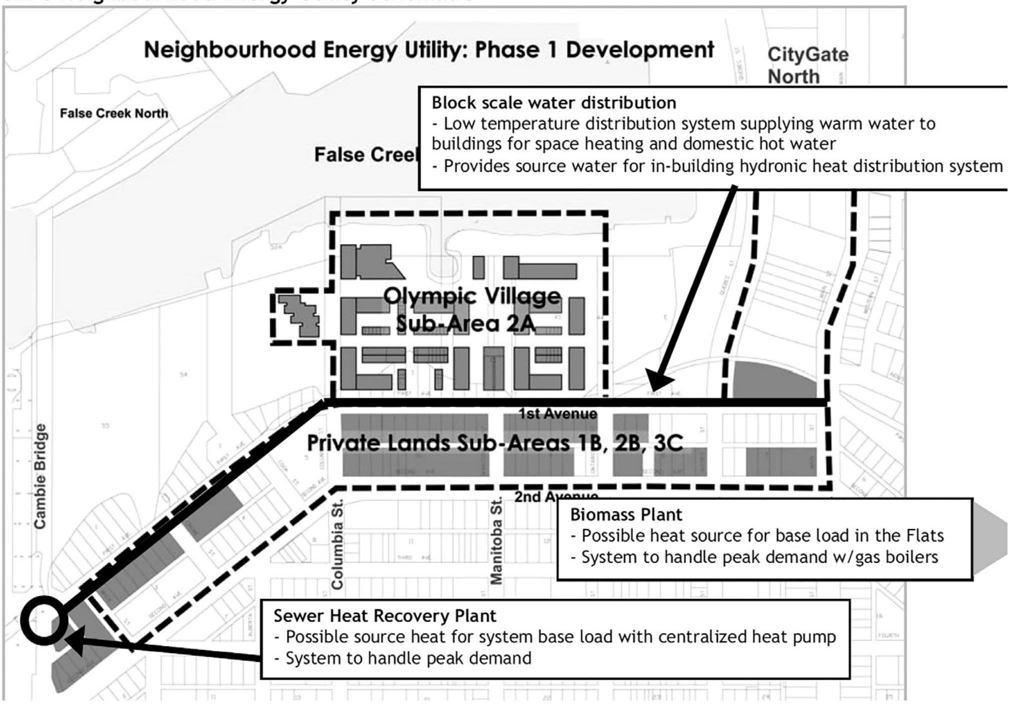

Fig. 7. SEFC Site Plan and Neigbourhood Utility. Graphic courtesy of the City of Vancouver

Fig. 8. SEFC – view. Courtesy of the City of Vancouver

The Currents, Ottawa, Ontario, Canada

This building project uses a passive solar heating system and reduces the impact to municipal water systems by reusing water.

The Currents tower (Fig. 9) was the first mixed-use facility in Canada to achieve a LEED Gold rating. The 44-unit condominium was built on a remediated brownfield and incorporates several different technologies and building construction methods that help support infrastructure systems. The southern façade is dominated by a SolarWall installation that gets heat from the sun during the winter months to preheat incoming air used then to heat and ventilate the residential units.

Fig. 9. The Currents, Ottawa (source: [18])

Retrofits

Existing buildings that were designed with a 50–100-year life expectancy (mainly institutional, hospitals, schools, etc.) usually are good candidates for retrofits such as re-glazing and installation of PVs or geothermal.

The Willis Tower, Chicago, Illinois, USA

This building project saves enough energy to supply one new hotel and adds capacity to the municipal grid.

Replacement of its 16,000 windows, installation of new gas boilers using fuel cell to generate electricity, solar panels to heat water for toilets, smart lighting and control systems combined with upgrade of elevators and escalators and conservation practices led to reduction of annual electricity consumption by 34 percent. The building saves 40% of water each year, or the equivalent of 156,448 full bathtubs, by relying on low water-flow fixtures [19] (Fig. 10). An adjacent 50-storey energy-efficient hotel uses renewable energy systems to fulfill its energy demand. This new building uses less energy than that saved in the renovation of the Willis Tower, thus the entire project is a net contributor to Chicago's infrastructure capacity.

Fig. 10. The Willis Tower, Chicago (source: [20])

District heating systems, well known and used in Europe can be economically feasible when applied to high- density developments, especially with a low-cost energy source. If cogeneration is added, the waste heat from a district heating plant can also be used to generate electrical power for the neighbourhood; or heat from municipal sewage systems can be transferred back to the heating plant.

