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## Can Buildings Save and Improve Municipal Infrastructure?

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# Can Buildings Save and Improve Municipal Infrastructure?

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**Abstract.** Architects, while creating the built environment, expand their knowledge by learning that buildings are more than places to live, work and play. 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 or indirectly by reducing their demands and creating supply and treatment systems, thus increasing capacity in community energy, water treatment and stormwater systems for others. They can also reduce wastage by recapturing heat lost through inefficient systems, sewers, and by using municipal waste as a fuel source. Buildings can use a lot of energy delivered by conventional energy sources. The reduction potential for their high energy (and water) demand always represents an opportunity to decrease the potential impacts on municipal infrastructure. It is also a significant part of the challenge to reduce or cut emissions, mitigate the effects of climate change and save on resources. The paper explains how buildings can mitigate such impacts while also acting as contributors to the infrastructure. The examples demonstrate various urban and building related design concepts combined with some essential aspects of costs and savings incurring in sustainable buildings and communities. When buildings act as infrastructure they can benefit not just the developer, occupant or owner, they can also spread those benefits to the neighborhood and community and much further- to the entire planet.

## **Motto:**

*Infrastructure is what makes us able to maintain modern and functioning societies [13]*

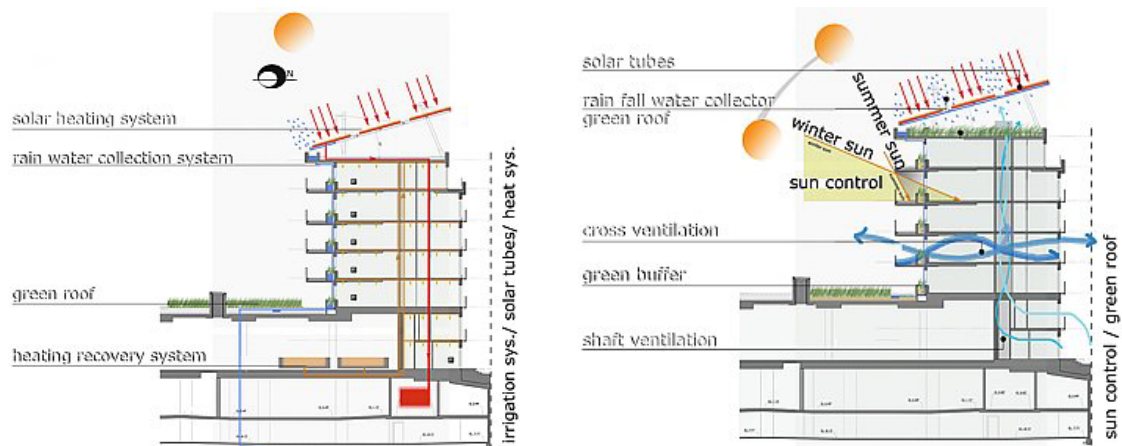
## **1. Introduction**

Buildings are subjected to the life cycle processes that have direct impacts on the built environment including the urban infrastructure. Their energy and water demands are a significant part of the challenge to reduce dependence on fossil fuels, to cut emissions, and save on natural resources. Such reductions can mitigate the impacts on, and the size of, municipal infrastructure. However, the building relationships with infrastructure systems can go in two directions: the typical collection and the other – contribution. This paper is based on the results of building research (some of it managed by the author) that directly relate to the optimization of size and performance of the infrastructure.

Buildings are implicated in the process of design, construction, and operation of infrastructure as their proper functioning depends on interrelations with it. Besides their traditional roles as shelters and providers of services, while fulfilling their needs from surrounding infrastructure, buildings can also contribute to it by producing energy, clean water, food and converting waste to resources (**Figure 1**). Such a new type of coexistence within the urban forms created by buildings represents a significant change in architectural and urban design approach.



Also, in the same way that a human body works as a system where each component relies on all other components, contributing buildings are a vital part of an ecologically engineered and healthy community infrastructure system. Both sustainable approaches: building and urban, create a base for such an urban ecosystem with alternatives for better buildings, better land use, and optimized infrastructure.



**Figure 1.** A simplified picture of engineered urban ecosystems (Source: City of Vancouver).

## 2. Aspects of buildings and infrastructure

Infrastructure has been defined as *"the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions"* [8] and that also means that engineers working with infrastructure should be more cautious about society and practices than solely about the technical aspect of it.

This paper describes the benefits of buildings as strategic contributors to such systems and presents some case studies where performance improvements led to the optimization of the infrastructure.

