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9.1 INTRODUCTION

Global warming has given a new dimension to urban design efforts that seek to integrate the infrastructure systems of a city into a sustainable and more natural built environment. For several decades, architects, planners, and designers have been calling for a more compact urban form that integrates nature with the city, as well as greater use of energy efficient building and transportation alternatives. However, the need to mitigate and adapt to climate change has created a new and more urgent driver for change. The result has been a transformation in approaches taken by leading edge designers and the elites responsible for urban infrastructure systems. Nowhere has this been more evident than in the water and energy sectors (Daigger, 2009; Dreiseitl et al, 2009; Hermanowicz, 2008 Lindsay, 2010; Poetz and Bleuze, 2008; Woltjer and Al, 2007). Mitigating carbon emissions has been taken up by local governments around the world, while water is the most visible vector for the effects of global warming. Many describe these responses under the rubric of the "eco-city."

Figure 9-1 EVA Lanxmeer eco-city with gray water filtered in wetlands, solar panels and energy efficient buildings. Photo Courtesy of Herbert Dreiseitl and Atlier Dreiseitl.

The eco-city rejects the idea of waste, instead seeking to transform it into beneficial uses within the city. In so doing, it seeks to reduce inputs of water and energy from afar. This concept is behind efforts to decentralize the production of energy and food and to create more local "green" employment. It also powers the three "R's" of solid waste management as well as transportation efforts such as transit oriented development, walkable neighbourhoods, and "complete streets." Architects, planners and landscape architects have used many of these innovations at the building site level over the past twenty years. The next breakthrough is to integrate these systems at the neighbourhood, block or development cluster to begin to approach zero emissions.

This paper begins by describing energy and water innovations at the site and building level before examining the experiences of six cities that have tried to integrate water, energy and solid waste utilities in new neighbourhoods. In so doing, these pioneers have begun to move towards the development of micro-utilities that use the landscape as the fifth infrastructure for true sustainability.

9.2 BUILDING LEVEL SOLUTIONS

Energy: Conservation & On-Site Production

Conservation. Over the past 40 years, since the first Earth Day in 1970 and the subsequent oil embargo in 1973, important work has focused on energy conservation in buildings. The R&D conducted on "super insulation", air infiltration, passive solar energy, shading, natural ventilation, daylighting, and energy efficient lighting and appliances forms a solid foundation on which we now confront the challenges of climate change. Study after study has shown when these strategies are designed and deployed wisely, they can save from 40-60% of energy consumption in typically constructed buildings (McKenzie & Company, 2009).

Smart and Decentralized Energy Production. Recent developments in technology have achieved even greater efficiencies in the area of lighting with LED's and in "smart buildings" with wireless lighting controls, occupancy sensors and real time HVAC management systems. Materials research and manufacturing breakthroughs in photovoltaic (PV) production are on the verge of making the wide spread application of PV's on buildings cost effective. Even now, PV's are cost effective in some markets, such as California. With this trajectory in technical development, the idea of designing "zero carbon" buildings is a tantalizing goal for the not so distant future.

Water

During the past twenty years, designers and planners have been devising solutions to decrease the demand for water at the building and site level and to prevent flooding. The following innovations can reduce water demand in residential buildings in the developed world by 50 to 85%.

Gray Waste Water[1]. Reuse of gray water at the building and site level has also emerged over the past 20 years as an important tool in reducing potable water demand. The Pacific Institute estimates that half the water used in homes in the United States can be reused for irrigation and toilet flushing. On-site gray water systems for toilet flushing are common outside the United States (Allen, et al., 2010).

Black and Brown Waste Water[2]. This is an area where small scale technologies are advancing rapidly. This concept processes the wastewater on-site and reuses the water for toilet flushing and irrigation. One approach to treatment uses natural processes such as the Eco-Machine, the Living Machine or specially engineered “boutique” systems. These systems flush the effluent through a series of tanks where living plants clean the waste and also take up the metals (Lens et al, 2005; Steinfeld & DelPorto, 2007). A second approach uses Membrane BioReactors (MBRs) to filter toilet waste through very small holes in a membrane. MBRs can filter out viruses, pharmaceuticals and even metals. However, as the size of the particle to be filtered out diminishes, the amount of energy needed to process the wastewater increases. The miniaturization of MBR’s, rapidly declining costs and increasing energy efficiency have resulted in robust small scale package wastewater treatment plants that can operate with a minimum of maintenance (Asano et al, 2008; Judd, 2006).

