Green Municipalities

A Guide to Green Infrastructure for Canadian Municipalities

MAY 2001

FCM | Centre for Sustainable Community Development

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Federation
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Municipalities

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1. A City Transformed

A world-wide effort to improve urban sustainability over the past decade has produced systems and buildings that are increasingly diverse and complex, with greater functional integration at all scales, from the building and site, to the neighbourhood and to the city.

The pattern is becoming clear. Infrastructure systems are evolving into 'ecological' forms that are more effective at looping scarce resources, and at cascading energy flows through multiple end uses. Greater emphasis is placed upon achieving thermodynamic efficiency for the systems as a whole, and upon creating systems that are inherently more adaptable and resilient. The net result is an integrated infrastructure system with a reduced ecological footprint over its life cycle, and with significant benefits for the community economy and quality of life. This is referred to as 'Green' infrastructure.

Like the term 'green building', the concept of Green infrastructure has evolved over time. Initially the focus was on using elements of the natural environment to replace or supplement the 'built' forms with which we are more familiar. Moderating the scale of the infrastructure was seen to be equally important. More recently we have been looking to incorporate appropriate technologies and green materials that match the quality of the resources and system design to the user needs. From this perspective, natural and low-tech products and systems are applied before complex or resource-intensive solutions. On-site and renewable resources are used wherever possible, and then supplemented by larger scale infrastructure as necessary. Green infrastructure is actually 'hybrid infrastructure' that is more resource efficient, adaptable and sustainable.

As a consequence of Green infrastructure, the process of system design and assessment is becoming more challenging and interdisciplinary. This Guide is one attempt to meet this challenge. It is intended to help each of us better understand and apply the concepts underlying the new Green infrastructure, and develop a new mental model for what our cities will look like in years to come.

HISTORICAL PERSPECTIVES AND IMPORTANT TRENDS

Infrastructure is a term for describing mechanisms that transform raw resources into the essential services required for our households and businesses. No city can operate without infrastructure, and thus system designs date back to cities of antiquity. In some cases, the systems haven't seen much change since that time. In fact, cities in Europe are still using elements of water supply systems that are over 2000 years old. Many ancient systems were well-designed, providing beautiful civic structures and clever integration of resource flows. The pools of the Siloam, described in the Bible, were actually Jerusalem's cesspools, where farmers would gather to collect the highly valued sludge for use on their market gardens. Many Roman settlements in northern Europe were piped with district heating systems that used warm gases from the large kitchens to heat floors throughout clusters of buildings.

The large, centralized water, waste, sewage and energy grids, that are so familiar in cities today, were first engineered in the 19th century, with water and sewer infrastructure beginning in the 1840s, and electricity grids in the 1870s. At that time, water and sewer systems, along with electricity, were massive and noble undertakings. Social activists and humanitarians focused on these types of housing services as the best way to improve family health, comfort and standards of living. In fact, the social movements of the early 20th century - including women's liberation - were largely focused on transforming the built environment, indoors and outdoors. (A similar process is now underway in many developing countries.) Little thought was given to environmental limits or to possibilities for integrating systems. Instead, single purpose agencies and businesses were created, often with monopoly status, and with a mandate to increase supply.

In the mid 20th century, the same process was repeated for transportation and community systems.

These traditional 19th and 20th century infrastructure systems are becoming increasingly costly to operate on a per person basis. A number of trends contribute to these rising costs:

- on-site demand for resources per dwelling is declining, as our homes and offices become more efficient;
- average occupancy per dwelling is also decreasing;
- the cost of securing a unit of resource is increasing; and
- land for facilities and distribution systems is ever more scarce and costly to acquire.

The cumulative effect of such trends is that a growing proportion of resources is being used in unproductive generation and distribution operations. At the same time, we are witnessing changes to technology and the economy that are creating radically new opportunities for Green infrastructure. For example:

- **Urban density** is increasing (or is planned to increase);
- **New "micro" utility servicing equipment** is on the market, including small-scale systems for water treatment, water recycling, cogeneration and heat transfer;
- **Innovative storage systems** are improving potential for renewable energy and on-site infrastructure. In some cases, the grid is also being used as a storage substitute. As flows of electricity, heat and water become bi-directional, on-site systems can easily share surplus resources and top-up local capacity.
- **Artificial intelligence (AI)** can now be used to reduce the need for expensive fail-safe systems, and to reduce maintenance costs for small-scale systems. AI can also facilitate the management of innovative storage and hybrid systems.
- **Deregulation of utilities** is helping to transform single-minded monopolies into flexible and market driven businesses focused on a broad range of customer needs - in some cases offering a service 'package' of gas, electricity, water, cable, insurance, telephone, appliances and sewage from a single supplier.
- **Delivery of infrastructure** is now changing from traditional general contracting to a more performance-based system, where a consortia of firms undertake to design, build, own, operate and transfer systems in accordance with broad, objective-based requirements.

All these innovations are opening the door to a far more flexible, diverse and integrated approach to providing urban services. It is important not to underestimate the extent of change now underway. Green infrastructure is likely to change the city as much as the introduction of automobiles, electricity or concrete. In fact, we may be talking about the first major change in urban form and function since cities were invented.

Long time constants will serve to soften the impacts of such change – for example, existing buildings may last 40 or 60 years, and highways and pipes can last even longer. However, the scale of change in our cities is analogous to what has already occurred with computers, where a large, centralized, expensive and single purpose 'main frame' infrastructure has been almost completely replaced by a network of on-site systems.

In the emerging green communities, elements of urban infrastructure systems are already moving much closer to – or inside – the buildings themselves, even in large urban centres. Increasingly, we see a blurring of the traditional boundaries that separate one type of 'building' from another, and buildings from their civil infrastructure. Large distribution grids and remote treatment and generation facilities are giving way to a network of distributed or 'on-site' infrastructure systems, with shared elements, finely integrated into the fabric of the built environment.

More diverse land use and building types complement the on-site infrastructure systems, by evening out the demand for services, and creating opportunities for re-use and synergy. The end result will be urban clusters that are more diverse and self-reliant, with mixtures of housing, commercial space and industry. In the process, the traditional parcelling of land uses, and isolation of industry and infrastructure will give way to a multi-layered approach. We will literally wrap our homes and offices around the industrial and infrastructure systems, as these systems become a key source of warmth, water, food and diverse employment.

In the existing older communities, such sustainable integration is more challenging. The pace of technological change will need to be matched to natural turnover rates for the stocks. Functional integration of systems must evolve incrementally. The performance of the existing systems must be carefully evaluated and forecasted in order to allocate resources between maintenance and refurbishment on the one hand, and whole scale replacement with alternative systems on the other.

Either way, the system design and engineering industry will have to consider an increasingly wide range of options. The life cycle impacts from energy and material flows will need to be assessed for diverse technologies, and for a much greater variety of scales and locations. We will need comprehensive models in order to combine the flows from different stocks (buildings, roads, plants, pipes and wires) and to allow fair comparisons between integrated and less integrated systems.

The first step in meeting such challenges is to transform the models we carry around in our heads, and redefine just how cities are intended to function.

A VISION FOR WHAT LIES AHEAD

The basic premise for Green infrastructure assumes that we must learn to adopt smaller scale urban systems, distributed more widely, located closer to and within buildings, integrated with elements of buildings, and integrated with other infrastructure systems.

Large grids and remote treatment and generation facilities will give way to distributed systems, organized into a nodal hierarchy.

At the neighbourhood scale, the nodes of a distributed infrastructure will include clustered, self-reliant, mixed developments of housing, commercial space and industry. In fact, every housing and office development may be seen simultaneously as an opportunity for a water factory, an electrical generating system, a solid waste management system, a stormwater management system, a communications node, an agricultural facility, and so on. The net result will be a city transformed.

Managing such a transformation will be difficult, given current norms for private property, and the existing fee structures and planning policies within municipalities and regional utilities.

Substantial new financial resources will be needed both to protect and enhance the carrying capacity of the local ecosystems, and to meet targets for reducing greenhouse gas emissions. Change itself can be a costly exercise.

The new design principles and evaluation methods that are introduced in this Guide are an essential part of infrastructure change management. The next chapter of this Guide (**Chapter 2**) will describe the basic features of Green infrastructure, and help us set some new directions. **Chapter 3** summarizes the full benefits of this new direction in social, economic and environmental terms. **Chapter 4** takes a quick look at each type of Green infrastructure, and outlines the opportunities for integrating infrastructure at both the building and the neighbourhood scale. Also included, are examples of how each infrastructure system might be integrated with other infrastructure systems. **Chapter 5** discusses the many obstacles to implementing these concepts. **Chapter 6** summarizes some of the most effective strategies for managing the risks and maximizes the benefits.

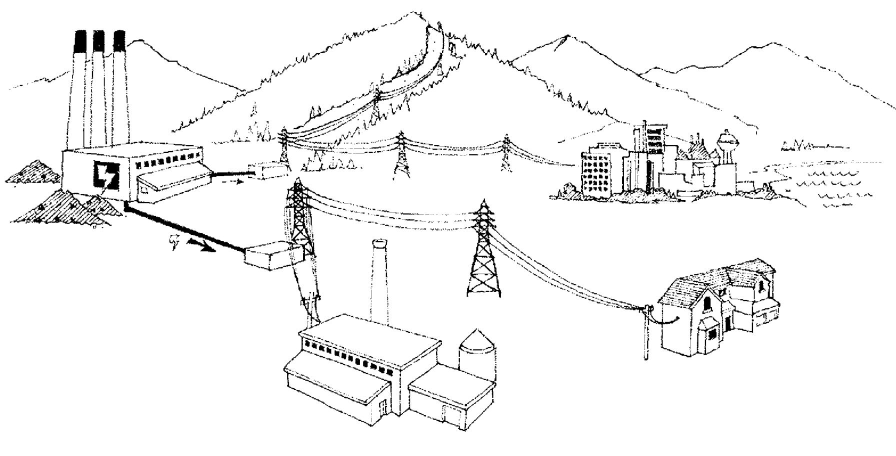
2. Features of Green Infrastructure

Ten features that help to define Green infrastructure are described and illustrated below. In combination, these features appear to produce infrastructure systems that are inherently more sustainable.

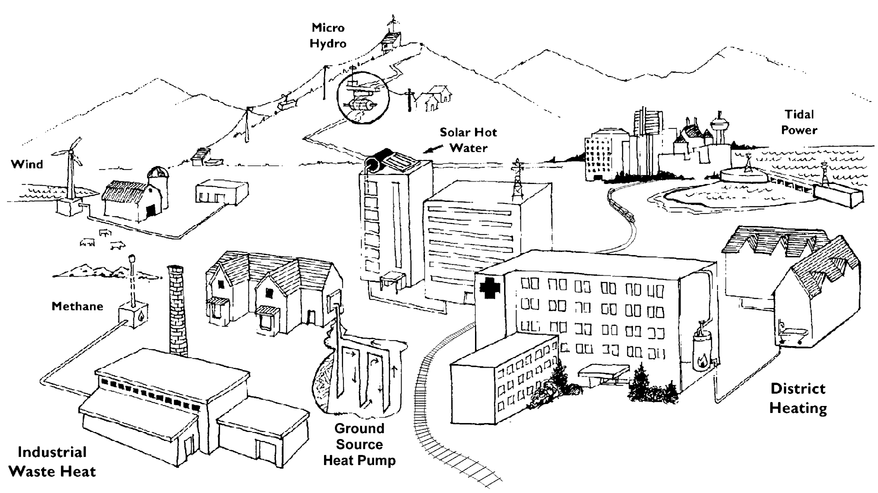
1. Distributed

Centralized plants and facilities are replaced with a variety of smaller scale systems, distributed throughout the service area. The distribution patterns take advantage of where the renewable resources are located. New infrastructure is also 'piggybacked' onto local capital projects like hospitals, schools, parks, and roads.

For example, a distributed energy system might collect thermal energy from many sources: methane at landfills or sewage treatment facilities, heat pumps connected to pipes in the ground or water bodies, solar water heaters on roofs, and industrial processes – all connected through a district heating system. Electricity might be generated at many points on the grid, using windmills next to lakes or on hills, and turbine generators in the local rivers, water pipes or ocean channels. Growing communities may also want to distribute electrical generating capacity within each new cluster of buildings along the principle transportation corridors – providing on-site electricity for lighting, appliances and the public transit system, while using the waste heat from electrical generators to heat the new buildings and domestic hot water.



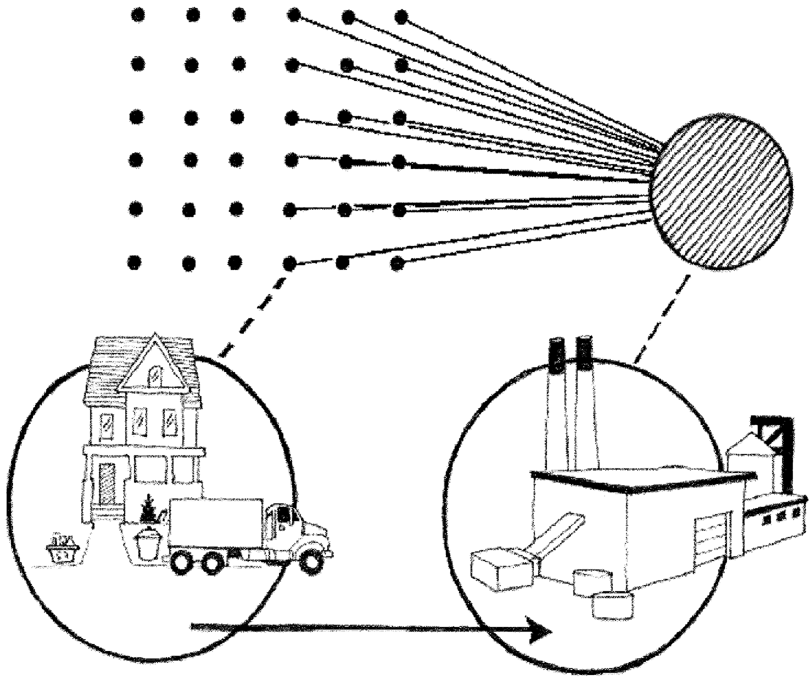
Centralized Energy System, circa 2000



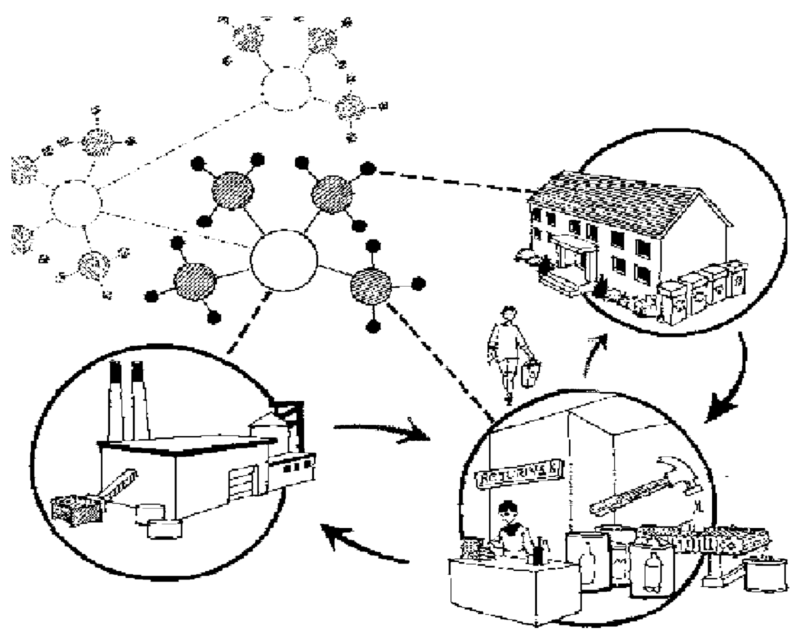
Distributed Energy System, circa 2050

2. Clustered

The distributed network is composed of nodes, structured in a hierarchy, from inter-urban, to intra-urban to intra-building. The nodes in this structure offer opportunities for adjusting and optimizing the location, load base, and the scale of elements within each infrastructure system. The nodes also provide convenient locations for integration of infrastructure. Spaces between nodes may be sized to match the scale of the servicing technology, the renewable resource base, food requirements, water treatment and supply needs.