Dockside Green, Victoria, British Columbia, Canada [21]

Project reduces municipal waste by using energy heating from biomass and reduces infrastructure loads with on-site water treatment systems.

The mixed-use development (Fig. 11) is supposed to produce its own heat (including hot water heating) converting wood waste into gas, eliminating fossil fuels and simply using a landfilled waste product. The sewage is treated on-site and reused (blackwater is filtered for reuse as greywater for flushing toilets and for irrigation).

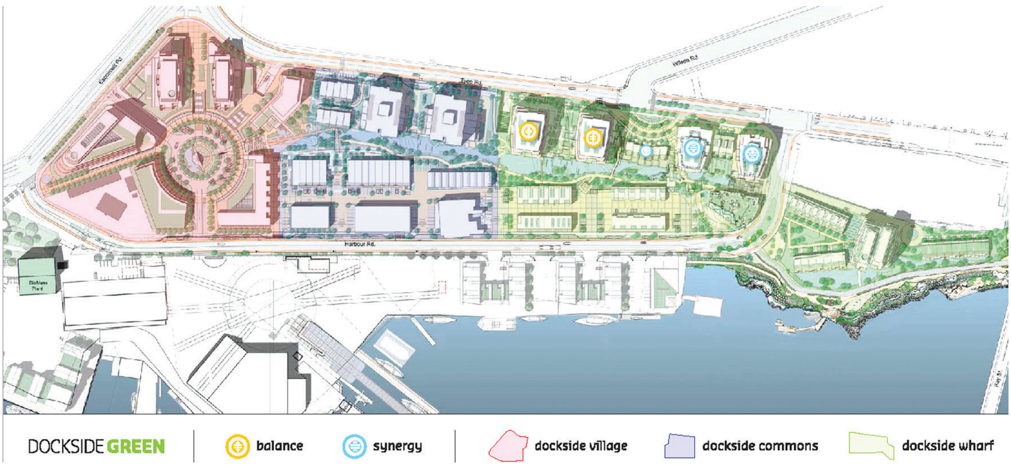

Fig. 11. Dockside Green phases. Source: Windmill Developments

Fig. 12. Greenway

A communal greenway serves as both a public greenspace and a vital part of the wastewater and stormwater management system, in which stormwater flowing to the greenway [22] (Fig. 12) is filtered and added for reuse for toilets and irrigation.

Water-saving appliances and fixtures are a standard issue reducing the need to draw potable water from municipal supplies. The 2008 crises has stopped the development (Fig. 13) for several years at

22% of expected density (Fig. 14) and it restarted only in January 2017 with a modified plan, which calls for another 100,000 m^2 of development and 1,000 residential units in buildings that go up rather than spread out, preserving; however, most of the environmental features planned in their original version.

Fig. 13. Phase 1Design
(source: Windmill Developments)

Fig. 14. Phase 1 in 2016 (source: [23])

4. Design Reality check

Regent Park, Toronto, Ontario, Canada [24, 25]

This project adds to the municipal infrastructure capacity by using a district heating plant. It also has the potential to generate electricity from renewable sources in future.

Regent Park – Canada's largest and oldest publicly funded community, the complete redevelopment of a 50 acre site in the centre of Toronto. The site was previously a rundown area with low rise apartments plagued by all kinds of social problems. Today it's a mixed use development of social and market housing, with cultural, religious, educational and

Figs 15 & 16. Regent Park's 22 – story building with district heating plant (inset). Courtesy of Doug Pollard

Fig. 17. Regent Park's today. Courtesy of CMHC

commercial uses (Fig. 17). The mixture of uses, with their differing peak loads, is important for maintaining a required constant load demand for the CHP system. Each building in this project is/will be built to LEED Gold standard certification.

Reconstruction included a natural gas-fired district heating plant in the centre of the development integrated into the first 22- story residential tower, which is situated next to the central greenspace (Fig. 15 & 16). The plant produces high- efficiency heating and cooling for all of the residential and commercial properties (around 12,000 people) and has the potential to generate electricity using renewable energy source such as geothermal and/or solar [26].