Stormwater. Rainwater harvesting is an important water source at the building level, and in many cases could provide anywhere from half to over 200% of the water needs of a building, or a city. In addition, as global warming results in heavier floods and more severe droughts, the natural cycle of water percolating into the soil or evaporating into the atmosphere in urban areas is disrupted by roofs, impervious pavements, and by channelling storm water into underground sewers. (See Figure 9-2) Buildings and their sites are increasingly being designed to slow down the rush of storm water. Such efforts include making driveways and parking lots more pervious, the use of swales instead of storm sewers, rain gardens and tree planting. Green roofs and walls are tools which also reduce the urban heat island effect and energy use (Novotny et al., 2010).

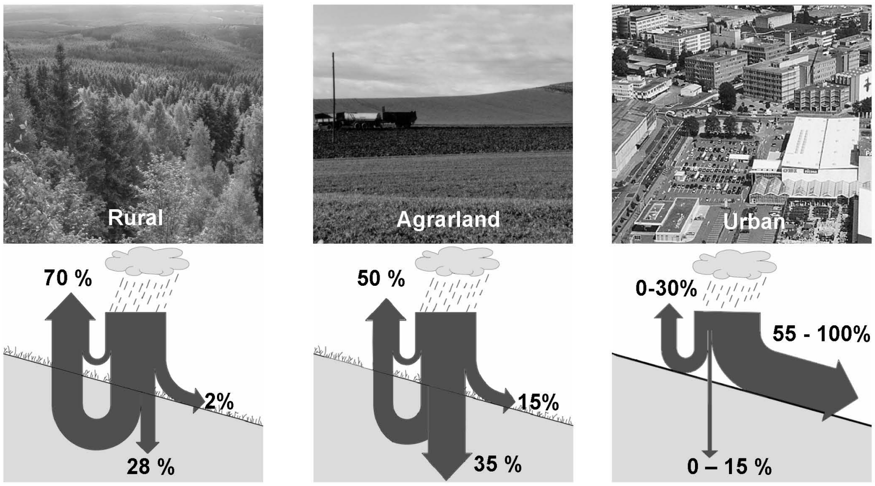

Figure 9-2 Comparison of storm water runoff in rural, agraland, and urban areas. Courtesy of Herbert Dreiseitl, Atlier Dreiseitl.

Integrated Systems for Water, Waste & Energy

Pilots for Integrated On-Site Concept. The most sustainable water, wastewater, and solid waste concepts have been developed in Europe and in the developing world. Pilot projects based on this concept attempt to mimic a natural closed loop cycle. Black, yellow and gray waters are separated at the building level, treated and reused with nutrient and energy recovery. Many pilots began as an effort to recover nutrients from black and yellow water, but as their sights turned to the production of energy through biogas and methane production, it became quickly evident that human biosolids combined with food waste was a more effective alternative (Elmer, 2009).

The GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit—now part of GIZ) headquarters building in Germany separates gray water, which is processed in wetlands. It also has source separation toilets which permit faeces to be mixed with food scraps for biogas production while urine is used as a fertilizer. Other buildings in Europe such as the BedZed development in London's Dockside area have partially integrated systems.

9.3 NEED FOR NEIGHBOURHOOD SCALE SOLUTIONS

The individual flows of energy, water and waste at the building and site level are small. They are constrained by the particulars of their site and climate, and limited by their program of operation which determines the size and timing of their energy and water use. In addition, when considered as a stand alone design problem, important external energy and water flows on which buildings depend are not included. Important elements for the liveability of a building such as adjacent water ways cannot be dealt with at the site level. Finally, solid waste, usually dealt with at a city or regional level, turns out to be an essential element in processing wastewater into energy and nutrients. From this perspective, while buildings are an important component in achieving a "zero emissions" eco-city, there are larger system concerns which suggest that opportunities for creating sustainability need to be examined at a larger scale.