The buildings are shown in the new paradigm, where most of them will not only behave as "passive collectors" but also as "contributors" by co-creating new synergies with their adjacent built environment.

The features for Green<sup>1</sup> buildings that are directly related to the infrastructure became a substitute for a more scientific methodology (**Table 1**). Only the most important issues were considered as per the following example: a building can incorporate water conservation techniques such as on-site water and wastewater treatment (**Figure 2**), rainwater collection, xeriscaping and green roofs reducing the impact to municipal water, wastewater and stormwater systems. If it treats local wastewater, it would be considered as a regenerative building. However, only impacts on infrastructure are taken into consideration, not other levels of "green".



**Figure 2.** Station Pointe Green, Edmonton, Canada. Planned mixed-use development with water treatment facility [9].

<sup>1</sup> The term "green" is used to denote the entire category of energy and environmentally friendly buildings that would include "sustainable," "living" and "regenerative" ones. The differences are not the subject of this paper.

**Table 1.** Characteristics of Green Buildings

Issue within	Systems/features applied	Impacted Infrastructure
General location	Not on fragile landscapes Does not contribute to urban sprawl Close to mass transit systems	All systems
Site	Focuses on surface water management and retention (holding ponds, porous paving) Xeriscaping Minimal or zero impact on local ecology Increased green space	Water Energy (cooling) Stormwater
Exterior	Renewable energy systems (geothermal, wind, solar) Window canopies or light shelves Green roofs Active transportation infrastructure (bicycle parking) Efficient exterior lighting, mitigation /elimination of light pollution	Energy Water Stormwater
Interior	Minimal use of materials (e.g., exposed structures, where possible and appropriate) Flexible layouts (movable walls, raised floors for services) Occupant controls of heat and light (not 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 recycling and composting bins)	Energy Water Waste Wastewater
Hidden features or attributes	High-performance building envelopes Materials selected to meet building goals High-efficiency mechanical systems integrated with other systems/elements Energy-efficient lighting systems Continued monitoring and optimization of system performance over time.	Energy Water Waste Wastewater

In the developed and developing worlds the reductions of both: the size and expansion of infrastructure can help existing and future problems; the author's research was related only to the most visible aspects of building's contributions that support such help and infrastructure improvements.

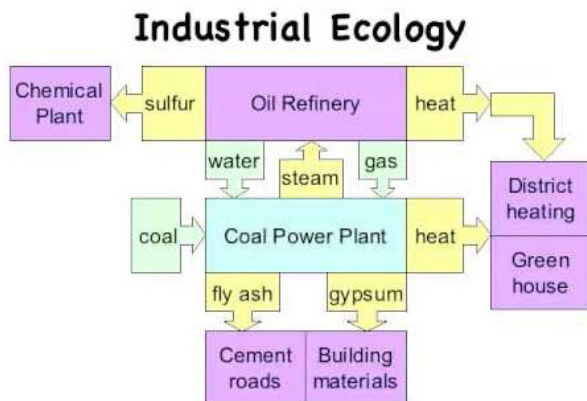
The challenge is to build new, well-thought-out infrastructure with connections to buildings that can share the energy produced on site and water received from the operations and rainfalls through the optimization of building design and the adequate climatic urban design [7].

The significant reduction of energy demand in buildings will mitigate the size of the required infrastructure, and that can also be achieved by recovering the heat losses by inefficient systems, capturing heat from sewage and by using gas emissions and municipal waste as a source of fuel. The entire urban areas can be supported by increasing the capacity of the energy and water systems through the direct contribution to the infrastructure, or by the reduction of demand so that the community could be self-supporting and resilient during the catastrophic events.

### 3. Buildings at work – examples supporting help and improvements to infrastructure

#### 3.1. Eco-industrial networks

So-called eco-industrial networks (EIN) and eco-industrial parks [11] are structured around both energy and waste sharing between producers and consumers (**Figure 3**) and while networks usually supply entire communities, the parks, generally, share within themselves, and then almost nothing is wasted, and everything is used.