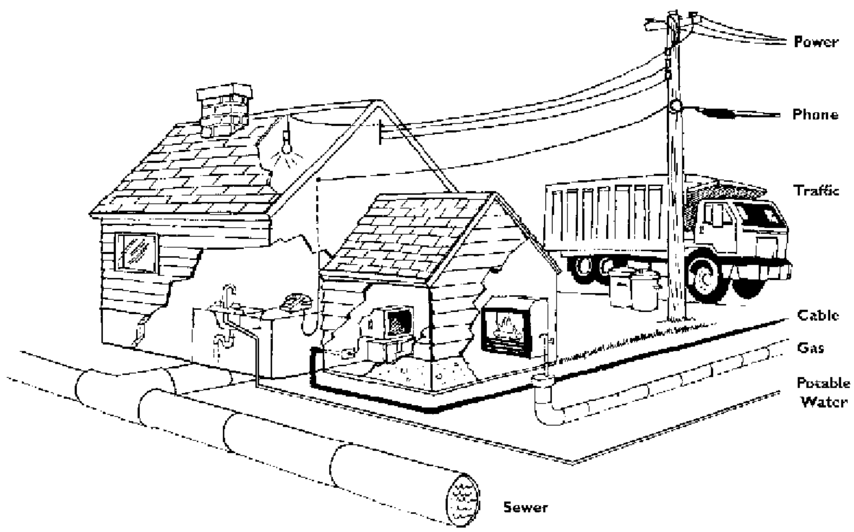
Remote & Isolated Solid Waste Management, circa 2000



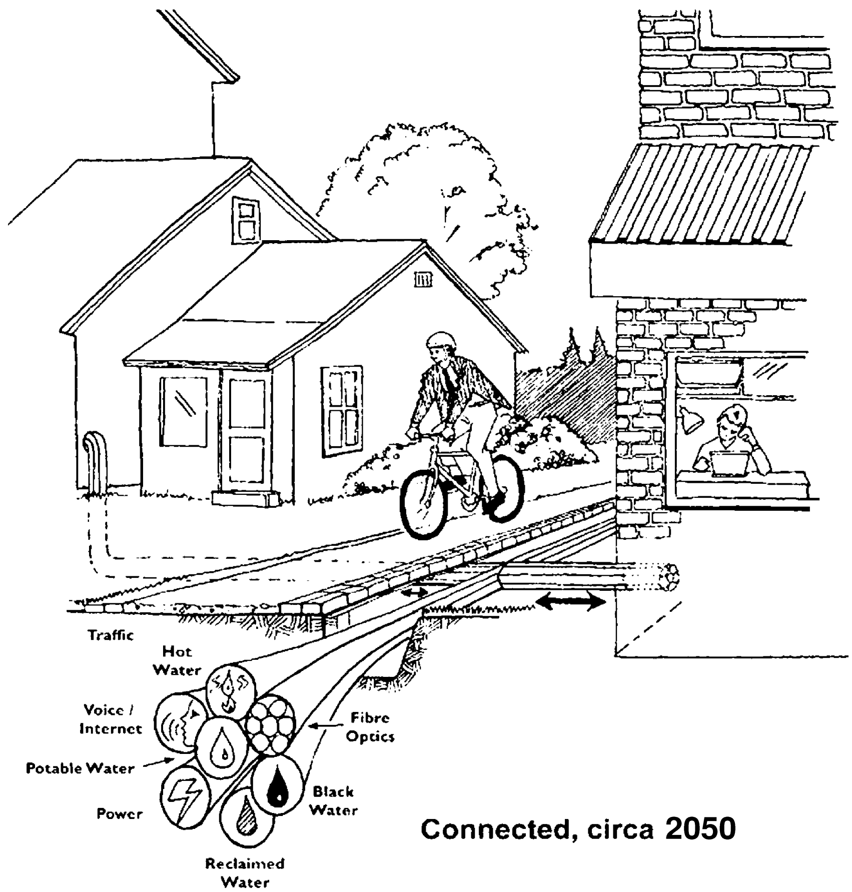
Clustered Solid Waste Management, circa 2050

3. Interconnected

A multi-service connectivity is provided between the cluster centre and points of demand and supply, and to storage and treatment facilities. Ideally this multi-service connectivity is capable of embracing all the flows - including resources, people and information. One approach may be multi-purpose corridors; another might be utilidors with standardized connections. It is these connections that are used to create loops, or in other words the trading, balancing, reusing and recycling of resources. Ultimately, a series of mini loops and bigger loops will lead to a 'circular metabolism' for the city and its hinterland. Like a living ecology, the essential nutrients are cycled through the system, driven by the renewable energy sources.



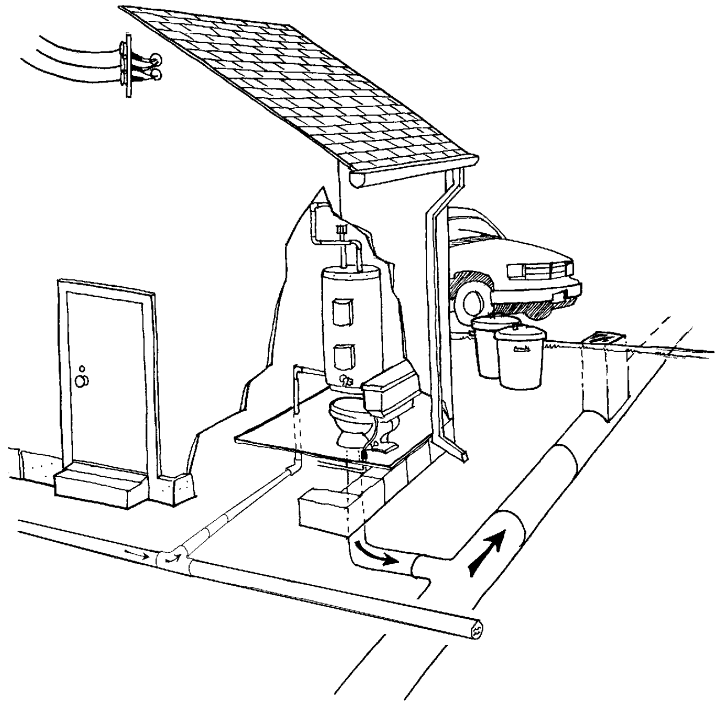
Disconnected, circa 2000



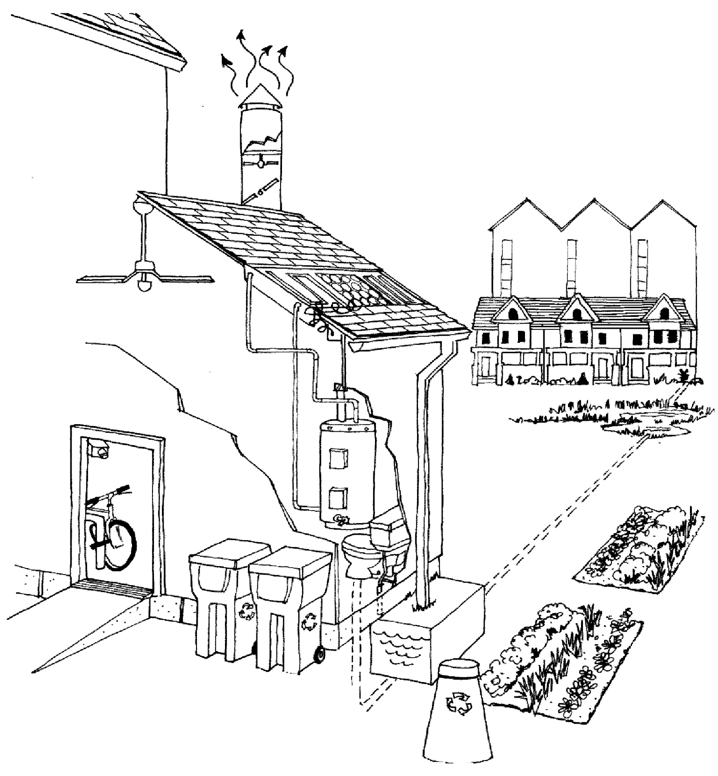
Connected, circa 2050

4. Integrated

Integration of infrastructure means using the existing components of the urban environment - roads, buildings, greenways, and so on - to serve as elements of the infrastructure system. An integrated system does not stand distinct from the surrounding built or natural environment, and instead is functionally integrated at all scales. Integration begins at the building (or micro) scale, and then moves outwards as necessary. At the building scale, integration may mean that walls, roofs, entranceways and other elements of the building serve to capture energy, water and wind, treat and separate wastes, and contribute to accessibility and transportation. These internal collection and separation systems allow the building to produce raw materials like clean, reclaimed water, photovoltaic electricity, used paper, CO_2, and so on. At the neighbourhood scale, systems are integrated with land uses and with other resource flows. Properly planned, this type of integration creates a true 'urban ecology'.



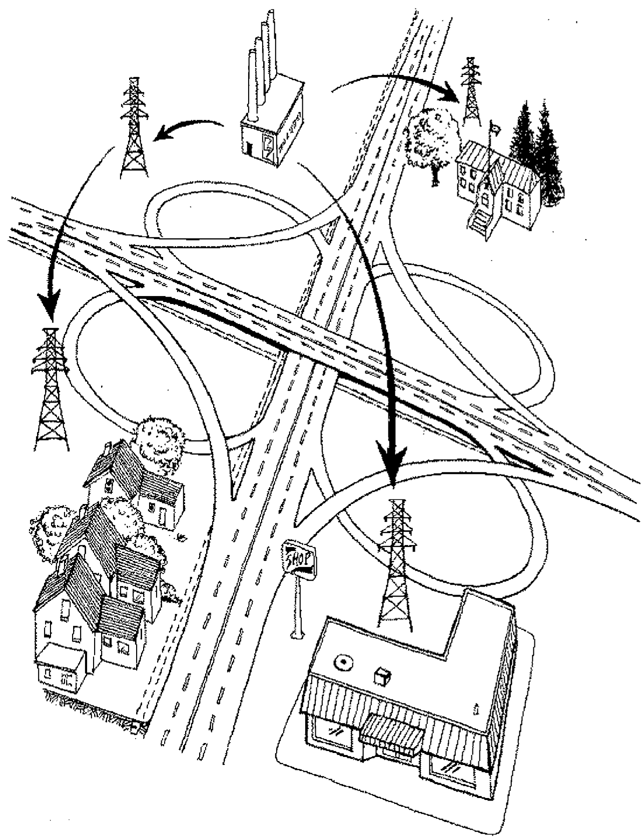
Non-Integrated Systems, circa 2000



Systems Integrated with Elements of Natural & Built Environment, circa 2050

5. Service Orientation

A service orientation means that the objective is no longer to connect buildings and distribute resources, but rather to provide a service. Instead of providing, say, natural gas, the focus is on providing comfort, cooking and cleaning services. In some cases this may be best accomplished by delivering natural gas; in other cases the best solution may be improved home design, or a solar water heater. Thus rather than simply sizing infrastructure systems for the worst-case demand scenario, and expandability, Green infrastructure investments seek to optimize supply and demand management to provide the best service. Sometimes an investment in demand side management can serve to reduce the size of loops and permit more efficient resource exchange. Or, demand side management may help to avoid costly expansions of off-site infrastructure, and to limit the loads to only what can be accommodated by the neighbourhood scale systems. Making infrastructure more sustainable means reducing the energy and resource intensity of the service, while enhancing value. This concept is sometimes referred to as 'eco-efficiency'.

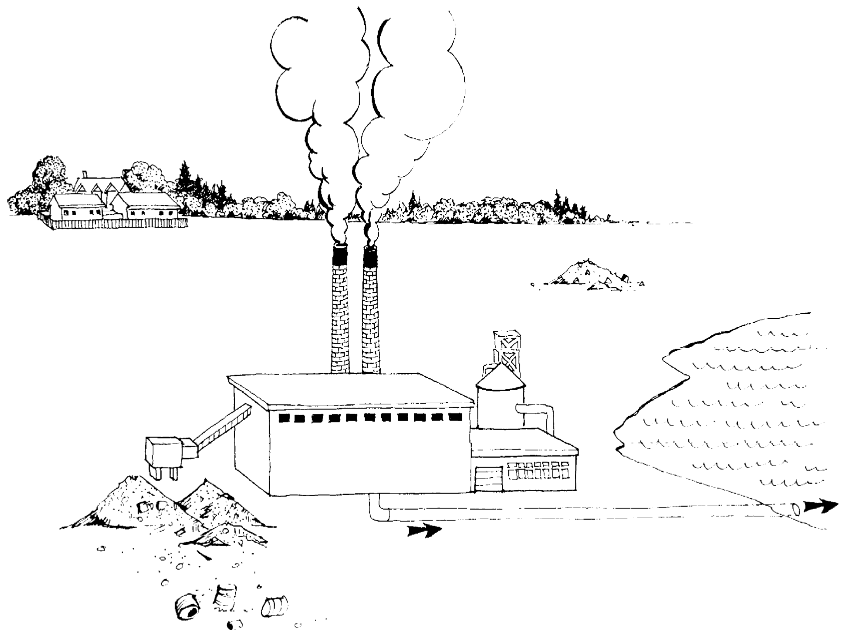


Supply-Side Solutions, circa 2000

Service-Oriented, circa 2050

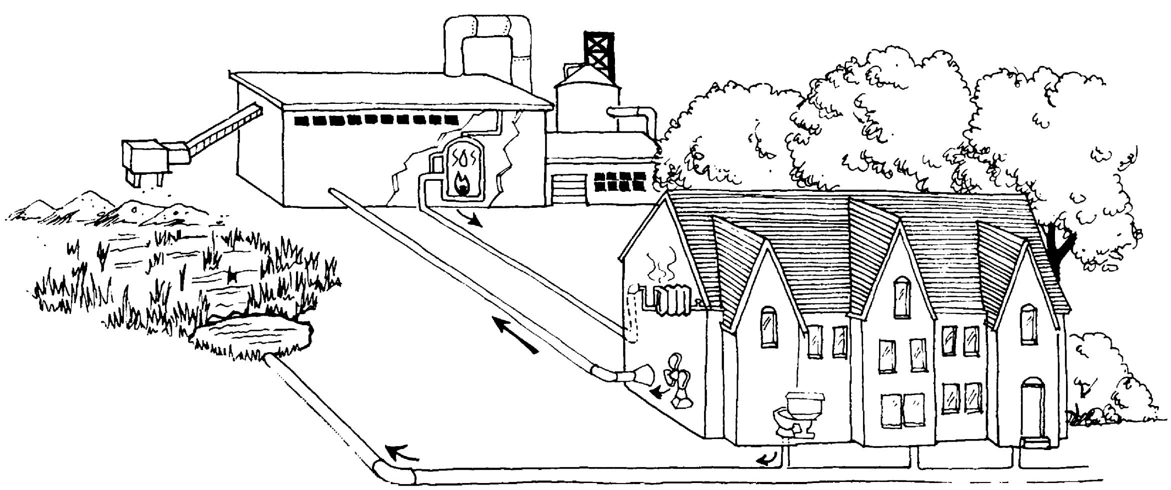
6. Responsive

One of the advantages of on-site local, smaller scale systems is their ability to respond to the local opportunities and constraints. On the input side, a system can be designed to accommodate the specific “waste” resources available from industry (e.g. sawmill waste, hot water) or from the local environment (tidal power, lake cooling, micro-hydro, wetlands). On the output side, a local system can be designed to preserve or enhance the local carrying capacity of the airsheds, watersheds, soils, and land base, and the integrity of the local ecosystems.