Neighbourhoods and intermediate to large scale mixed-use development projects offer intriguing advantages and opportunities. First, neighbourhoods have a mix of uses which makes it easier to balance loads and match the intermittent supply of renewables. Second, neighbourhoods have larger flows of energy, water and waste with which to work. Third, their design can influence transportation choices and reduce automobile use. Fourth, when designing at the neighbourhood scale, the urban landscape can be brought into play to temper the climate, absorb carbon, clean stormwater and sewer effluent, provide biomass for energy and even grow food. (See Figure 9-4)

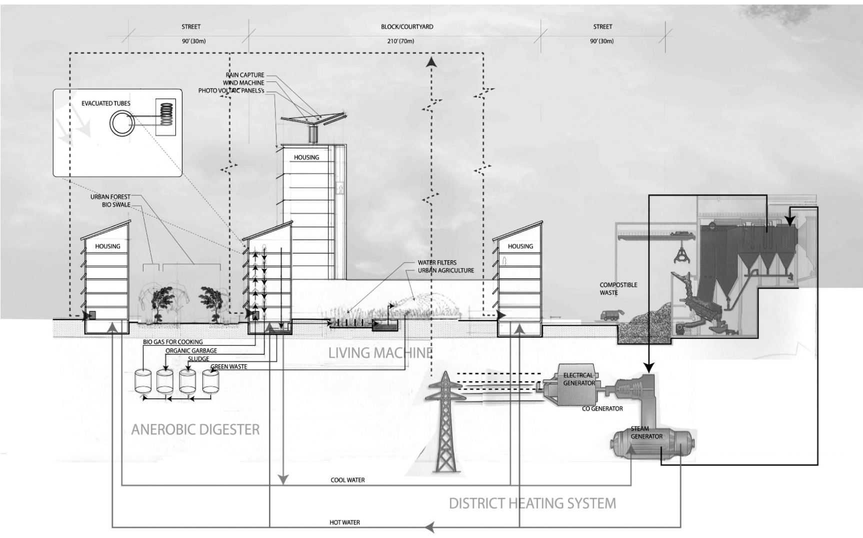

Figure 9-4 Schematic of Sustainable Infrastructure Systems for an Eco-Neighbourhood or Eco-Block. Source: Harrison Fraker and team. 2010, University of California

Neighbourhood scale development (from 400 to 10,000 units of housing) is also a relatively typical form of development, both for private real estate developers, but also for cities doing urban renewal on underused or "brown field" industrial sites all over the world. If neighbourhoods can become their own micro-utility, supplying most if not all of their energy while treating and recycling their water and waste, a whole new form of sustainable development is possible. In addition, if all of the energy can be generated locally and much of the waste processed on site, the cost and loss of efficiency in distribution infrastructure and transport can be avoided.

9.4 SIX ECO-NEIGHBOURHOODS

We identified six eco-neighbourhoods built in European cities which exemplify the whole systems approach to urban design: **Bo01/Western Harbor** in Malmo and **Hammarby** in Stockholm, Sweden; **Kronsberg** in Hannover and **Vauban** in Freiberg, Germany; **Lanxmeer** in Culembourg, NL; and **solarCity Pinchling** in Linz, Austria. There are other developments which look at water/energy/waste holistically which have been designed but not built

(Qingdao, China; Denver's Living City Block; Portland's proposed Eco-Districts and others noted in the Novotny and Novotny article in this volume).

These neighbourhoods fulfil basic criteria for sustainable design: 1) each is transit-oriented with an emphasis on walking and biking and convenient access to public transit (within 5 minutes). 50- 80% of all daily trips are by pedestrian, bike or public transit, 2) all have aggressive conservation goals of approximately 100kWh/m2-year for total energy use and employ local renewable energy strategies, 3) all have attempted closed loop systems for water/wastewater and have integrated natural water features into the design of the community; 4) all are mixed use with a jobs to housing balance of at least 50%, 5) all have a net density of approximately 30-40 units per acre and range in size from 400 to 8000 housing units; and 6) most have been developed with a high degree of citizen participation; 7) many of these feature local gardens for on-site food; and 8) solid waste is integrated in some for energy production.

Figure 9-5 is an aerial photo showing the urban plan of **solarCity Pinchling** in Linz Austria. Source: Linz AG website.