**Figure 3.** Idea of EIN [10]



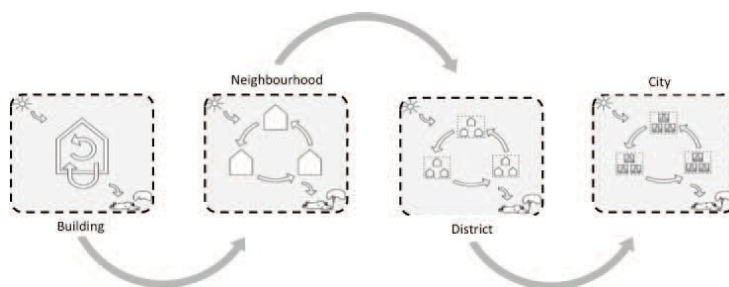
**Figure 4.** View of Kalundborg [11]

An example of such EIN is Kalundborg (**Figure 4**) in Denmark. It is an old case, but very useful here because the whole concept is well described, its performance notwithstanding. It started a long time ago with a single power station project and over time expanded 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 its economics and environment. They do it on the basis that by-products from one business can be used as low-cost inputs by the others.

Treated wastewater from one place is used as cooling water by the adjacent power station which sells “waste” process steam to others. Surplus heat from the power station is used for heating adjacent homes, and warm a local fish farm. Another 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, is delivered to others as well as the excess heat is used to heat the households eliminating about 3,500 oil-burning domestic heating systems [4].

### 3.2. Synergy Zones

Larsson et al [2] synthesized two essential ideas: **Smart Grids**- optimization of supply and demand of electrical power at a regional level, and a **Synergy Zone** dealing with the interaction of 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, a methodology for optimization of supply and demand, and distribution networks.



**Figure 5.** Knotting the flows at every scale. Source: Tillie et al.

Tillie et al. [4] developed an inventory of buildings with different thermal needs patterns/schedules. An appropriate mix of buildings (a heat/ cold ratio close to one) and heat/cold storage facilities at the neighborhood scale, can reuse the waste streams, reducing almost 50% the thermal energy consumption while the reused heat 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

(**Figure 5**). Since heat is a natural by-product of many industrial processes, the preferred location of buildings would be close to industrial or manufacturing plants (**Figure 6**).

Buildings that produce energy for their own needs and others can be the most cost-effective. Combined Heat and Power (CHP) systems achieve peak efficiency when they run continuously on full-time loads in their neighborhood underlining the need for mixed-use schedules. With its water treatment facility, and greenhouses such systems can also remain functional even in times of emergency or disasters.



**Figure 6.** North Vancouver – Identification of industrial buildings with excess energy or waste and potentially “served” adjacent areas. (Source: CMHC).

Local production can also reduce the peak energy demand, thus creating a strong push from utilities for energy efficiency, especially when the cost of a new infrastructure comes to light. Many of the building developments, while acting as an infrastructure, can either reduce their impact on community infrastructure (number and size) or eliminate the need for its elements such as electricity grids and municipal waste and stormwater systems. Depending on the infrastructure components such buildings should have certain features that will benefit all sides as per **Table 2**.

### 3.3. 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** a mixed-use development on a brownfield site (**Figure 7**)- another example of relatively old, but well-documented ideas of buildings contributing to the municipal infrastructure capacity by producing on-site renewable energy, reducing stormwater runoff, providing energy by methane from household waste. All garbage, organic waste, and recyclables are connected to the underground vacuum system. Water is heated by seawater and solar, and the heat is distributed through municipal sewage and waste infrastructure. Green roofs are 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 [1].

**Southeast False Creek, Vancouver, B.C., Canada.** This project contributes to the infrastructure by using a district heating system with sewer heat recovery (Figure 8), PVs, rooftop solar thermal modules and urban agriculture within the community that was used as an Olympic Village during 2010 Games.

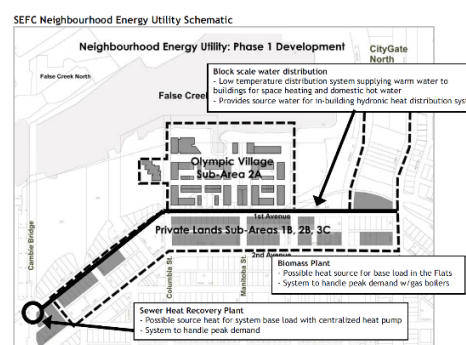
### 3.4. Energy Providers

The most visible roles buildings can assume as infrastructure contributors are as energy producers with the help of renewable sources. They can reduce greenhouse gas (GHG) emissions, direct energy costs, and provide backup power during both power outages and peak energy demand alleviating the need to build new power plants- elements of infrastructure.