Unresponsive Design, circa 2000

Green infrastructure can also respond to the historical patterns for both built and natural environments. “What kinds of local plants and animals work well together? and is it possible to use a similar combination of species and shapes for creating green spaces and cityscapes?” or “Why did the traditional architecture use large roof overhangs, and how might such architectural features also become functional elements of on-site infrastructure?”

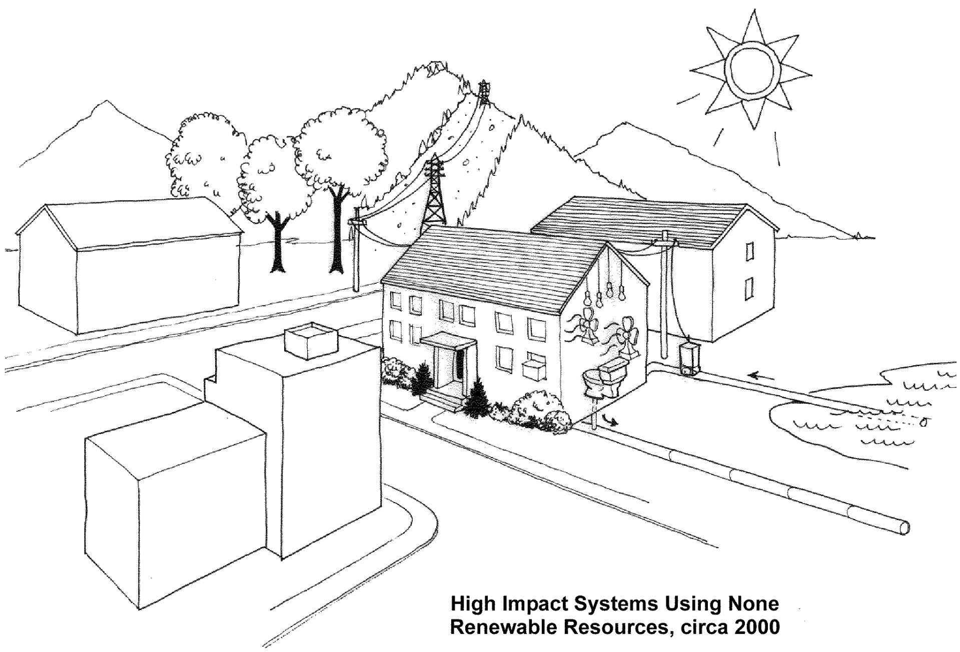


Responding to Local Sensitivities & Opportunities, circa 2050

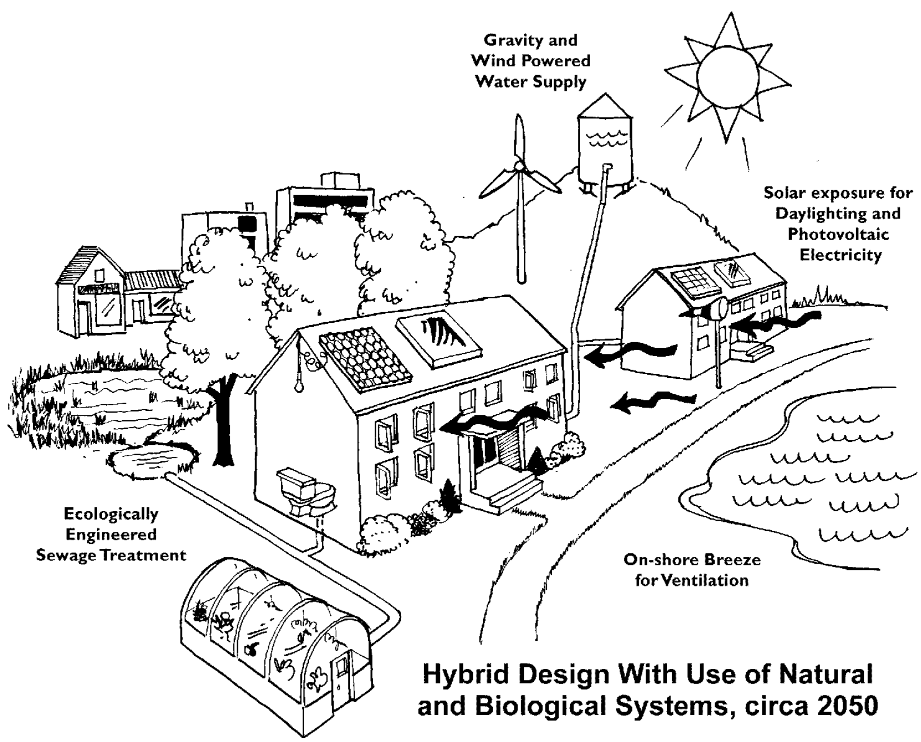
7. Renewable, Low-impact

Similar to Green buildings, Green infrastructure is intended to maximize use of existing on-site resources and, where possible, to incorporate ‘living machines’ designed to mimic natural ecosystems. One of the best examples of renewable, low-impact technology is an ‘ecologically-engineered’ wastewater system that treats run-off and sewage with micro-organisms and vegetation. Other common examples are systems that obtain usable energy from sunshine, micro-hydro, wind, and geothermal sources.

In theory, there is sufficient local natural resource wealth of this type to provide adequate levels of service for housing, without any additional infrastructure. However, from an economic perspective the best solutions are hybrid systems that supplement these local, renewable resources with imports from elsewhere.



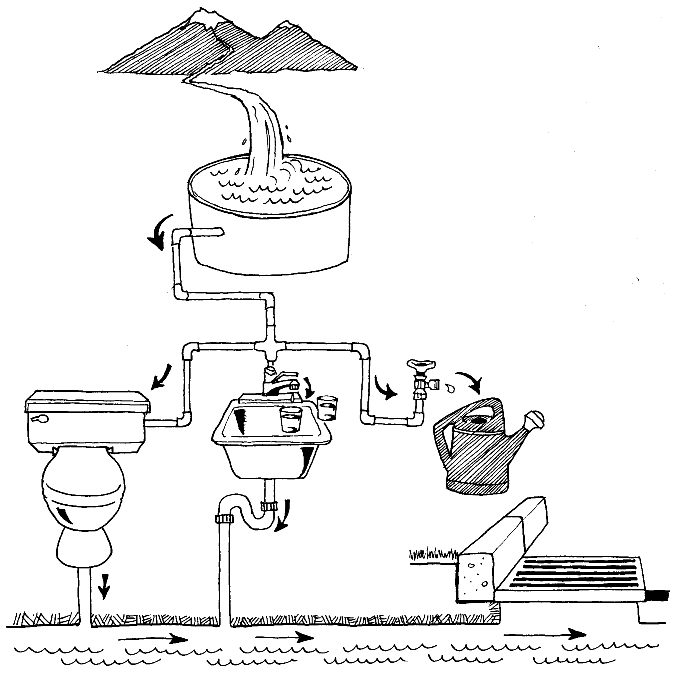
High Impact Systems Using None Renewable Resources, circa 2000



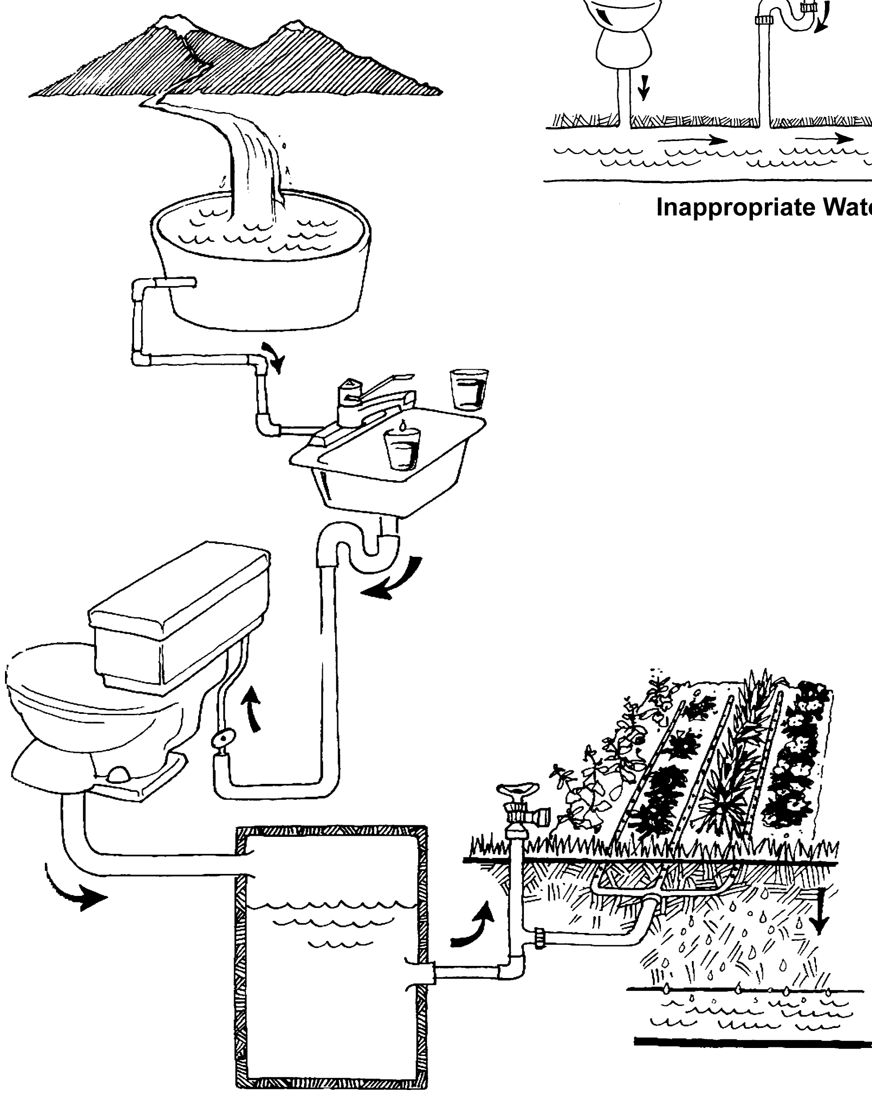
Hybrid Design With Use of Natural and Biological Systems, circa 2050

8. Appropriate (or Well-Matched)

The choice of technologies and material used for constructing infrastructure should be appropriate for the users' requirements, and for the social context. Choices should also contribute to 'greening' the entire economy. Most importantly, this means matching high quality resources with the most demanding end uses. For example, high quality water is used for drinking and food production, lower quality water is matched to washing and flushing, and the lowest quality water is used for irrigation and water features. Energy is treated similarly (see next page).

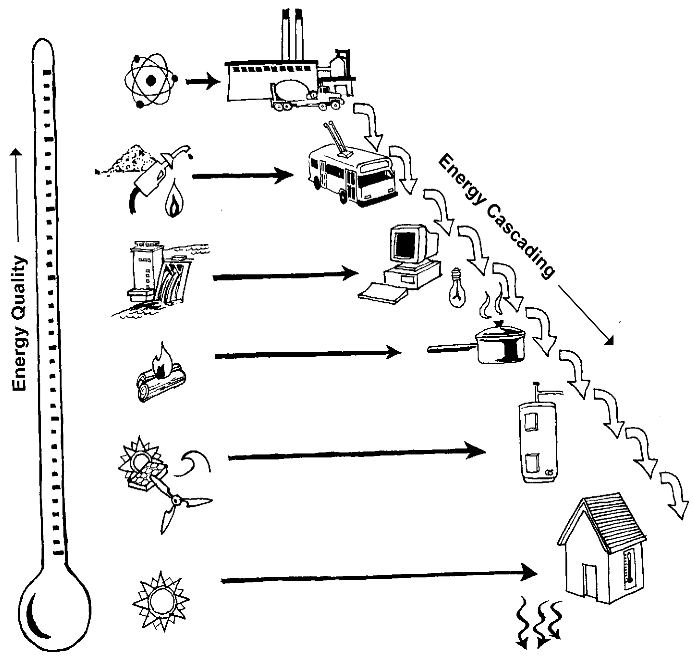


Inappropriate Water Use, circa 2000

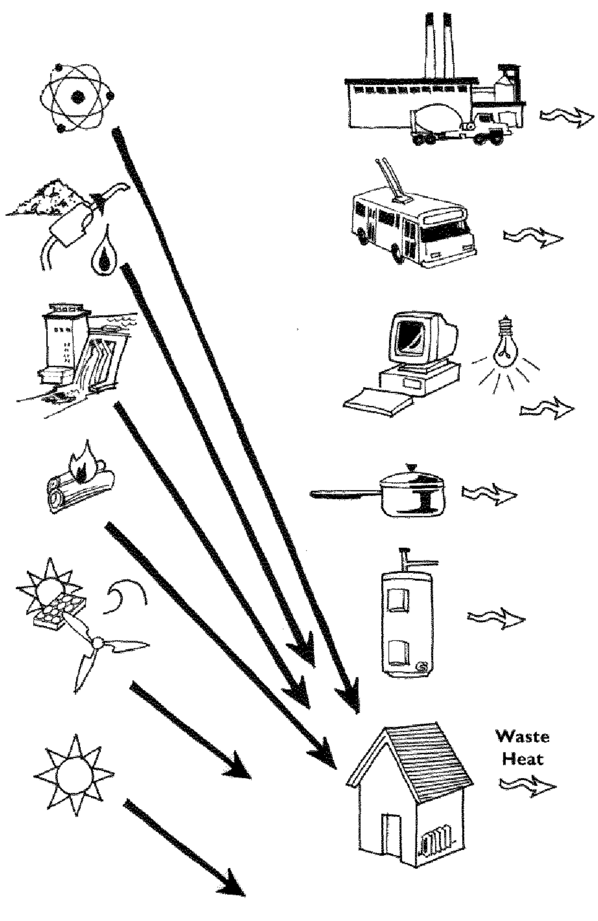


Appropriate Water Use, with Cascading, circa 2050

High quality energy, like electricity, is used for lighting, computers, motors and transportation; natural gas is used for cogeneration, industrial processes and steam; waste heat is used for water heating and, lastly, space heating. Of course, it is also important to cascade the energy resources, using the waste resource from one end use as the input for a lower quality end use.