9.4.1 Energy in the Eco-Neighbourhoods

These neighbourhoods all use passive solar energy for the building location, design, insulation, siting and construction. They also develop sustainable energy resources on and off site before using conventional energy sources. Together, they demonstrate four possible strategies for generating energy from local renewable sources: wind, solar, geothermal and waste, each with a different emphasis and combination. **Bo01/Western Harbor** uses local wind generation to power a geothermal ground and ocean water heat pump for heating and cooling. **Hammarby** has 3 different waste-to-energy systems: the first burns combustible garbage to power a local district heating and electric cogeneration plant (off-site), the second recovers heat from the sewage treatment system and the third converts sludge to biogas for cooking (1000 units) and to power local buses. Similarly **Lanxmeer** has designed an on-site biogas system that uses its blackwater, garden and kitchen waste, which is owned by the community. (See

Figure 9-6) **Kronsberg** has two large scale wind machines (totalling 3.2 megawatts) which generate 50% of its electricity combined with a gas fired heating and electric cogeneration plant, which provides the other 50% electricity. **Vauban** has a local heating and electric cogeneration plant powered by waste wood chips from the area.

While all these neighbourhoods demonstrate good energy conservation standards, Kronsberg, Vauban and solarCity have many sections that meet the very aggressive "passive house" standard of 15 Kwh/m2-y for heating.. Vauban also has several solar developments (called "plus energy houses") which combine a passive solar direct gain system for heating and a roof-top photo voltaic array for electricity, that delivers +15% energy back to the city. Together, the neighbourhoods have employed all types of solar collection. Bo01 uses evacuated tube collectors to assist the district heating system. Hammarby uses flat plate panels and evacuated tubes to preheat domestic hot water. As a test case, Kronsberg combines a large solar hot water array with a large seasonal storage tank in order capture summer solar energy to augment winter solar heating. All the neighbourhoods have applied photo voltaic arrays.

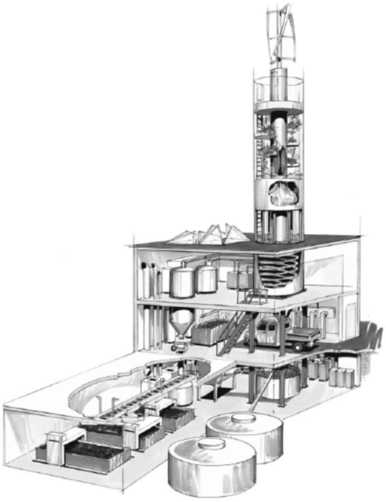

Figure 9-6 EVA Lanxmeer Biogas Schematic. Source: www.lanxmeer.nl

9.4.2 Water and Waste in the Eco-Neighbourhood

All the eco-neighbourhoods collect storm water from the streets to filter and clean it using different forms of bio-swales, before returning the storm water to streams, lakes and/or the aquifer. One innovative approach is the use of "green" transit tracks. There are some green roofs in Hammarby, Bo01, Lanxmeer, and Kronsberg which help to buffer rainwater and act as a form of insulation both winter and summer. Mandatory tree planting is required in some for storm water. The goal for most of the communities is to manage the water so that the areas' natural water balance is the same after development as it was before.

All of the developments maximize the amenity value of water. They use water features to form or preserve the landscape, and as recreational and ecological preservation areas. The best incorporate features that are aesthetically and spiritually pleasing. Some of the developments have used engineered features while others have restored or incorporated ponds, creeks and waterways otherwise into the urban design. (See Figure 9-7)

Figure 9-7. Walkway and storm water in Bo1, Malmo, Sweden. Photo by Brandon Schauer http://brandonschauer.com

Many of the developments have used the landscape to process gray water sewage and other ecological sewage systems. A building in Vauban transports faeces through vacuum pipes to an on-site facility which combines this with foodscraps to generate biogas for cooking. Lanxmeer does not send any of its sewage to the city's wastewater treatment plant. Instead, buildings in this development have separate pipes for gray and black (toilet) wastewater, with the black going to the biogas plant noted above, and the gray water purified in reedbeds and ponds (Poetz,and Bleuze, 2008). solarCity Pinchling–Linz has piloted an urban urine diversion toilet system in a primary school and for 88 dwelling units. The urine is currently disposed into the central system due to the lack of permits for its use in surrounding agriculture (Ulrich, 2009). This development also uses wetlands to process graywater.