**Table 2.** Types of infrastructure features that building can support within its urban context [11].

Infrastructure Component	Building Element(s)	Potential benefits to developer, occupants, municipality, community
Energy (heating, cooling, electricity, ventilation, humidification)	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) Natural, no- or low-VOC finishes (related to indoor air quality, ventilation needs)	Reduced energy demands on municipal utilities Reduced equipment size 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 The growth of renewable energy and sustainable building technologies Revenue opportunities with surplus energy or carbon credits
Roads & Transportation	Optimal urban design (e.g., fused grid) Transit-oriented development Limited parking spaces Active transportation infrastructure, (bike paths, racks, and storage, sidewalks)	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	Reduced impacts, size, and cost to municipal water, wastewater and stormwater systems Reduced stormwater runoff Reduced water costs for occupants Reduced cooling requirements and the urban heat island effect
Waste (garbage, recycling, composting)	On-site composting and recycling facilities Reusable/recycled/recyclable building materials On-site waste reduction during construction and demolition	Extended lives of municipal landfills Reduced GHG emissions from landfills (methane = 20x the global warming of CO <sub>2</sub> ) Reduced landfill tipping costs by limiting construction waste and creating revenue from selling useable construction materials
Green space	Site location Community gardening spaces (including green walls and roofs)	Avoidance of disturbing sensitive nature Native or drought-resistant flora Reduced op & remediation costs Provision of social, recreation and fitness opportunities for residents

**Figure 7.** Aerial view of BO01. Courtesy of the City of Malmö.**Figure 8.** SEFC Site Plan and Neighborhood Utility (Source: City of Vancouver).

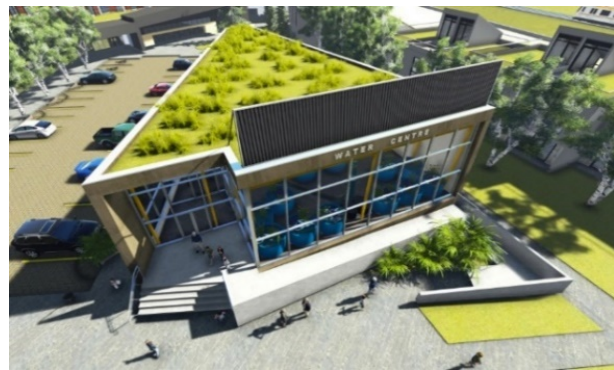
### 3.5. Greywater reuse systems

Used in new and existing buildings, capture water from laundry, showers, and sinks, then treat and reuse it for toilet flushing or irrigation, conserve municipal potable water and can also reduce the wastewater infrastructure; however, the systems' costs can often outweigh the savings.

**Equilibrium™ Communities project – Station Pointe Greens (SPG), Edmonton, Alberta, Canada.** The planned residential and commercial development (**Figure 9**) based on Passive House requirements for total energy use was expected to result in a transit-supportive 250 units per hectare. SPG would have a biological wastewater treatment facility (**Figure 10**) to treat 100% of the wastewater to be re-used for toilets flushing and irrigation and would reduce the stormwater run-off through green roofs over 50% of the site and bio-retention cells.



**Figure 9.** Aerial view. Source: Hartwig Architects



**Figure 10.** Wastewater treatment facility. Source: Hartwig Architects

## 4. Conclusions

The buildings are active collectors or “takers”, but can also contribute to the municipal infrastructure and improve it by being designed as buildings that:

- reduce their energy demand [1] [6] through improvements to the envelope, form, and shape [14]
- act as producers of energy to further minimize the need for the expansion or new energy plants and the related infrastructure in all forms and as producers of clean water and food
- free up capacity within their energy systems, including renewable sources
- include systems that treat and manage potable, waste-, and stormwater, reducing or eliminating needs to be connected to municipal systems while also protecting watersheds, if possible
- mitigate rainwater impacts as well as heat losses and gains by improved roof design
- can support food production as well as the installation of solar energy production systems [5]
- consider both urban morphology and urban geometry aspects in its design [7]
- have a high level of control (smart) over its functions within a comfort zone of its occupants
- are designed as a part of a community with the efficient road and other infrastructure grids

The infrastructure is an essential part of our built environment. One of the crucial aspects is the resilience of its systems to recover from the impacts of natural disasters and food shortages [8].

The trouble is that even if we know how to improve it now, we may be designing it for the last century rather than the next [15]. Through the design of today's buildings as per conclusions above, we should perhaps look at creating smart, sustainable and resilient infrastructure – smaller, less expensive and more decentralized – while looking differently at both: the infrastructure, and by extension, the architecture.



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