Well-Matched Energy with Cascading of Waste Heat to Other Uses, circa 2050

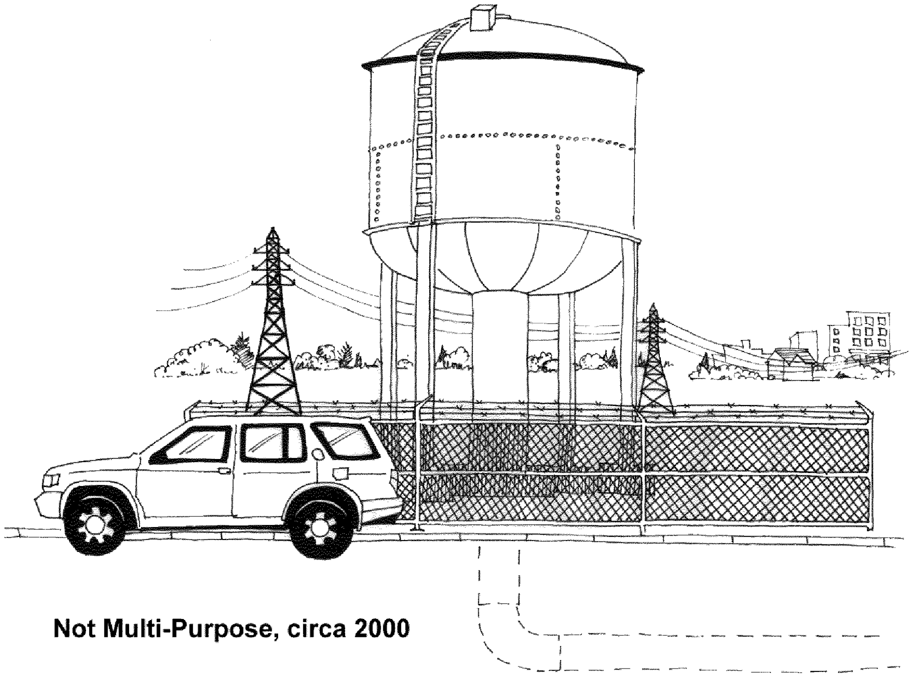


Inappropriate Matching of Energy Quality & End Use

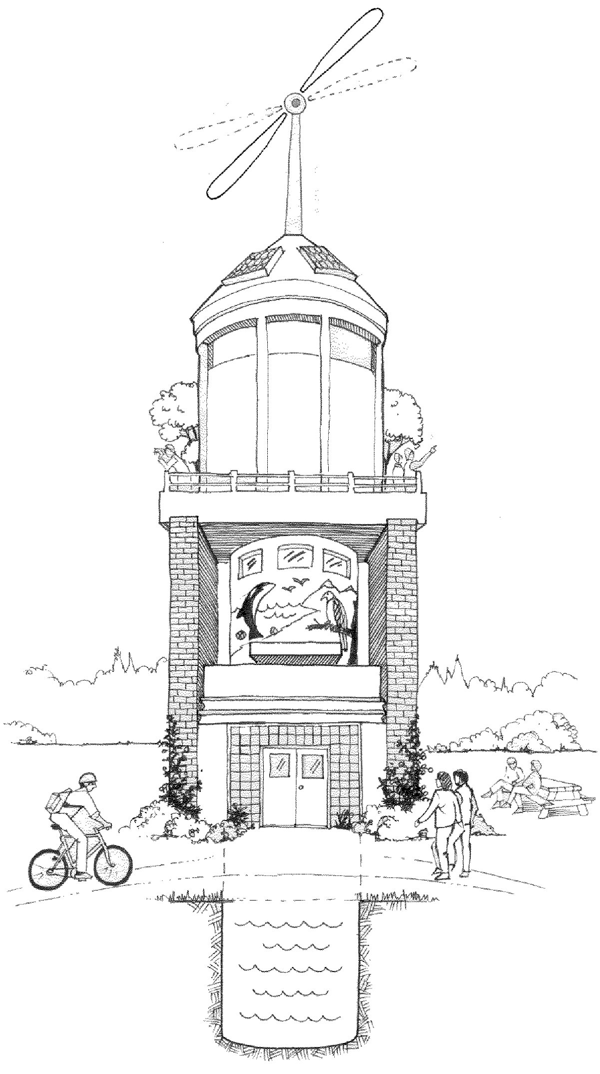
Another aspect of 'appropriate' design is the selection of materials used for constructing infrastructure elements. The same principles apply: match the quality of the material to the users end needs, and ensure that the materials are designed and installed in ways that facilitate later reuse or recycling. Finally, the system design itself needs to be appropriate; for example, by matching the level of complexity with the management and maintenance abilities of the local operators. As systems become more localized, the needs may increase for modularization, standardization, and computerization.

9. Multi-Purpose

Each element in a new infrastructure system can be designed to contribute to a multitude of purposes and thus provide a range of additional services to the community. This process emulates the elements in a living ecosystem (bio-mimicry) where a stable and efficient system is created by using single components for multiple functions. In the case of neighbourhood scale infrastructure, a good example might be polishing ponds for wastewater. Properly designed, these might become part of a "multipurpose on-site pond system" that is aesthetically landscaped, and that functions as aquaculture, groundwater recharge, irrigation water storage, prefiltered stormwater detention, wildlife habitat and emergency fireflow reservoirs. Even a water storage tower can be designed to serve multiple purposes: e.g. a viewing tower, a gathering place, a support for solar and wind power, a means of advertising the neighbourhood values, and a means of contributing to the beauty and diversity of urban areas.



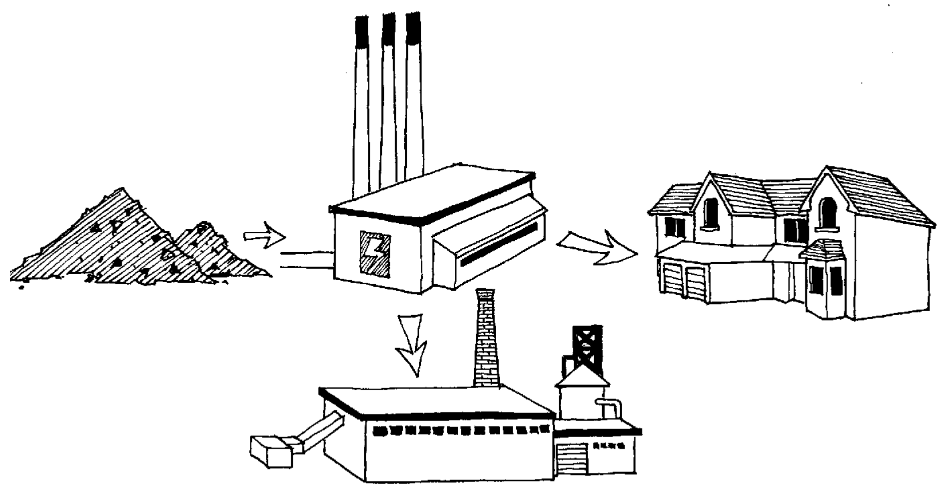
Not Multi-Purpose, circa 2000



Multi-Purpose Water Tower, circa 2050

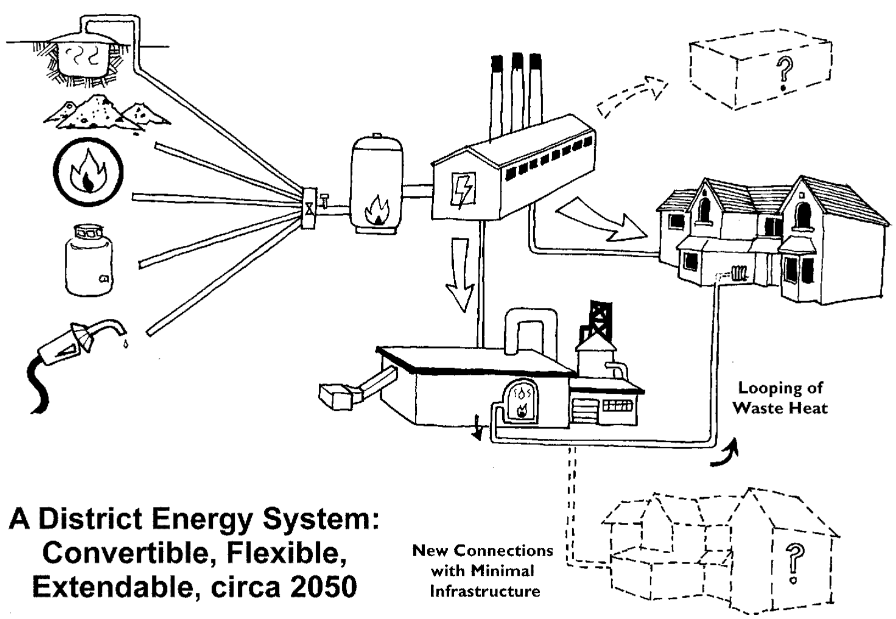
10. Adaptable

Adaptability refers to the capacity of systems to accommodate substantial change. Over the course of a system's lifetime, change is inevitable, both in the social, economic and physical surroundings, and in the needs and expectations of consumers. All other things being equal, a system that is more adaptable will be utilised more efficiently, and stay in service longer, because it can respond to changes at a lower cost. A longer and more efficient service life should, in turn, translate into improved environmental performance over the lifecycle.



Energy Plant with Limited Adaptability, circa 2000

The concept of adaptability can be broken down into a number of simple strategies that are familiar to most designers: flexibility, convertibility, and expandability. In practice, these strategies can be achieved through changes in design, and through the use of alternative materials and technologies. A district heating system, for example, can use a single, convertible boiler to quickly switch the whole neighbourhood from one source of heating energy to another. Thus the community can effortlessly adapt to changes in energy availability, cost, environmental impact or whatever. Infrastructure that is smaller scale, and distributed, may be inherently more adaptable, because it is less vulnerable to environmental changes or social transformations. It may also be more adaptable than a one-time investment in large systems, because an incremental pace of growth can accommodate diverse and innovative technologies and policies.



A District Energy System: Convertible, Flexible, Extendable, circa 2050

3. Benefits of Green Infrastructure

Green infrastructure contributes to urban sustainability because it generates significant benefits in all three spheres of concern: social, economic and environmental. The full range of such benefits is presented in this chapter. These benefits represent the essential arguments for adopting and promoting the features of Green infrastructure.

Interestingly, the same list of benefits can be cited as an argument for any type of Green infrastructure system - from energy to solid waste to transportation. More detailed examples of features and benefits for each type of infrastructure will be described in the next Chapter.

SOCIAL BENEFITS

Resilience

A cluster structure, with diverse technologies, can be much more resilient when confronted with ice storms, earthquakes, tsunamis, fire, terrorism, civil unrest and other calamities. Loads can be shared if one system is destroyed, and resources can be substituted at the scale most appropriate.

Aesthetics & a 'Sense of Place'

On-site infrastructure offers new opportunities for beautification of public spaces and creating a 'sense of place'. The vegetation and watercourses associated with open stormwater systems, for example, can help make a neighbourhood both distinct and beautiful. A number of communities in Europe have used leading architects to design the local wastewater treatment greenhouses and the community heat and power plants. These facilities become landmarks and statements for the community. Moreover, integrated, on-site systems offer cities a more 'human scale' environment.

Amenities

If capital projects are carefully designed for multiple uses, the community benefits from new amenities and recreational opportunities.

Flexibility

Sometimes it can be a problem to locate new growth in specific locations because of the need to pump sewage or extend pipelines. On-site infrastructure can thus allow cities to more effectively use their land base.

Conflict Avoidance and Resolution

It is becoming increasingly difficult to export wastes from cities, and to locate large infrastructure elements, including facilities and right-of-ways. Incorporating infrastructure into the more organic process of neighbourhood and building development is likely to be more amenable to community control and acceptance.

A Greater Choice of Lifestyles

A diversity of infrastructure systems creates the possibility for greater choice in lifestyle. The neighbourhoods can make trade-offs between convenience and cost. For example, small residential communities, in the Netherlands, often choose very different approaches to dealing with automobile access, with some neigbourhoods restricting parking spaces, others sharing cars, and others offering transit passes and cycles as part of property ownership.

ECONOMIC BENEFITS

Lower Costs

Green infrastructure often results in lower lifecycle costs when compared to traditional larger-scale, non-integrated systems. For example, demand side management (the service orientation) can reduce the need for public expenditure. Converting waste products into resources creates a new revenue stream for consumers. Small-scale facilities typically need much simpler fail-safe systems, which greatly lowers capital costs.

Delayed Capital Outlays

Green infrastructure is more incremental, since some (or all) of the elements are located in buildings or at the neighbourhood level. This creates opportunities for more gradual phasing of investments, and thus helps to delay major capital expenditures. The incremental approach also makes it easier to match capacity with demand, and thus avoid the cost of over-sizing systems.

User-pay

To the extent that infrastructure elements and functions can be integrated into buildings or urban development projects, the municipality and utility can off-load a portion of the capital costs to the users. This is consistent with a User-pay principle, and encourages more efficiency and conservation within the marketplace.

Longer-term Investments by Stakeholders

As building owners and developers become stakeholders in the creation of utility services, they are likely to see the wisdom of investing in demand side management and lifecycle costing. For example, if a developer can partner with a micro-utility, and create dwelling units with exceptionally low operating costs, the units are certain to be more marketable. This can reduce risks for the developer and investors. The micro-utility may also allow the developer to 'participate' in the long-term revenue stream related to provision of services like water, waste, energy, and communications. For example, a single monthly management fee for owners may cover the costs (and provide profits) for providing a whole range of infrastructure services. The incentives are thus created for private sector investments in high performance housing, since lower operating costs will increase profits both from sales and the on-going management of micro-utilities.

Local Job Creation

Green infrastructure creates more employment within the community. Less money is spent on constructing and operating facilities in remote locations. Less money is spent on importing products like electricity, gas and water. Instead, a portion of the investments is made locally, and helps to circulate money within the local economy, and to create jobs closer to where people live. The looping of waste materials back into raw materials can also contribute to new local industries and long-term employment. Once raw materials are reclaimed, additional processes can be integrated within the building and/or neighbourhood to process the raw materials into products. And if the Green infrastructure is a more efficient system, it should leave more dollars in the hands of local residents - dollars that can be spent on protecting the local environment and enhancing the competitiveness of the community.

Local Procurement

Infrastructure elements that are integrated at the local scale frequently involve local procurement, which boosts business in the community.

Security

Large systems dependent upon a single resource flow are dangerous for the economy. For example, consider the recent flight of businesses from California after the electricity brownouts caused by natural gas scarcities and poorly regulated marketplaces. The natural and adaptable features of Green infrastructure provide businesses with a lower risk of such business disruption. This also applies to virus attacks, natural disasters, and other crises.

Quality of Service

Many types of Green infrastructure provide a higher quality of service and provide communities with a competitive edge. District heating, for example, can be more reliable and more professionally managed and maintained than would ever be possible for a single-building system; the users also save floor space and reduce numbers of maintenance personnel. If transportation infrastructure includes 'work at home' options, and a good match between housing and jobs, then Green infrastructure should significantly reduce the transportation and overhead costs for businesses and employees.

ENVIRONMENTAL BENEFITS

Efficiency

More efficient use of resources is achieved through reductions in the size of the distribution system, reductions in overall capacity, and better matching of resource quality to the user's needs.

Innovation and Upgrading

A distributed system using small scale, cluster-structure technologies, is a system that is well suited for trying out new technologies, and for integrating technological advances in a rapid, incremental style. Consequently, all marginal investments in new infrastructure can be accomplished using the latest (and now rapidly improving) green technologies. The net effect of such ongoing improvement is to upgrade the average lifetime efficiency of the entire system.

Restoration

Because Green infrastructure is responsive to local conditions, it can respect local carrying capacity and adapt to the environmentally sensitive areas. For example, if a community is located close to wetlands that are at risk, then the new housing developments can employ biofiltration technologies, 'daylight' the streams and re-create natural systems that protect the sensitive area from run-off. Such land use and wastewater management techniques can actually contribute to restoring and enhancing the wetland by regulating and augmenting water flows.