Stream and Creek Restoration. Another component of the eco-city is stream and creek restoration. This is important to assist building level storm water solutions and to promote infiltration, increase wildlife diversity and the amenity value of the natural water way. The eco-neighborhoods above have restored water bodies and streams. In addition, Zurich, Copenhagen, the eco-city in Tianjin (see Figure 9-3) are in the process of restoring their canals to natural streams. In South Korea, a large freeway constructed in the bed of a former river was dismantled and the river restored--to the delight of residents when the dragonflies returned to the area.

Figure 9-3 Creek Restoration in Tianjin, China. Photo courtesy of Herbert Dreiseitl and Atlier Dreiseitl.

Solid Waste and Recycling. All the eco-cities or clusters have well developed systems for solid waste collection and recycling. Bo01 and Hammarby use an evacuated (vacuum) tube system. In Bo01 above ground receptacles for recyclabes lead to underground pipes which transport the material outside the area. Trucks then pick up the material and take it for energy production. In addition, food scraps for 200 households are processed with a garbage disposal (food grinder) to produce methane that is used to power school buses. In both the Swedish developments dried organic waste is burned in a co-generation plant, while green waste is composted. The other case studies all have aggressive recycling goals of zero waste and compost green waste.

9.5 IMPLICATIONS FOR URBAN DESIGN AND WATER

These neighbourhoods show that zero emissions operation is achievable on a decentralized basis. They also show that it is not just a matter of finding and applying the “right” technical systems and following the “right” development process, as important as these may be. It involves thinking of technical strategies and urban design as one, creating a high quality built environment, one which fosters a vibrant experience. The challenge for designers is to learn how sustainability strategies can enhance the quality of the built environment and deepen the experience of peoples’ everyday lives. How do concepts of urban design – the design of the streets, blocks, parks and urban landscape interact with strategies for sustainability? Are there conflicts? What, if any, trade-offs have been made?

Figure 9-8 Schematics of urban design patterns for Kronsberg, and Vauban, Germany. Source: Harrison Fraker and team. University of California. Shaded area is ¼ mile diameter.

On one level, the urban design, the principles of urban form for these neighbourhoods are similar. (See Figure 9-8) They assume a traditional plan of streets and blocks. Each plan is then modified to take advantage of the particular conditions of the site and landscape, including such features as lakes, shorelines, hills, orientation for sun and wind, and views. Different open space strategies for parks, recreation areas, courtyards, plazas and urban landscape functions further enrich the form of each neighbourhood. While quite traditional as an urban design framework, the subtle responses in design of the blocks, the architecture, the streets and especially the design of the urban landscape are where the neighbourhoods come alive, suggesting further design strategies for sustainability.

An additional feature of the integrated design approach is that the developer can become a micro--utility and could charge residents for the service, recovering the added cost of the systems. The micro-utility can then be turned over to the residents or the local jurisdictions for operation. An analysis of the cost of the integrated system was performed for the proposed eco-block in Chengdu by one of the authors. Sustainability initiatives were estimated to increase cost of development by 5%-10%. The 10 year internal rates of return (IRR) range from 2% to 10% depending upon the scenario. Payback periods range from 10 years to 7 years. The information control systems needed to coordinate the energy, water and waste flows are cost effective and not prohibitively expensive (Fraker et al, 2008).

These efforts also point to a new approach to the design of public open space, including the street right-of-way and local parks. In many jurisdictions, 30-40% of urban land is public open space. In the private sector, even in high density neighbourhoods (100+ units per acre, net) most site designs provide more than enough area in the semi-private courtyard space for wastewater treatment. If the area inside private property lines, not covered by a building foot print, is included, more than 50% of urban land is available to support ecological functions. This presents a tremendous design opportunity for recycling water, urban agriculture and creating urban forests in both the public and private realms.

The next generation of water, wastewater and solid waste thinking integrates the urban landscape into the whole-system operation. The landscape can clean and retain storm water and clean sewage effluent as well using a “living machine” or wetlands concept after the sludge has been removed and sent to the anaerobic digester. Or it can accommodate a small scale MBR. The area necessary to treat the effluent is easily accomplished within each block design. This enables the treated water to be collected and recycled at the block scale, eliminating the need for sewer lines and reducing the length of water supply lines. An extensive tree planting design strategy yields wood chips, which, along with other landscape clippings, adds fuel to the combustible solid waste-to-energy system. The urban landscape can also provide local food for residents along with tempering the climate, while enhancing the experience of the public realm.