5. Renewable Energy

Buildings as Energy Providers

The most obvious role buildings can assume as infrastructure components is as energy producers with the help of renewable sources such as wind, geothermal and solar to heat, cool and power. Using such sources can reduce GHG emissions and direct energy costs, and provide backup power during both power outages and peak energy demand when renewable energy supplied into the grid can alleviate the need to build new power plants thus element of infrastructure.

The Centre for Interactive Research on Sustainability (CIRS) Building, Vancouver, British Columbia, Canada

This building reduces the impact to municipal infrastructure systems by use of a geothermal heating system and PVs to generate electricity.

The CIRS [27] is located at the University of British Columbia (UBC) in Vancouver and is dedicated to research collaboration and outreach on urban sustainability. Its vision is to be the most innovative high performance building in North America and an internationally recognized leader in accelerating the adoption of sustainable building and urban practices.

CIRS key features (Fig. 18) significantly mitigate the infrastructure needs and improve the environment by:

- 600 tons of carbon dioxide sequestered in the structure,
- Campus energy consumption reduced by 275 megawatt-hours per year,
- Water 100% supplied by rainwater,
- Campus carbon dioxide emissions reduced by 150 tons each year.

The building uses waste heat generated by an adjacent buildig as well as a geotherml heating system.

The Solar Aquatics System™ duplicates, under controlled conditions, the natural purification process of fresh water streams, meadows and wetlands (Fig. 19). Using greenhouses to enhance the growth of algae, plants, bacteria and aquatic animals, sewage flows through a series of aerated, plant covered, tanks and constructed wetlands where contaminants are eliminated typically in less than three days [28]. Besides saving energy, buildings can produce some or all of it, depending on weather conditions with photovoltaics integrated into facades (Fig. 20).

Fig. 18. Graphic courtesy of the International Initiative for a Sustainable Built Environment

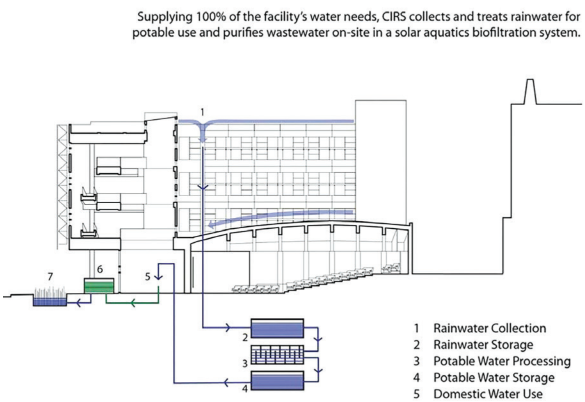

Fig. 19. Graphic courtesy of the Perkins+Will

Fig. 20. CIRS Photo courtesy of blogs.ubc.ca

Bahrain World Trade Center (WTC), Manama, Bahrain [29]

This project uses wind energy to generate a portion of the electricity demand of the buildings.

Completed in 2008, the WTC is a complex with two 240-metre high towers. Three 29-metre wind turbines were installed on bridges between the towers which funnel and accelerate wind velocity (Fig. 21). Each tower has a slightly different sail-like shape helping reduce pressure differences between the bridges. Combined with increased wind speed at high levels, this provides an equal velocity between the turbines and promotes greater efficiency. The three wind turbines operate approximately 50% of the time, providing between 10–15% of the electricity for both towers.

Fig. 21. The Bahrain WTC building has three 29-metre high wind turbines. Image courtesy of Wikipedia (By Fred Hsu [30, 31])

Greywater Reuse

Greywater reuse systems, used in new and existing buildings, capture water from laundry, showers and sinks, then treat and reuse it for toilet flushing or irrigation. They conserve potable municipal water and can also reduce the wastewater infrastructure thus reducing water and sewage costs for owners and infrastructure costs to municipalities; however, some Canadian projects show that systems' costs can often outweigh the savings (problems with training and maintenance).

BedZED, London, UK

Beddington Zero (fossil) Energy Development or BedZED, is targeting low energy and renewable fuel, including biomass CHP and PVs, zero net carbon emissions, water conservation strategies, and biodiversity measures.

BedZED combines both functions: capturing rainwater for reuse and processing blackwater on site to serve residential and office space. BedZED also produces its own energy in a CHP system, produces electricity with PVs integrated in the glazing, has green roofs and other sustainable strategies to eliminate the need for municipal infrastructure [32] (Fig. 23). It contributes to the transportation system by supplying shared electric vehicles (powered by windows' PVs) and eliminating commuting by integrating work spaces nearby (Fig. 22).