Synergy

By converting wastes into raw resources within the city, Green infrastructure creates new opportunities for commercial and industrial activity close to where people work and live. These short loops contribute to the emergence of municipal and industrial ecologies. Land use can be explicitly organized around maximizing the potential synergy from converting wastes into profitable resources and commodities. For example, water flows through a city can be cascaded from energy generation to residential, industrial and finally agricultural sectors, once the municipality co-ordinates the land use and industrial strategy for this purpose.

Biodiversity and Productivity

By responding to environmental constraints, and incorporating living elements and ecological systems as elements of infrastructure, the biodiversity and productivity of the local area is increased and strengthened.

4. Best Practices for Green Infrastructure

STORMWATER SYSTEMS

A Green Perspective

Historically it made sense to pipe stormwater away from urban areas, and dump it straight into the receiving waters. Pipes were needed regardless (for sewage) and these sunk costs made alternative stormwater systems appear costly. This situation has now changed. Piped stormwater needs to be treated in order to protect the quality of receiving waters, and this treatment adds significantly to operating costs. Moreover, the capacity requirements of the treatment plant and pipes need to be much larger to cope with the peak storm flows - or the result is overflows and pollution. As cities age, the stormwater pipes are becoming costly and difficult to maintain and replace. Finally, the quantity of stormwater flow is increasing as urban areas become dense, mixed-use communities with a higher percentage of impervious area.

For all these reasons the traditional curb, gutter and storm drain systems are contributing to higher cost sewage treatment systems, system failures, and increasing run-off into watercourses. The increased run-off water causes deterioration in water quality, bank erosion, increased flooding, low summer base flows and degradation of fish habitat and riparian ecosystems.

The best way to avoid these negative impacts is to eliminate most of the stormwater pipes, and instead slow down and store the run-off, then release it slowly, in order to more closely mimic natural conditions. Essentially, the built environment of a city has to function like a forest in the rain. Three approaches can be adopted, in the following order:

1. increase tree and vegetative cover to increase capture of rain above ground, and to increase evaporation,
2. absorb rainfall back into the ground where it is filtered and returned slowly to the receiving waters, by interflow in the soils, and
3. store stormwater in shaded detention storage areas for later release.

Storage of stormwater is the last option because it can lead to disruptions in stream flows and concentrations of polluted sludge overtime.

Regardless of which approaches are used, the best strategy is always to start at the source - the impervious building and site. Rainfall capture on private building parcels should be maximized, and then supplemented and balanced as necessary by means of improved street design, and storage ponds or wetlands downstream.

The natural 'open' features of a Green stormwater system are significantly less costly than the conventional curbs, gutters and pipes, with a 30% average savings in capital costs. Maintenance costs may be slightly higher, although it is sometimes possible to allocate these costs to the budget for parks and recreation, since an open system provides more diverse and attractive landscaping, with improved microclimate, habitat and food production.

Integration of StormWater Systems at the Scale of Building and Site

Green roofs and directing roof run-off: In high-density urban areas, much of the building site will be dedicated to roof areas. Therefore part of on-site stormwater infrastructure includes:

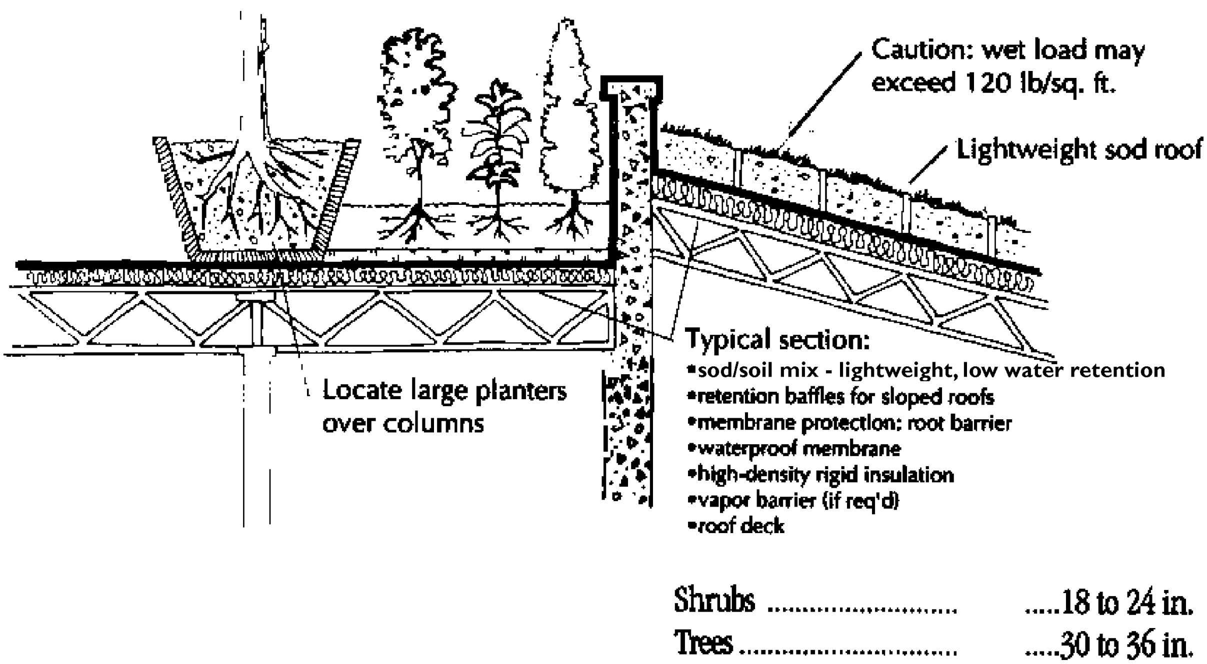
Vegetative cover to capture and slowly release rainwater. A typical green roof can hold 25mm of rainfall, the equivalent of a one- or two- day small storm event. A portion of this rainfall is retained by the roof and used by the plants or re-released into the air. The remainder is drained more slowly from the roof, thus mitigating the negative impacts of run-off.

Directing roof run-off to cisterns allows it to be collected and stored. Depending upon the natural environmental conditions at the site, this stored water could either be released slowly to the stream, or re-used as non-potable water in the building for toilet flushing and laundry purposes. There is also a role for garden irrigation.

Directing roof run-off to landscaped areas, drywells and infiltration basins allows water to seep into the ground. The landscaped areas should use berms, curbs and depressions to direct and retain flows and allow time for infiltration. Drywells, or French drains, are particularly valuable for small sites, since they can supplement limited infiltration areas.

Manufactured sediment traps are available that intercept run-off from drainage areas, and slowly release it while trapping sediments.

Best practices for site development can be described in guidelines, and used to ensure that land clearing, excavation and construction activities are not allowed to generate run-off, erosion and silting problems in surface waters.



Best Practices for Green Infrastructure

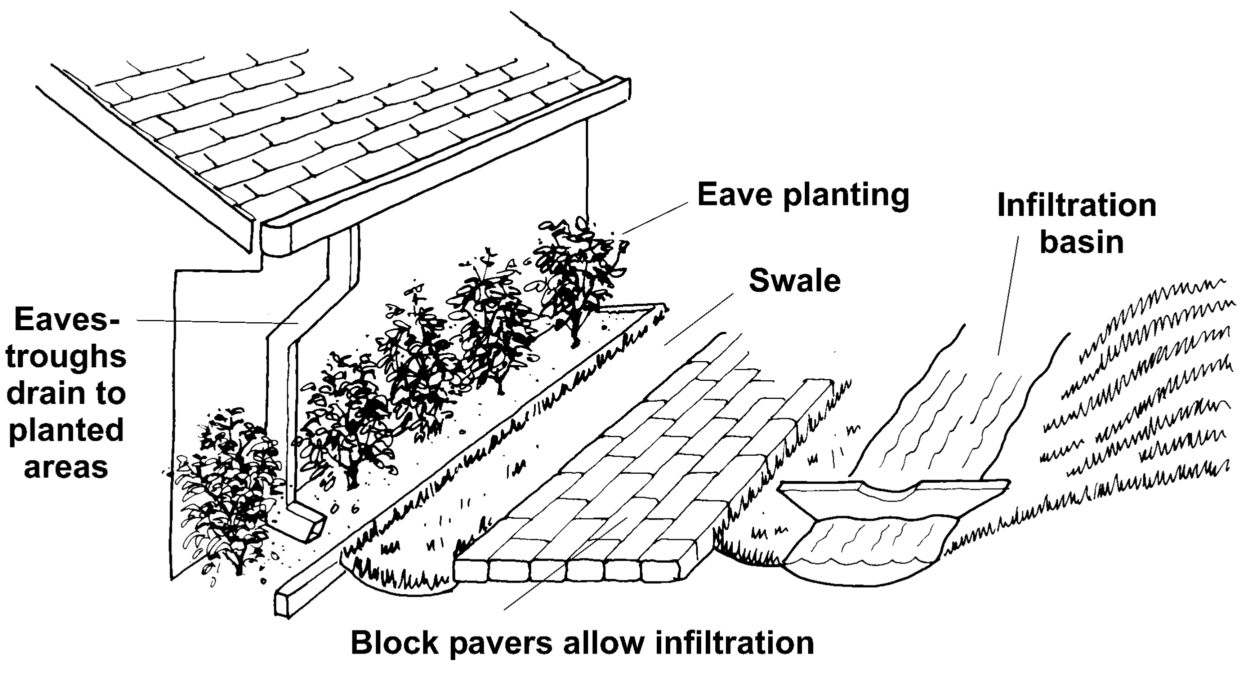
Integration of Stormwater Systems at the Neighbourhood Scale

Grass swales and vegetated strips are shallow depressions with vegetative cover designed to accept run-off. They can be used to transport run-off on the surface to detention areas or catch basins. They also allow for percolation, nutrient uptake and the reduction of the transportation of suspended solids. Swales along roadways can very effectively intercept and store run-off water, especially if the swale is constructed using deep soils, with high organic content (25%).

Dry detention ponds temporarily detain run-off for up to 24 hours, using a fixed outlet to regulate outflow at a specified rate. This allows solids and pollutants to settle out.

Constructed wetlands: Wetlands constructed specifically for the purpose of treating run-off and wastewater are known as "constructed wetlands". These 'permanent pools' temporarily impound run-off, then settle and retain suspended solids and associated pollutants.

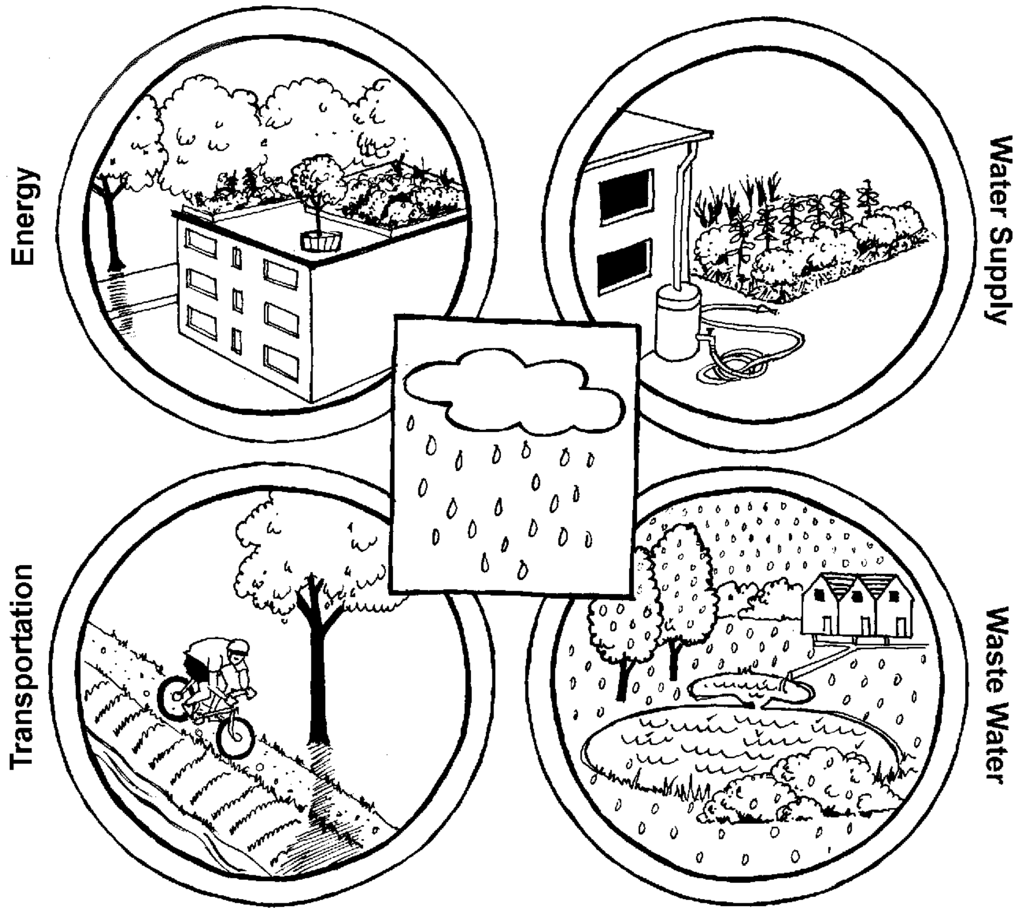
Matching area and type of pond surfaces to their use: Use impervious pavement (concrete & asphalt) only where regular car, bus or truck traffic is expected. Use porous asphalt, paver blocks or large aggregate concrete for parking and highly used bicycle and pedestrian areas. Use lattice blocks for overflow parking, and crushed stone or brick for pedestrian paths.



Integration of Stormwater Systems with other forms of Infrastructure

Elements of Green stormwater infrastructure can be integrated into systems for transportation, food production, sewage treatment, and organic solid waste management. For example:

- Use of deep landscape soils throughout the city not only increases infiltration on-site, but also increases plant growth, and substantially reduces irrigation requirements. These soils can also be used on rooftops, where they act as a temperature buffer, or in community gardens and private gardens where they are ideal for vegetables.
- The organic matter additive to the above soils can come from composting operations that divert organic waste from the solid waste stream, or from composted sewage sludge. On-site composting by occupants can also provide an on-going supply of top-dress.
- Storage of roof rainwater in cisterns not only reduces stormwater impacts, but also provides water for limited irrigation (drip systems), flush toilets or laundry purposes - with corresponding reductions in potable water supply from municipal systems.
- Infiltration systems can be integrated with walking/cycling routes and public squares, by using pervious paving materials and plantings.
- Surface run-off and treatment systems can sometimes be combined with bio-remediation and constructed wetlands for sewage treatment, for enhanced water flows and wetland performance.



Integrating Stormwater Management with Other Systems

Amble Greene, District of Surrey, BC: Case Study of On-site Stormwater Management

To address these stormwater-related issues, some municipalities in British Columbia's Fraser Valley began using innovative stormwater infiltration systems. Designed in 1979, Ambleside Greene was the largest of these developments. The infiltration system in Amble Greene (a development within the larger Ambleside site) is made up of a combination of grass swales and French drains. One small section of Amble Greene is connected to a traditional storm drain system; most of the site is not. The infiltration system is designed to allow continuous and ubiquitous infiltration of stormwater. For enhanced infiltration, the project design calls for a simple street section without a conventional "curbed" road system. The installed system was substantially less expensive than the conventional alternative at that time. In current dollars, the system costs translate into approximately $150 per linear meter of the stormwater system; with a total stormwater system cost for the 153 units of $140,100.

LIQUID WASTE

A Green Perspective

A number of companies and communities in Canada have been adopting integrated, ecological approaches to wastewater treatment and water reclamation.