The next generation of water-energy-waste infrastructure can also be used to mitigate the heat from climate change and the additional flow of water during wet periods. Figure 9-9 shows an integrated landscape that has the ability to create a micro climate of its own. In an orchard with processed gray water, the temperature is 80 degrees compared to over 100 at the entrance by the asphalt roadway. See also Figure 9-10 (next page) of Potzdammer Platz in Berlin, where local climate effects were consciously sought by the landscape architect.

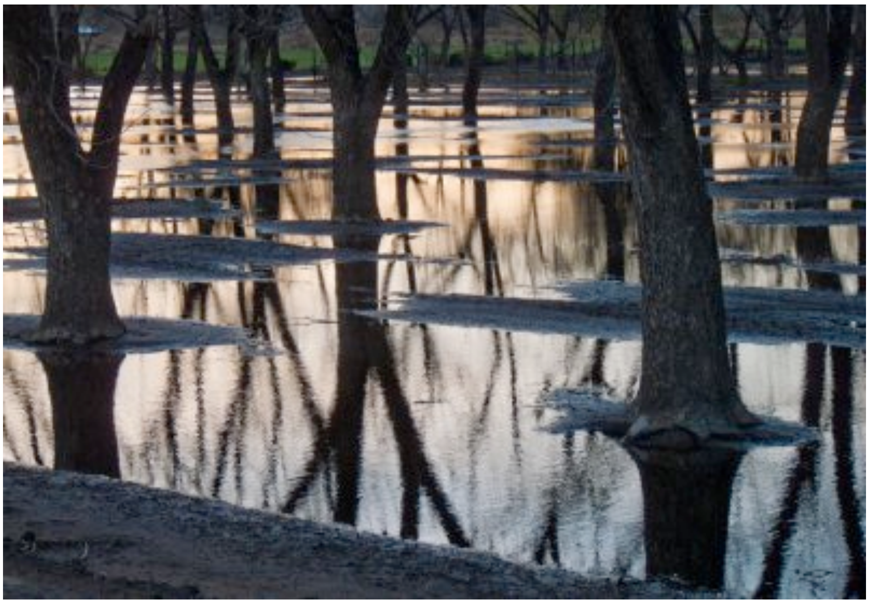

Figure 9-9 Photo by Tom Conelly, www.pbase.com. 2009.

9.6 CONCLUSION

The neighbourhoods described above indicate that a greater integration of waste systems and the urban landscape are the last pieces in the puzzle, the final secret to achieving “zero emissions” operation. The neighbourhood is the scale that brings them into play and the landscape is both the technical underpinning and the aesthetic place making element, becoming the fifth infrastructure. The challenge will be to engage the centralized utilities and the technical wizards with the urban design professionals to make “sustainability” a compelling whole. This will require new institutions and new ways of interacting. The goal must be to turn the city and its water into what Professor Elizabeth Meyer, Professor of Landscape Architecture at the University of Virginia has called “sustaining beauty.”

We also recall that:

"Water is the heart of all life. In the past, we built water and wastewater systems infrastructure to protect ourselves from diseases, floods, and droughts. Now we see that fundamental life systems are in danger of collapsing from the disruptions and stresses caused by this infrastructure. New and evolving water technologies and institutions that mimic and work with nature will restore our human and natural ecology across lots, neighborhoods, cities and watersheds." (Nelson, et al, 2007)

Figure 9-10 Potzdammer Platz, Berlin, Germany. Courtesy of Herbert Dreiseitl, Atlier Dreiseitl.

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[1] Because regulations differ from place to place, so do gray water definitions. Generally gray water, or light gray as some call it, refers to water from wash basins, laundry, and showers; dark gray includes kitchen wastewater, although some include kitchen waste water in the general designation of “gray.”

[2] There is no uniform convention for designating brown and black water. Brown and black water can be the effluent from a source separation toilet containing only the feces. Black water also refers to water from toilets with both urine and feces.