EquilibriumTM Communities [34] project – Station Pointe Greens [35], Edmonton, Alberta, Canada

Project based on Passive Design principles will include, if built as planned, apartments in buildings from 6 to 18 storeys, and townhouses (Fig. 25) resulting in a transit-supportive 250 units per hectare. SPG will have all amenities on-site and a biological wastewater treatment facility (Fig. 24) to treat 100% of the wastewater to be re-used for toilets flushing and irrigation. The design includes reduction of stormwater run-off through green roofs over 50% of the site and bioretention cells. All those features combined with the light rail station and bus terminal, contribute to a very significant potential reduction of the infrastructure.

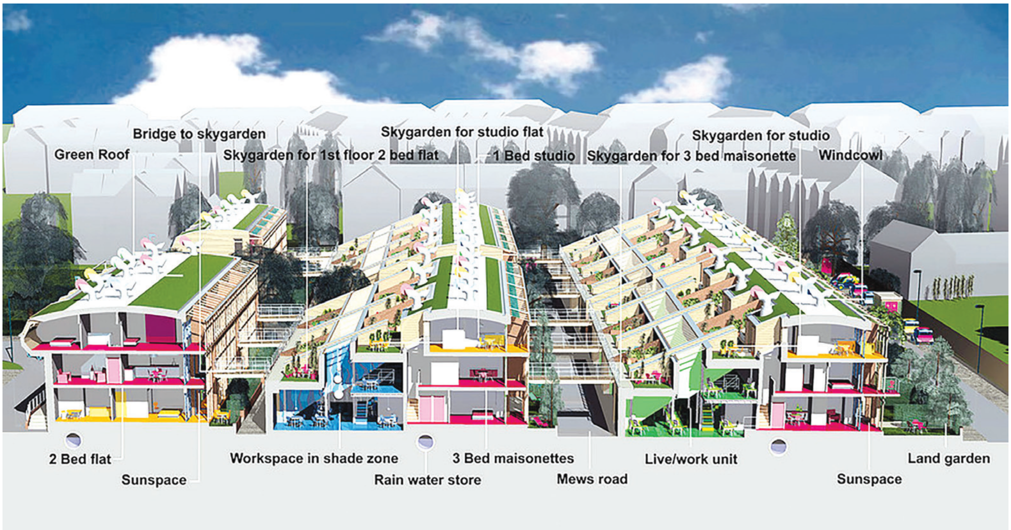

Fig. 22. Sectional perspective. Courtesy of zedfactory (source: [33])

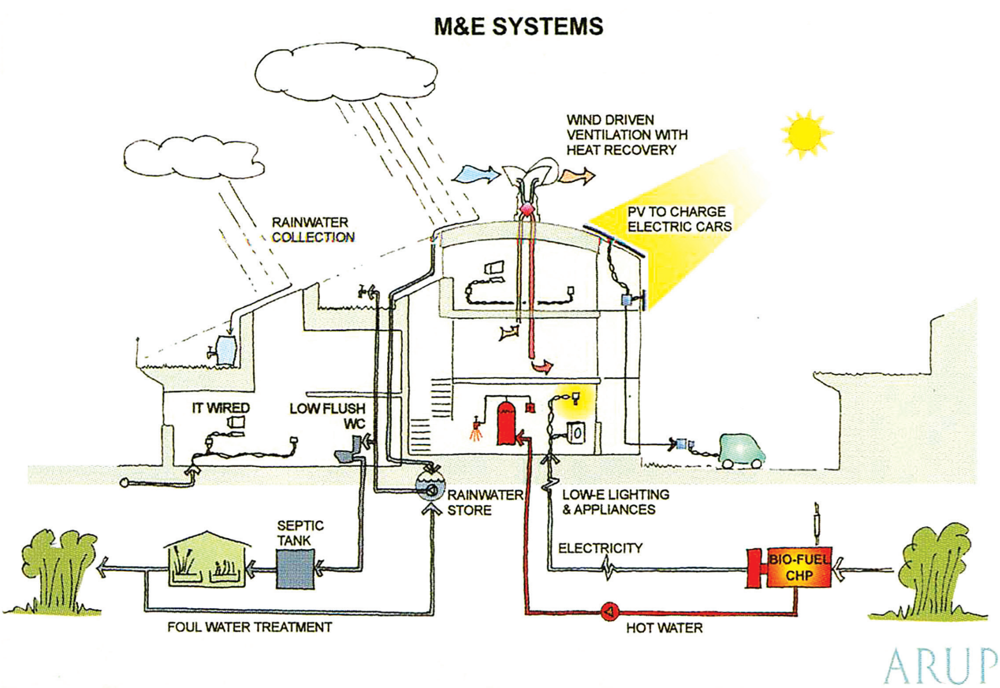

Fig. 24. BedZed, courtesy of ARUP

6. Challenges & Design Considerations

Changes can be difficult and usually are. Some in the development community believe ideas used are too expensive or complicated. Following are some of the challenges.