The growing acceptability of using natural systems for treatment has set the stage for broader application. Green wastewater infrastructure can offer superior service by removing not only pathogens, but also VOCs, hydrocarbons, nutrients, herbicides and pesticides.

Moreover, such systems don't simply manage the wastewater, but instead transform the resource into reclaimed water, soils, nutrients, CO_2 and biodiversity. By incorporating natural systems at a local scale, it becomes possible to re-integrate these resource flows into the "urban ecology" contributing to local industrial processes, while minimizing distribution costs and land use.

Integration at Building and Site

Flow reduction at source: Green wastewater infrastructure begins with measures to reduce the flow of wastewater leaving the building. Stormwater is directed into open drainage systems. Water use indoors is minimized through use of water-conserving fixtures.

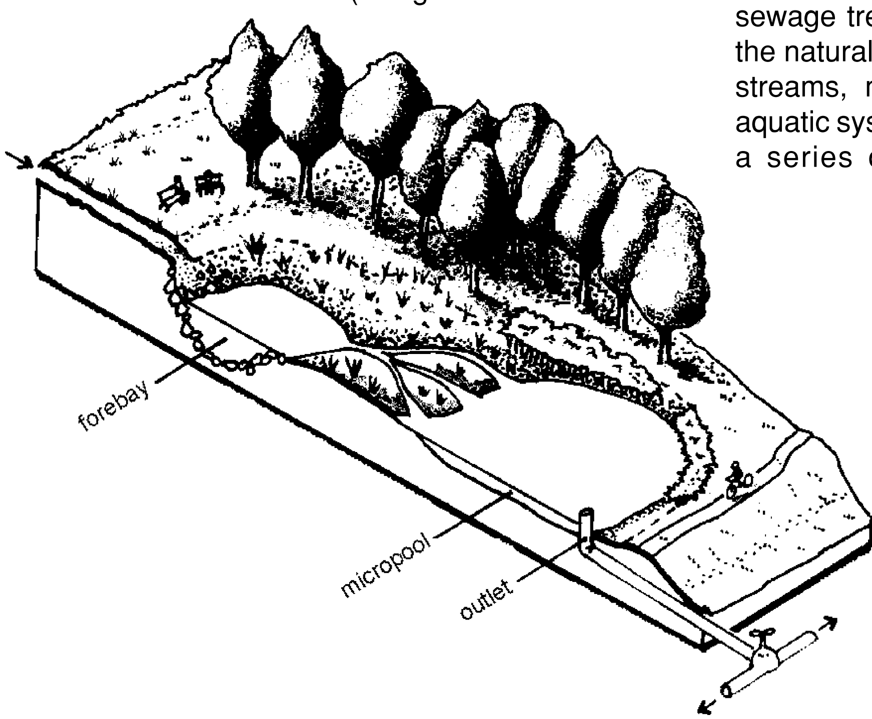
On-site composting: At one extreme it is possible to cope with all the sewage at the building site, using waterless composting toilets. An aerobic composting system is continually ventilated and reduces the volume of waste by 90%. The end product is a humus-like soil amendment product that is rich in nitrogen and other useful elements.

Returning nutrient-rich humus to the earth restores depleted soil conditions. Fluid waste is treated in small reed patches next to building. Substantial amounts of water are saved relative to conventional flush toilets.

On-site primary treatment: It is sometimes an advantage to a install primary sewage treatment system only at the building scale. For example, multi-unit residential buildings in urban areas can be equipped with watertight, concrete septic tanks next to their foundation. These tanks then become the primary treatment stage for all wastewater. The advantage of locating the primary treatment system next to the building is that it becomes possible to provide very low cost, flexible and advanced secondary treatment at the neighbourhood scale. Basically, a submersible pump is used to decant the fluid in each septic tank, and then economically transport the fluid through small-diameter PVC pipes over short or long distances to a neighbourhood scale digester.

Integration at Neighbourhood Scale

Constructed wetlands: Wetlands constructed specifically for the purpose of treating run-off and wastewater are known as “constructed wetlands”. These ‘permanent pools’ temporarily impound run-off, and settle and retain suspended solids and associated pollutants. Two approaches are possible: surface flow wetlands that are suitable for buildings or large clusters, and subsurface flow wetlands suitable for smaller volumes (using 1/4 the land area but at 4 times the cost). When properly designed and operated, surface flow wetland systems are similar to tertiary treatment - they effectively reduce biochemical oxygen demand, suspended solids, nitrogen, metals, trace organics and pathogens in wastewater to levels that meet environmental standards.



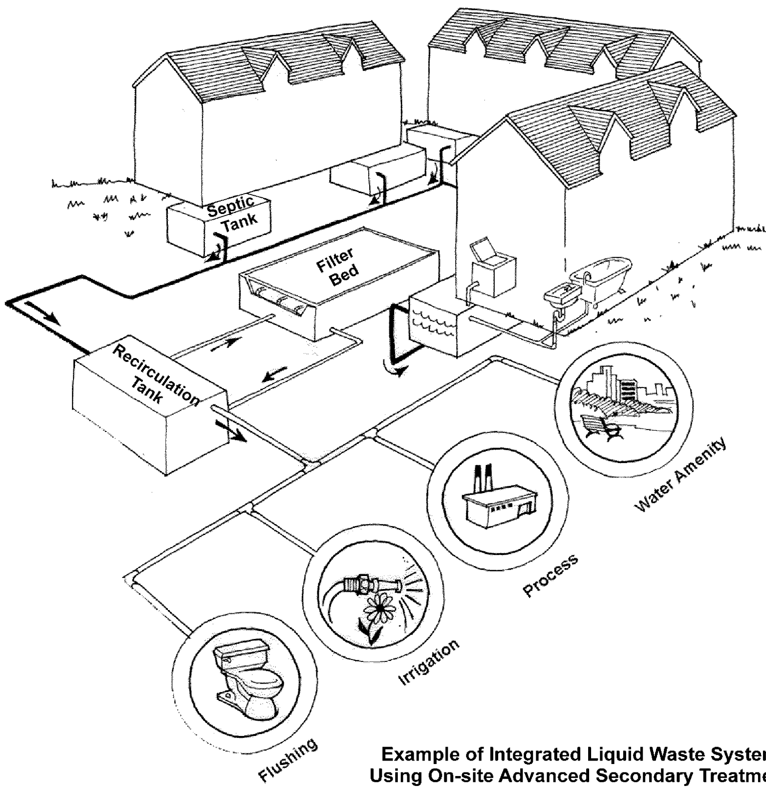
Advanced secondary treatment using aggregate or membrane filtration: These systems can be dedicated to serve large multi-unit residential buildings, or clusters, or even small towns. Essentially a piped system transfers effluent from septic tanks to a central location. A recirculation pump repeatedly sprays the effluent over a subterranean gravel or membrane filter, which drains back to the tank. After 2 or 3 days of periodic spraying, the aerobic digestion is complete, and the effluent is colourless and odourless (although still high in nitrogen). This treated effluent is suitable for use in augmenting and flushing ponds and rivers, and for use in irrigation, in non-potable water systems, and in industrial processes. The filter bed can occupy a small area between the cluster of buildings, where it can serve as a multi-purpose outdoor courtyard for passive recreation activities.

Solar aquatic sewage treatment systems: Solar aquatics is an ecologically-engineered sewage treatment technology that replicates the natural purifying processes of fresh water streams, meadows and wetlands. In a solar aquatic system, the wastewater flows through a series of clear-sided tanks located in greenhouses, and then through engineered streams and constructed marshes where contaminants are metabolized or bound up. Bacteria, algae, plants and aquatic animals are all part of the treatment system. Solar Aquatics technology can be used to treat sewage flows from 20,000-500,000 gallons per day. The treatment has been applied to sewage, septage, boat waste and ice cream processing waste.

Integration of Liquid Waste Systems with Other Forms of Infrastructure

Heat from sewage: In a decentralized water reclamation system, energy can be extracted from discharged water by means of efficient water-to-water heat pumps. The captured heat can then be used to heat water for space conditioning of greenhouses and other buildings.

Methane capture: The decomposition of municipal organic wastes and sewage may produce methane, which can be piped to buildings or to a cogeneration plant for electrical generation and heat. Some sewage treatment plants are powered and heated by methane from this source.



Example of Integrated Liquid Waste System
Using On-site Advanced Secondary Treatment

Reclaimed water: Tertiary treated sewage can be classified and sold as reclaimed water when taken through a number of additional and prudent steps (UV disinfection, carbon and membrane filtration). Alternatively the reclaimed water can be used for irrigation of golf courses, parks and grounds, or for toilet flushing, construction uses such as aggregate washing, concrete manufacture, and wetland and stream augmentation. Permaculture landscaping can help to convert water reclamation facilities into productive and diverse gardening systems, converting the nutrients into useful biomass and biodiversity.

Bioponics: An integration of aquaculture and hydroponics is defined as a "bioponics" system. Usually housed in a greenhouse, these systems can be integrated with greenhouse based water reclamation systems.

Humus: Sludge is collected from sewage treatment plants and used as an organic additive to support the stormwater filtration systems and other types of urban landscaping, agriculture production and land restoration.

Errington, BC: Case Study of a Municipal Solar Aquatic Wastewater Treatment Facility

Errington is a remote mobile home community that suffered from a failure in their sewage treatment system when excessive infiltration overloaded the disposal fields. Their solution was to replace the fields with an above-ground greenhouse. The new Solar Aquatic System was designed to utilize the existing network of septic tanks and pump stations. The homes were fitted with low flush toilet devices, low flow showerheads, and sink aerators. Stormwater flows by gravity into a septic tank from where it is pumped into a blending tank. From there it is processed through a series of solar tanks located in a 210 m^2 greenhouse. The tanks contain pond plants, such as water hyacinths. The greenhouse also supports integrated bioponics - producing compost fertilizers, garden bedding plants, fish and snails, and hydroponic herbs and flowers.

The system was built for $200,000 and serves 46 homes. The annual operating/ maintenance cost is $10,000.

POTABLE WATER SYSTEMS

A Green Perspective:

Green infrastructure for potable water begins with matching the quality of water to the end use, and then cascading the wastewater flows through a series of lower quality uses. High quality potable water is best used only for top-grade drinking water, and by the food and beverage industries. Other functions, such as toilet flushing, landscape irrigation, clothes washing, and so on, can be fulfilled using non-potable water such as greywater.

After matching quality with needs, designers and planners should optimize investments between increased water supply on one hand, and more water-efficient technologies on the other. Investments may be low flow fixtures, water efficient appliances, and drought resistant gardening. High returns are possible from investments.

Load management is a third strategy, and may include on-site storage of water in cisterns, as well as behavioural modification through metering, rate structures, water bans and so on.

Ottawa, ON: Case Study of Water Capture On-site, Mountain Equipment Co-op

The Mountain Equipment Co-op building in Ottawa has a pre-cast, concrete rain storage cistern that stands adjacent to the building. It has a storage capacity of 65,000 litres. Its dimensions are 2.4 m (8 ft) in diameter and 6.0 m (20 ft) high. The storage device receives stormwater from the building's rooftop. The rainfall-capture potential for a 635 M^2 roof in Ottawa is approximately 550,000 litres per year. Water from the cistern is used to irrigate landscaped areas in summer months. An overflow mechanism diverts stormwater to municipal pipes when the cistern has reached its storage capacity.

Integration of Building and Site

Cisterns can be used at the building site to store water captured from roofs, and to provide occupants with a source of water for toilet flushing, irrigation and - with filtration - drinking and washing.

Grey water systems within buildings help to cascade water flows from bathtubs, showers, bathroom washbasins, and water from clothes washing machines, laundry tubs into toilet flushing and garden irrigation.

Two-pipe systems provide buildings with the means for using reclaimed water. The reclaimed water may be generated at the neighbourhood scale from wastewater, and looped back into buildings in a separate piping system for all non-potable uses. An increasing number of cities are adopting two-pipe systems for all new commercial buildings (e.g. in San Diego and Hong Kong).

Integration at the Neighbourhood Scale

Water reclamation: Reclaimed water is wastewater that has been treated to meet or exceed drinking water standards before being reintroduced into the raw water supply.

Integration with Other Types of Infrastructure

Cooling: Potable water can be used as a coolant to provide supplementary air conditioning for buildings.

Heating: Potable water can also be used as a source of heat, if heat pumps are submersed in the wells, reservoirs or storage tanks.

Electricity: Water reservoirs with flow control dams can be equipped with micro-hydro generators for on-site electricity. Windmills can also be integrated with the water system to assist with pumping water from the ground and overland. The windmills provide electricity generation during times when pumping is not required. Water infrastructure at the regional level may require substantial amounts of pumping power and can represent the largest single energy account in a region.

ENERGY SYSTEMS

A Green Perspective

Green energy infrastructure refers primarily to systems that rely on low-impact renewable resources. These resources can vary depending upon the location, and include wind, sunshine, geothermal, run-of-river hydro, tidal and wave power, wood waste, landfill gas and biogas, agricultural, forestry and animal wastes, and lake and ocean cooling. Generally, the use of such renewable resources can greatly benefit from the existing energy grids. The grid absorbs peak demands, and acts as a storage system when renewable sources are surplus.

Green energy infrastructure should be an integrated and planned system that connects all activities within the city. Municipalities in northern Europe have demonstrated the advantages of integrating energy into urban plans, rather than focusing on energy conservation and efficiency in isolation. A planned system helps to ensure a mix of energy supply, and a more effective matching of energy quality to end-use. Buildings and industries become both suppliers and consumers of heat and power. Energy flows are engineered to cascade from the highest quality to lowest quality uses. Distribution losses and transformation losses are minimized by means of on-site generation. The urban form and building placements are carefully designed to optimize use of on-site forces like sunshine, breezes, hydro and heat generating activities. And finally, energy resources are extracted from wastewater, solid waste, and all other resource flows within the city.

As the energy marketplace is deregulated and becomes diverse, all cites will face new choices about their energy partners, their mix of energy sources, and how their energy commodities are converted, stored and transferred. Such choices can radically alter the energy efficiency of the entire city. For example, the City of Toronto converts raw energy resources like coal and uranium into usable energy at an estimated efficiency of 50%, while the City of Helsinki, which uses waste heat from energy generation to heat 91% of the housing, achieves an efficiency of 68%.[1] In future, the involvement of cities in energy systems planning will become an important strategy for enhancing the competitiveness and resiliency of the local economy, and for achieving social goals for affordable housing and a cleaner airshed.

Building and Site

Solar space heating: Many surfaces on buildings can serve to harness solar energy. Passive solar heating already represents about 15% of the energy supply to houses. With appropriate planning and design, this can be economically increased to 20 to 25%. Innovative capture and storage systems can include seasonal shading devices, solar orientation, thermal storage using building materials, and double envelope construction.

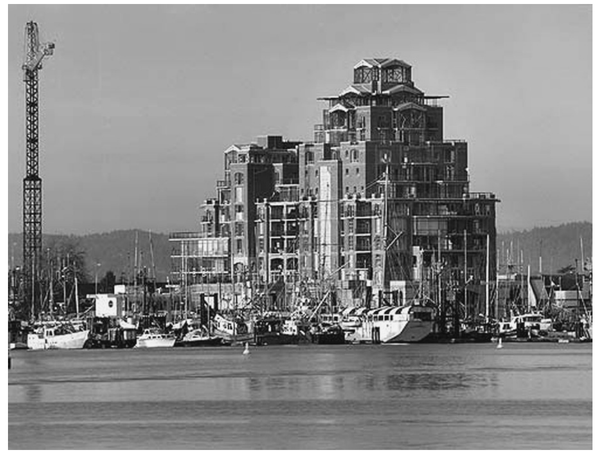
Solar hot water heating at the building level has the potential for supplying over 50% of total needs.