Cost

A number of studies show that there are no significant differences in average costs between sustainable buildings and conventional ones. While there can be additional costs, they are typically not as high as perceived by the development industry.. This is primarily because operational savings are often found through measures such as lower heating and cooling loads, revenue from construction waste, the sale of surplus energy, higher market values, etc. These long-term savings can offset increased capital cost as shown in Table 3 below.

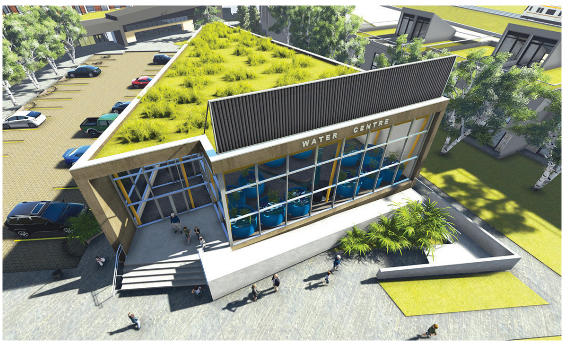

Fig. 24. Wastewater treatment facility

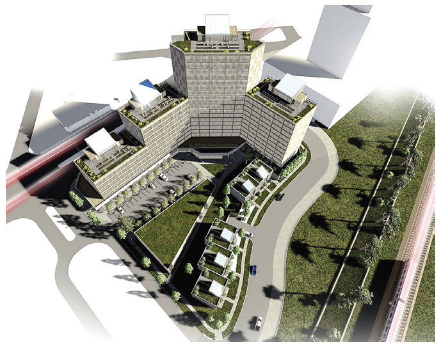

Fig. 25. Aerial view. Courtesy of Hartwig Architects

Table 3. Cost of measures and related benefits [1]

Capital and operating costs	Reduced energy demand optimizes capital and operating costs by reduced equipment size (e.g., heating, ventilation or cooling systems, etc.) [8]
Density bonuses	Offered by municipalities to developers in exchange for the provision of certain amenities that benefit the community as a whole
Building envelope	The high performance envelope can reduce the costs of mechanical systems
Renewable energy	Reduces the need for fossil fueled energy, creates a potential source of income
Energy efficiency	Combined with reduced GHG emissions allows developers to sell carbon credits or reduce operating costs (long-term savings can be included in higher building sale prices)
Daylight, high efficiency lighting	Properly designed, located and shaded buildings (to avoid overheating) and use of LEDs reduce the energy requirements
Transit-oriented development	Proximity of transit can substantially reduce the requirements for parking spaces and their cost [9]

Active transportation amenities	Secure bicycle parking or better pedestrian areas, can reduce the amount of parking required and make streets safer [10]
Green roofs	Green roofs reduce stormwater runoff and provide additional insulation, which can reduce heating, cooling requirements [11]
Xeriscaping	Planting native and/or drought-tolerant plants can reduce water consumption and landscaping maintenance costs
Rainwater capture	Reduces the cost of water required for irrigation
Incentive programs	Many levels of government and utilities offer incentive programs for green buildings or for energy-efficiency retrofits
Preferential financing	Some financial institutions offer preferential financing for green buildings
Preferential insurance rates	Some companies offer credits for firms that incorporate renewable energy [12]

However, from a developer's perspective, first costs are the most important factors and long-term savings are rarely considered, unless developer owns and operates such buildings.