Solar-powered parking lot lighting can replace conventional systems, with on-site batteries used to store PV energy for night-time lighting.

Heat pumps and free cooling systems can be incorporated into larger buildings or clusters of buildings. These systems are especially economical when used to extract heat or cooling from nearby water bodies.

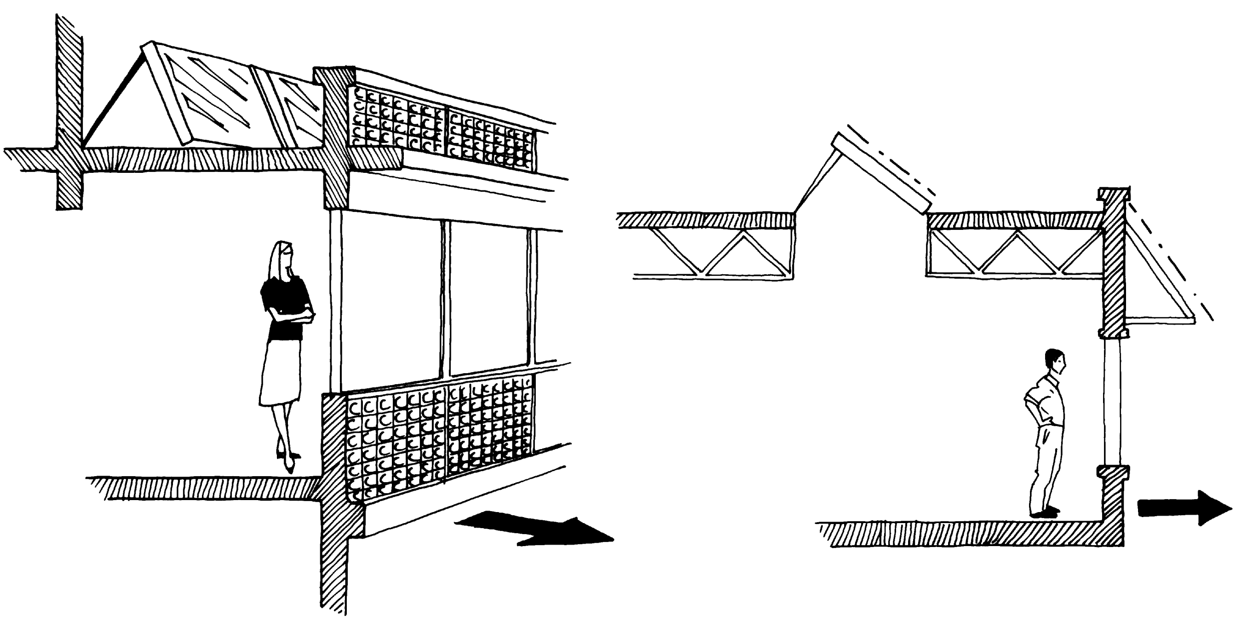
[1] **The Potential for District Energy in Metro Toronto**, Metro Toronto Works Dept., CANMET NRCan, Ontario Hydro, 1995

Shoal Point, Victoria, BC: Case Study of Renewable Energy Supply On-site,



Shoal Point is a residential multi-family development in Victoria, BC. It is a thirteen-storey complex that provides two floors of commercial use below 156 waterfront condominiums. One of the many innovative energy-efficient features is the use of ground source heat to warm and cool the building. A geothermal heat pump in the building will draw ocean water from the nearby Inner Harbour. It will extract and transfer the heat to a circulating liquid that runs through a closed-loop internal system, throughout the building. Suites that have an individual heat pump will extract and circulate the heat into their suite. During hot weather, the procedure is reversed - the pumps draw heat from indoors, dissipating it into the ocean water as well as providing cool air for suites. The system is designed to be an open-loop system, returning the ocean water back to the Inner Harbour after circulation. The technology has a coefficient of performance of 3.0 to 6.0, versus conventional electric or fossil fuel burning technologies that are 0.6 to 0.8.

Photovoltaic panels on roofs and awnings are being used in many residential areas to generate electricity, much of which is fed back into the grid. The grid allows this energy source to be utilized continuously: for example, office roofs supplement power to households on weekends, residential roofs supplement power to the offices weekdays.



Integration at the Neighbourhood Scale

Co-generation at local scale can involve micro-generators sized to match the base heating load for the development. In this way all the waste heat from electricity generation can be used locally, greatly increasing the overall efficiency. Supplemental electricity and heating needs can then be met by grid sharing, or by a combination of other on-site technologies.

District heating can involve using a single boiler complex to supply heat for space and water heating throughout the neighbourhood. Loops of small-diameter, well-insulated hot water pipes efficiently transfer the heat to buildings as far away as seven kilometres. The boiler complex can be located in a larger commercial centre (hospital, mall) or industry that requires a large, well-managed system regardless. The energy resource mix and emission controls for the entire neighbourhood can be adjusted at a single location. Each building benefits from reductions in floor space requirements, higher quality service, and the other benefits of Green infrastructure.

Renewable resources are collected from the regional inventory, and distributed to the building clusters as part of the energy supply system. Local sources may include:

- methane from landfill and composters;
- micro-hydro;
- wind turbines.

Long term storage facilities can be provided at the neighbourhood scale. For example, a large underground reservoir can be heated from solar water heaters mounted on a cluster of buildings. In this way, the heat from summer sunshine is stored for use throughout the winter and contributes from 50 % to 70 % of the overall heating demand in the cluster. The storage volume can be incrementally increased to match the growth of housing, using earth ducts with high mass.

Heat transfer between hot & cold spaces can reduce the total energy requirement. Large buildings may need cooling year round and the heat can be concentrated and piped to smaller buildings that need heating. Ventilation of larger parking garages is another source of heat for nearby buildings.

Integration of Energy Infrastructure with Other Types of Infrastructure

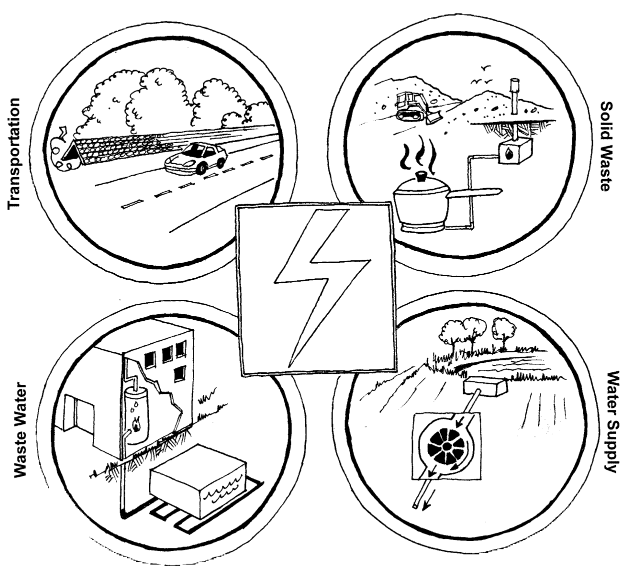
Incineration of solid wastes is sometimes a source of energy supply, if no economic options exist for the recycling of some plastics and organics.

Methane is a renewable energy source derived from liquid waste digesters and landfills.

Heat pumps can draw useful heat from sewage flows and water reservoirs.

Photovoltaic arrays can be mounted along the south-facing walls of highway barriers, and other accessible, low-impact locations.

Mini-turbine generators can be mounted in water supply and stormwater systems, and at outlets of large water reservoirs.



Integrated Energy Infrastructure

SOLID WASTE SYSTEMS

A Green Perspective

Green infrastructure systems for solid waste management are actually systems for managing material resources, and eliminate waste altogether. A Green material management system requires coordination among all the players involved in the supply chain, in order to ensure that materials are designed, packaged, transported, and assembled in a manner that minimizes material use and that facilitates re-use and recycling. The use of toxic products is minimized throughout the construction process, as are superfluous materials for decorative finishing.

To facilitate green procurement policies, manufacturers may choose to become 'service providers'. In this role they are contracted to provide a service instead of a product. Thus any materials and goods remain the property of the manufacturers and are directly repossessed at the end of their useful life.

Elimination of waste means that urban land development must be consciously planned to preserve existing vegetation, compost materials, or landscape debris. Roads and sites should be layed out in ways that help to equalize the cut and fill, thereby reduce haulage and disposal.

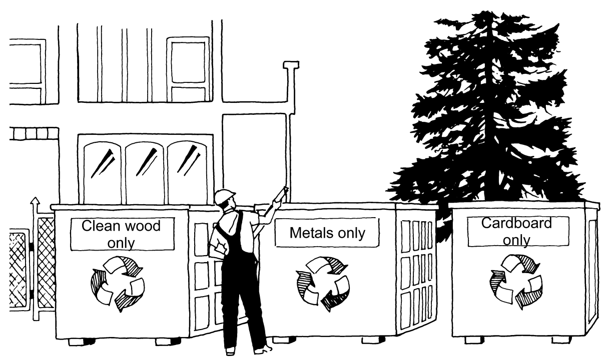
Organic materials from homes and restaurants must be kept within the neighbourhood (instead of being trucked large distances to landfills) and used to enrich the landscape and to enhance the performance of other infrastructure systems. The nodes for collecting, separating, storing and re-using waste materials need to be carefully integrated into the neighbourhood land use so as to ensure accessibility and social acceptability.

Integration of Building and Site

Compost production: Biosolids, biomass and offsite community based organic materials can be composted onsite with combinations of in-vessel composters and vermiculture composters. Heat and CO_2 generated from such activity can be added to greenhouses for increased productivity.

Separation and storage facilities: Waste management at homes, offices and shops can be greatly improved if design guidelines stipulate adequate space for separation and storage, at convenient locations on-site.

Construction waste management plans: A large percentage of the waste stream is comprised of land clearing, construction and demolition materials. The only effective solution to managing this system is for each urban development project to adopt a construction waste management plan, as defined in current publications by CMHC and others.



Integration at Neighbourhood Scale

Re-use it and recycling depots: A key 'node' for Green material management is the walkable re-use it and recycling depot. Such facilities can be integrated with schools, local industrial centres or parks. Depending upon location, scale and local economy, they can handle a wide variety of items from bottle returns to used building parts. They can also function as a place to meet your neighbour and a source of local employment.

Composting:

In-vessel composters are large containers that process organic wastes over a two-week period. A hopper at one end is used to load the vessel. An auger automatically mixes and turns the waste materials. A fan is used to ensure adequate supplies of oxygen. Additional materials may be added to the vessel to ensure that the mix of organics is suitable for efficient composting. The end product emerging from the opposite end of the vessel is humus that can be used in manufacturing soils, and in restoring damaged landscapes.

Vermiculture systems use worms to rapidly digest and sanitize organic wastes, including kitchen waste and shredded cardboard. The end result is more worms, and a high quality organic fertilizer.

Enzyme-based composting systems are proprietary machines that process organic wastes over several days using enzymes that accelerate the decomposition process.

Windrows of organic waste typically require a few acres of land. Raw organic materials such as yard trimmings are laid out in rows and turned periodically. After they are degraded by microbial activity, the end product is relatively stable, reduced in quantity, and free of offensive odours. The humus-like material can be recycled as a soil amendment and fertilizer substitute.

Halifax, NS: *Case Study of Waste Diversion and Composting*

What started as organized opposition to a failed landfill and a proposed incinerator resulted in one of the most innovative solid waste management systems in North America. The HRM has a population base of 350,000, with annual waste generation of 260,000 metric tons. In the early 1990s, after years of usage, the wetland area landfill servicing the region, was discovered to have had caused severe environmental damage that affected nearby residents. Ultimately, the HRM compensated the community, approximately $5 million, and bought out the adjacent homes. The situation prompted a review process to determine a new waste management strategy for the region.

The end result of this process was the Halifax Regional Municipality's (HRM) advanced municipal solid waste (MSW) management system. This system has significantly reduced the amount of waste that goes to landfill, and as a result, contributed to a decrease of approximately 0.5 megatonnes of carbon dioxide equivalent (Mt CO2E) GHG emissions per year, or about 1.4 tonnes per resident compared to 1995, from the municipality's landfill site. The system has also helped achieve a 61.5% reduction in the amount of waste per person sent to landfill between 1989 and fiscal year 1999/2000.

The new system was implemented without a property tax increase. Capital costs, which totalled $70.1 million, were financed through a mixture of public and private capital, along with design/build/operate contracts between the private sector and the municipality. While operating costs for the new systems have been more expensive than the old system, $32.5 million per year compared to $23.4 million in 1996, both public and governmental bodies are satisfied with the new system, and consider the additional costs incurred justifiable. It should also be noted that a significant portion of the operating costs (approximately 33%) is recovered through tipping fees, and that 125 jobs were created through public private partnerships.

The HRM solid waste management system includes an innovative combination of new policies and facilities:

- Residents are asked to separate waste into recyclables, compostables, and hazardous materials;
- Collection zones are rationalized into eight (from 25 before amalgamation);
- A combined mixed waste processing facility, a 13-bed composting system and landfill;
- Two privately-owned composting facilities handling 61,000 metric tonnes per year;
- An expanded materials recovery facility.

The landfill handles stabilized materials only and is virtually methane-free, has no odour problem, and no on-site leachate collection system.

Aerobic digesters use thermophilic (heat responsive) microbes to process organic waste over a 72-hour period with zero harmful environmental discharge. The digested waste is converted into organic fertilizer products with high market value in both liquid and dry-pellet form.

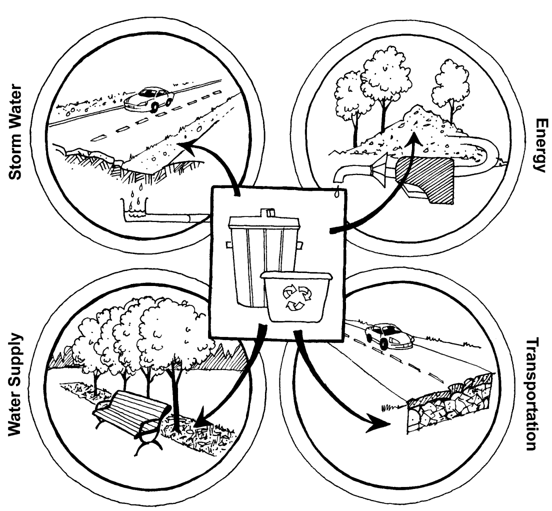
Transfer and sorting stations: Neighbourhoods can accommodate small transfer and sorting stations that can be used to further separate the waste stream and compact the material before shipping to users of the resource. Local stations increase opportunities for workers to live nearby. It may also be possible for other small-scale industry to locate close to the station, and benefit from reduced transportation requirements.

Integration of Solid Waste Infrastructure with Other Types of Infrastructure

Stormwater: Organic waste materials can be composted and incorporated as an absorptive soil additive in an open stormwater management system.

Energy: Local, renewable energy source can include the methane generated from composting solid wastes, and from incineration.

Water supply: Organic waste materials can also be top dressed on landscaped areas, and used to minimize irrigation water supply requirements.



Integrated Solid Waste

Solid waste management depots in the neighbourhood can also be used to reduce requirements for roads and to support lifestyles that include neighbourhood shopping and walking.