Street Patterns with building as urban component and infrastructure contributor

Main road network within any community is created by local streets and usually big part of its infrastructure budget is used there over lifetime. Paved/ impermeable streets increase stormwater systems and contribute to the urban heat island effect, which in turn increase the demand for cooling. Well-designed streets, however, can mitigate traffic, enable active transportation, reduce the transportation energy and related GHG emissions. Several CMHC [36] studies show how even minor adjustments to street patterns can create opportunities to build higher density developments and reduce the impacts to municipal infrastructure. One such road pattern is the "fused grid" that combines conventional and grid-based layouts, optimizes use of land, requires less hard surfaces, allows for higher densities and more open space, and is more cost effective to service and maintain (Fig. 26).

Table 4 [2]

Fused grid elements	Potential Benefits
Traffic calming and control	Reduced noise and air pollution Fewer cars can reduce wear and tear on roads
Street design	Pedestrian and cyclist safety Reduced noise and air pollution Better stormwater management and permeable surfaces
Greenspace and water retention	Promotes better water quality Improves local air quality Provides habitat for plants and animals and local flora

Table 4 cont.

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, etc.)	Encourages active transportation Promotes greater physical activity among residents

Fused grid neighbourhoods encourage greenspaces throughout a development that can provide connections between neighbourhood elements and food production locations, function as storm and wastewater management components, make higher density more acceptable when developed in conjunction with open space, and more viable for locating co-generation and shared energy systems [2].

Streets may now be used as stormwater collection routes, if not built as permeable, greywater gardens, and linear, vegetated parks that cool and improve air, stormwater quality and provide habitat and pleasure. The sheltered courtyards are ideal for food production, rainwater storage, grey water purification etc. and some of them may function as greenhouses.

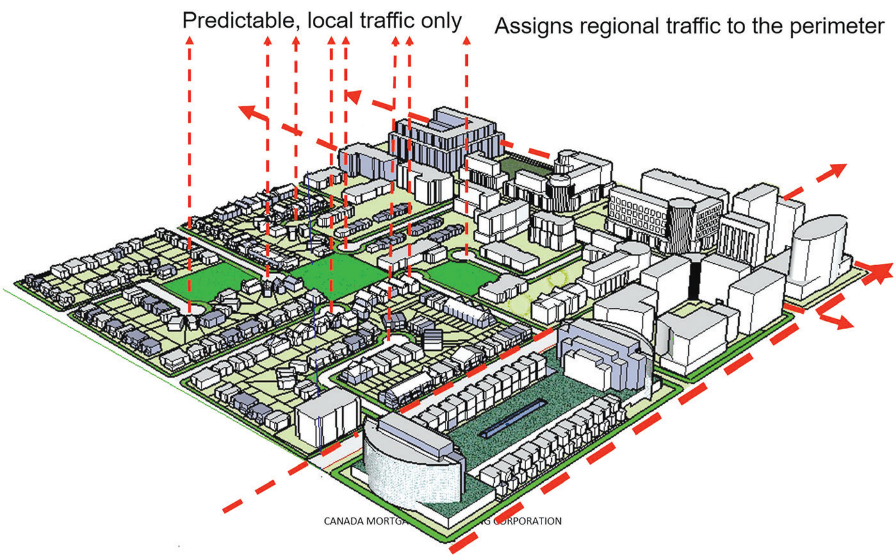

Fig. 26. Modelling fused grid. Courtesy of F.Grammenos

7. Fused Grid in Works

Saddleton, Calgary, Alberta, Canada

By using a fused-grid model, the project reduces the additional road space that can then be used for on-site stormwater storage and treatment.

The fused grid was implemented for the Saddleton, a site with the density between 25 and 30 units/ha, 50% higher than conventional. Heavy traffic was shifted to major perimeter roads and smaller collector streets were introduced. High density buildings are along light rail corridors (Fig. 27). Green spaces are used instead of hard surfaces. When compared to the conventional suburbian design, the fused grid pattern, as applied in Saddleton, cuts road space by about 2.2 hectares, making it available as habitat, recreational space, food production, stormwater treatment areas (Fig. 28).

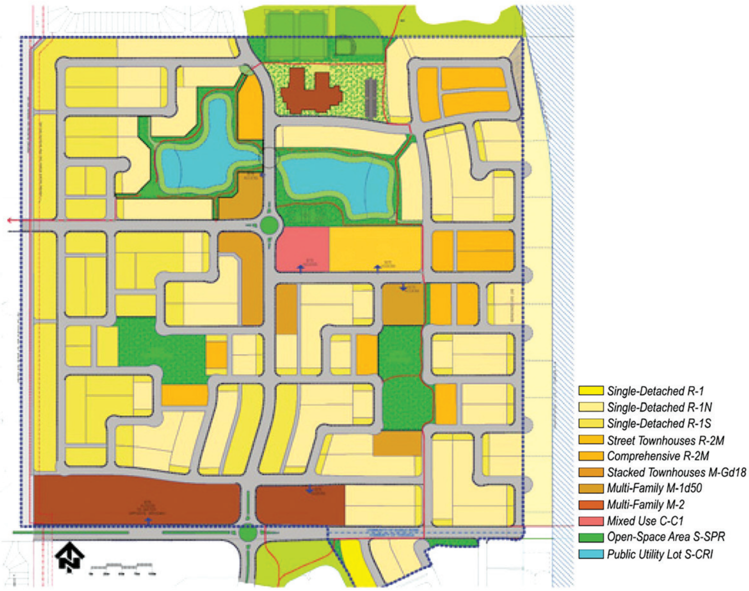

Fig. 27. Saddleton street network and land use pla

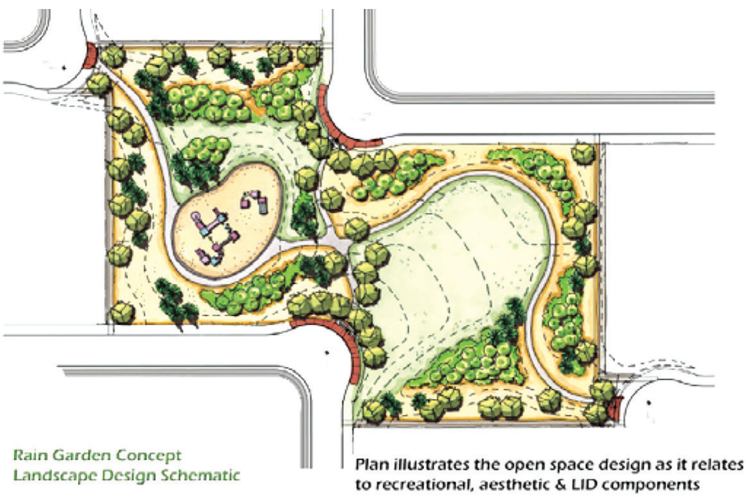

Fig. 28. The rainwater garden space – recreation, pathway node and rainwater filtration. Courtesy of CMHC

8. Conclusions

Infrastructure matters because it represents the major capital outlay for the developer and a key accounting element in pricing, after land. (...) to be competitive infrastructure costs have to be equal to or lower than what conventionally has been achieved in previous developments or by the industry at large [2].

The infrastructure can be significantly improved and reduced by including buildings as direct contributors to it that should:

- Be designed as a part of community design with the efficient road and infrastructure grids,
- Be a net-zero/positive energy producers to minimize the need for new energy plants,
- Include systems that treat and manage water, wastewater or stormwater, reducing/eliminating the need to be connected to municipal water systems,
- Use less energy, cut GHG emissions, air pollution and reduce their dependence on fossil fuels [4].

Once buildings are identified with their potential roles, the next step is to analyse the neighbourhood capacity and needs in terms of energy, greywater, blackwater, heat (including sewer/waste heat). Then the analysis would show what to do with buildings to make them the best contributors. For example, improvements made to building envelope would increase the energy performance. Almost all roofs, part of the envelope, may become candidates for roles such as to mitigate rain water impact, heat losses and gains, air quality improvement, food production as well as installation of solar collection/energy production systems.

Other buildings would also be analysed in regards to the feasibility of upgrading their performance and reducing their needs in the future. Even recent buildings may have a potential there, especially those built to the basic code requirements, or with only a profit in mind.

There are many existing tools, a lot of data, experience and expertise to learn from and the next step to make buildings as contributors to a community infrastructure can be relatively easy and no matter what reasons are behind the actions, when buildings act as such, the benefits can spread to everybody from the owner to the greater community.

Bibliography

[1] Kujawski W., Pollard D. – some case studies, Grammenos F. – Fused Grid. Boddy S. – writer Contracted by CMHC, *Buildings as Infrastructure Contributors*, Article for Ontario Association of Architects – OAA, CMHC, 2009.

[2] Grammenos F., Lovegrove G.R. *Remaking the City Street Grid. A Model for Urban and Suburban Development*, 2015.

[3] Larsson N., Salat S. *Performance Synergies in Small Urban Zones*, 2013.

[4] Pollard D.,*Corelation of Infrastructure and Nature,* Article for American Institute of Architects, 2016.

[5] Tillie N. et al. 2009a. REAP: *Towards CO2 neutral urban planning*, 45th ISOCARP Congress 2009.
[6] Tillie N. et al. 2009b. *REAP Rotterdam Energy Approach and Planning, Towards CO_2 – neutral urban Development*, Rotterdam.
[7] Pratt R.G. et al., *The Smart Grid: An Estimation of the Energy and CO2 Benefits*, U.S. Department of Energy Revision 1, 2010.
[8] BioRegional Development Group, *Beddington Zero Energy Development*, 2002.
[9] Canada Green Building Council, *Green Building in Canada: Overview and Summary of Case Studies*, 2006.
[10] City of Ottawa, *Cash in Lieu of Parking Review*.
[11] Transport Canada. Urban Transportation Showcase Program, *Complete Streets: Making Canada's roads safer for all*, http://publications.gc.ca/collections/collection_2012/tc/T41-1-72-eng.pdf (access: March 2017).
[12] CMHC, Green Roofs: A Resource Manual for Municipal Policy Makers, 2006, https://www03.cmhc-schl.gc.ca/catalog/productDetail.cfm?lang=en&cat=123&itm=73&sere=2&start=1&stfl=green%20roof&fr=1495130589887 (access: March 2017).
[13] Ceres, *From Risk to Opportunity: Insurer Responses to Climate Change*, 2009, http://insurance.lbl.gov/opportunities/risk-to-opportunity-2008.pdf (access: March 2017).
[14] https://en.wikipedia.org/wiki/Eco-industrial_park (access: March 2017).
[15] https://www.youtube.com/watch?v=bYs9DFGQxHg (access: March 2017).
[16] https://en.wikipedia.org/wiki/Kalundborg_Eco-industrial_Park (access: March 2017).
[17] https://www.iisd.org/business/viewcasestudy.aspx?id=77 (access: March 2017).
[18] http://vancouver.ca/home-property-development/southeast-false-creek-neighbourhood-energy-utility.aspx (access: March 2017).
[19] http://korbanltd.com/portfolio/the-currents-wellington-street-ottawa (access: March 2017).
[20] http://www.willistower.com/building-information/sustainability (access: March 2017).
[21] https://traveldigg.com/willis-tower-the-chicagos-skyscraper (access: March 2017).
[22] http://www.timescolonist.com/life/islander/new-beginning-for-dockside-green-project-in-vic-west-1.9377150 (access: March 2017).
[23] http://www.solaripedia.com/13/247/2607/dockside_green_water_feature.html (access: March 2017).
[24] www.googleearth.pl (access: March 2017).
[25] http://urbantoronto.ca/news/2015/05/scale-model-regent-park-gives-insight-future (access: March 2017).
[26] https://www1.toronto.ca/city_of_toronto/city_planning/community_planning/files/pdf/regentpark_planning-rationale.pdf (access: March 2017).
[27] http://www.fvbenergy.com/projects/regent-park-community-energy-system (access: March 2017).
[28] https://en.wikipedia.org/wiki/Centre_for_Interactive_Research_on_Sustainability (access: March 2017).

[29] http://www.ecotek.ca/ECO-TEK_Ecological_Technologies/Home.html (access: March 2017).
[30] https://en.wikipedia.org/wiki/Bahrain_World_Trade_Center (access: March 2017).
[31] https://www.flickr.com/photos/fhsu/4486351029 (access: March 2017).
[32] https://commons.wikimedia.org/w/index.php?curid=46532306 (access: March 2017).
[33] http://www.bioregional.com/beddington-zero-energy-development-case-study-report (access: March 2017).
[34] https://goo.gl/images/yADkxz (access: March 2017).
[35] https://www.cmhc-schl.gc.ca/en/inpr/su/eqsucoin/eqsucoin_003.cfm (access: March 2017).
[36] https://www.cmhc-schl.gc.ca/odpub/pdf/67063.pdf (access: March 2017).
[37] https://www.cmhc-schl.gc.ca/odpub/pdf/66071.pdf (access: March 2017).
[38] https://www.cmhc-schl.gc.ca/odpub/pdf/63760.pdf (access: March 2017).
[39] http://www.cscd.gov.bc.ca/lgd/greencommunities/sustainable_development.html (access: March 2017).