TRANSPORTATION AND COMMUNICATION SYSTEMS

A Green Perspective

Green transportation infrastructure begins by redefining transportation as a service. The object is accessibility, not moving people. Hence, the Green infrastructure for transportation may actually consist of land use planning that locates jobs close to or inside houses, and that ensures clusters of services like shops, schools and parks are within walkable distances from most residences. The cluster structure is thus a key design element. Connections between clusters, at varying scales, should provide resource-efficient transport, including the provision of a safe, dependable and convenient transit system, high quality amenities for non-vehicular transport (bicycles and walking) and the provision of amenities for non-fuel powered vehicles. Connections are also important, since communications technologies can sometimes provide access with less movement of people, vehicles and materials.

Electricity generated from renewable resources is especially well suited for light rail systems and trolleys. Longer distances between major nodes are best suited for mass transit. European cities have demonstrated that it is possible to lure people out of their single occupancy vehicles when dense mixed-use neighbourhoods are combined with extremely clean, convenient and affordable transit. Ultimately, we are looking for a system that discourages use of private vehicles inside cities, and that converts the large road surfaces and fuel expenses into amenities that improve the quality and scope of living within the cluster.

Integration of Building and Site

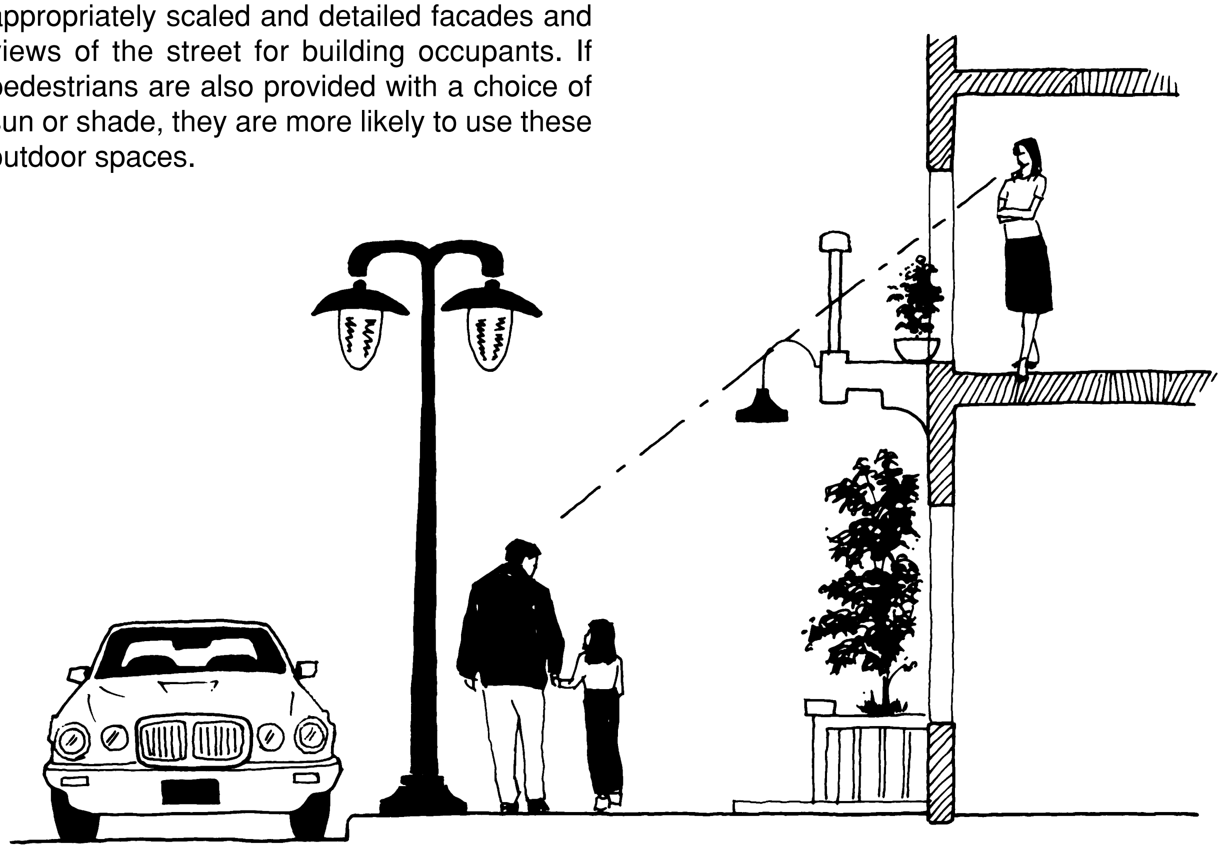
Complementary building occupancies: Locating several complementary occupancies within a project – housing, services, retail, commercial and/or light industry – often eliminates the need for many automobile trips, as occupants use lower-impact transportation modes such as biking, walking and transit. Parking spaces in mixed-use buildings and developments can often be shared between occupancies with differing schedules, reducing the area of impervious parking pavement, stormwater peak flows and pollution.

Pedestrian and bicycle amenities: The need for automobiles is also reduced by making streets safer and more attractive to pedestrians, by providing bicycle facilities at destinations and by creating safe, continuous bicycle paths. Building design can encourage these options by providing secure bicycle parking, showers and changing facilities. Building designs can improve the comfort and safety of pedestrians with appropriately scaled and detailed facades and views of the street for building occupants. If pedestrians are also provided with a choice of sun or shade, they are more likely to use these outdoor spaces.

Live-work spaces: Building designs can include swing spaces that can be easily converted into home offices with soundproof walls, direct access to exterior, and suitable wiring, cable connections and lighting.

Comfortable and convenient access to transit: Design details can make a big difference to the level of accessibility and comfort provided to transit users. A clear line of sight to transit stops is ideal, with paths that avoid crossing traffic, and with weather protected shelters over doorways, transit stops and high traffic pathways.

Charging facitilies for electric vehicles (EV):
Access to charging stations may show market penetration of electric vehicles. The solution is for each building to promote at least one EV parking stall for every 20 on-site stalls.



Best Practices for Green Infrastructure

Integration at Block and Neighbourhood Scale

Network of pathways: The provision of pedestrian and bicycle paths encourages walking within the neighbourhood as an alternative to driving to other locations to satisfy basic needs. Paths should connect residential areas to amenities as well as to neighbouring communities. A fine-grained network will include local connections within blocks that in turn connect with a neighbourhood system as well as the larger citywide network.

Integration of Transportation Infrastructure with Other Types of Infrastructure

Transportation routes can serve as integrated utilidors with pipes for heating, cooling, methane, hydrogen, communications and so on.

Transportation: Walk and cycle paths can also function as filtration strips for stormwater.

Solid waste: Walkable communities can use central locations to provide residents with easy access to material recycling and re-use depots.

Stormwater: Urban run-off from paved surfaces can be reduced and treated on-site if the road surfaces are minimized and if the remaining non-vehicular pathways and open areas are designed to be permeable. Natural landscaping can also be integrated into car parking areas, where it can help to treat run-off and replenish ground water supplies.

Energy: Shading of parking areas and building surfaces reduces the amount of solar radiation reaching them, which can in turn significantly lower energy demand for building cooling.

Best Practices for Green Infrastructure

Portland, OR: Case Study of a Transit-oriented, Pedestrian-friendly Housing Project

The 3.7-acre infill mixed-use development includes three housing projects and two commercial/retail areas that collectively provide a range of affordable rental housing prices and sizes and the potential for convenient residential services. The development process was highly collaborative, with the general contractor, major subcontractors, engineers and designers all involved in the design process from the beginning. The development illustrated the importance of establishing a dialogue with the various city agencies involved in the implementation of projects.

Environmentally sound business practices were a major goal of the project. The development specified materials with high recycled content for the insulation, sheet rock, carpet pads, and finishing materials, participated in construction period recycling, applied low-VOC, non-toxic adhesives and paints for improved indoor air quality, installed energy star window (21% more efficient than code requires), and utilized continuous ventilation systems. The landscaping is maintained without the use of pesticides, and biodegradable cleaning products are used in the building.

The developer chose the property to use existing public transportation infrastructure and convenient, underused location. The project is within walking distance of major shopping and community centres, light rail buses, employment districts and recreational facilities. Situated in a neighbourhood within Portland's central city, the project is located nine blocks from light rail, within five blocks of four high-frequency bus lines, and surrounded by a growing network of bike lanes and routes. Locking bike racks, lockers to store bike equipment, pumps, and a workstand for resident use are all provided on site. CarSharing Portland, Inc. located several vehicles at the complex, and with help from the City of Portland, head-in parking was added to narrow the street, slow traffic and create a pedestrian buffer.

Issues surrounding water conservation and stormwater were addressed with the installation of low-flow plumbing fixtures and close to 95% on-site stormwater management (half of the site posses 100% on-site management, the other half experiences 80-90% on-site management). On-site stormwater retention and mitigating features include narrow driveways, several bioswales, a 2,000 sq/ft extensive green roof, permeable surfaces and a back-up dry well.

5. Common Obstacles to Greening your Infrastructure

Understanding the form and function of Green infrastructure is the first step. However, integrated multi-functional infrastructure projects are, by nature, a difficult sell. Many of the benefits are indirect, the risks appear to be substantial, and the number of stakeholders can be overwhelming. The change management strategy must address many challenging obstacles.

FORMULAE THINKING

Engineers have been trained to use slice-and-dice, component-based design methods that are simple, clear and wrong because they optimize components in isolation (thus "pessimizing" the systems of which they are a part) and focus on single rather than multiple benefits.

FRAGMENTATION OF AUTHORITY

Historically, the development of each type of infrastructure occurred at different times, largely in isolation. This has left us with agencies, industries, and monopolies organized around specialized mandates and with compartmentalized worldviews.

FRAGMENTATION OF ECOLOGIES

It is especially hard to respond to local carrying capacity and constraints if other decision-makers erode the benefits. For example, reducing pollution in your valley or river can be pointless if another jurisdiction, upstream, then chooses to pollute at much higher levels. For example, the British Columbia lower mainland has been improving air quality for the last 10 years, but this is now threatened by a proposed power plant to be located just across the US border.

SUNK INVESTMENTS

The very substantial capital outlays that have been dedicated to existing infrastructure can eliminate the potential for cost savings from Green infrastructure. Sometimes property taxes are already predicated on paying for larger, centralized systems, and thus anyone who invests more money to reduce reliance upon such systems ends up paying twice.

INFLEXIBLE POLICIES

Many types of existing policies prevent holistic thinking and on-site applications. The worst problem is the many prescriptive policies that only recognize one way of achieving results (the status quo) and thus frustrate innovation within the marketplace. Health and safety policies may not reflect the new ecological technologies, and the relative importance of protecting environment. Land use policies may run completely counter to the concepts of mixed use and urban ecology.

BUNDLED FEES

Subsidies and fees are often structured in ways that are insensitive to variations in user loads and consumption rates. For example, development cost charges may be based entirely upon factors like zoning and floor area, despite the possibility that the design of greener buildings and on-site infrastructure may reduce or even eliminate the requirement for certain types of municipal infrastructure investments.

RATE-BASING

The common practice of distributing new capital costs across all users of a service can sometimes send the wrong message to those customers making investment decisions. It may be many times less expensive for a builder, for example, to reduce electricity loads or peak water consumption through on-site technology, than for the utility to invest in increasing the supply at the margin. However, the financial incentives for the builder are lost because of rate basing. All users pay the price of servicing the building instead of the one with power to decide. This situation is especially problematic when - as is often the case - a small increase in the load from the building sector results in the need for a whole new power generator or water reservoir. In essence, the builder and new home buyer save a few dollars in the short term, while the entire ratepayer population is forced to pay far more than necessary.

LARGER UTILITIES SUPPORTING STATUS QUO

Despite efforts at deregulation, it is still possible for large utilities to influence the market, and to purposely under-price new initiatives that threaten their market base.

LACK OF COMPREHENSIVE COST/BENEFIT MODELS

Cost/benefit modelling of infrastructure options cannot currently account for the potential benefits of integrated systems, since the models are not broad enough. Although saving water typically saves energy, decision-makers do not consider these types of ‘indirect’ dollar savings.

6. Tools For Making It Happen

The many obstacles to Green infrastructure emphasize the importance of adopting methods and tools that contribute to successful change management. Some especially useful strategies are outlined below. Cities that adopt such strategies and learn as they go are cities that will remain in control of their fate, and reap the benefits.

TOTAL COST ASSESSMENT

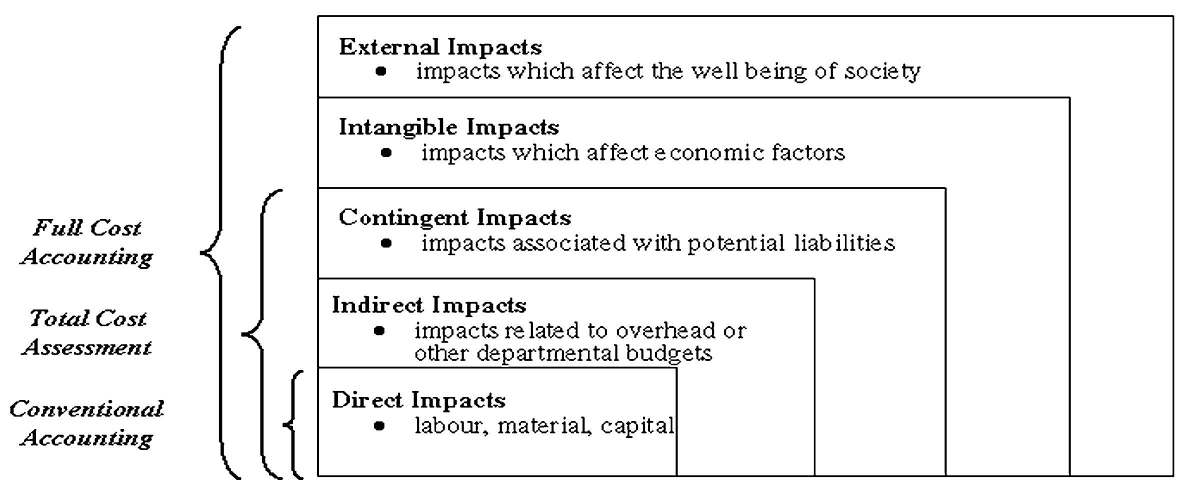
Green infrastructure is a non-starter as long as cities apply conventional accounting practices, that separate budgets into 'silos', and that reward false economies. For example, a city engineering department may choose to save costs by purchasing less efficient and less costly aerators for sewage treatment. However from a 'total cost' perspective the savings are false, since another department will have to pay extra costs in order to operate the aerators over the next 15 years. The solution is Total Cost Assessment (TCA), which expands the analysis to include a broader range of direct, indirect, contingent and less quantifiable costs.

TCA can optimize the looping of money and reallocation cost savings from one type of infrastructure to another in order to finance the lower cost integrated system. For example, if mixed-used communities require less travel and therefore smaller roads, it should be possible to take money from the roads budget to pay for amenities in the denser, mixed-use areas of city. Instead of paying for highway construction and upkeep, invest in building designs that allow people to work comfortably at home, and in improved systems for co-ordinating tele-workers and buses. To achieve highly integrated systems, it may be necessary to create a "megafund" for redistributing money across all classes of infrastructure interventions. Each infrastructure system should compete and cooperate in their proposals to access part of the "mega-fund", thereby forcing their financial departments to adopt TCA methods.

THE INTEGRATED DESIGN PROCESS

Many Green infrastructure solutions are intimately related to decisions about urban form, open space and land use. Thus it is vital to consider the infrastructure simultaneously with land use concept planning - something which is not usually done nor typically required as part of the Development Approvals process. The best method for addressing these issues is to require that partners and departments adopt the Integrated Design Process (IDP) for all major site development and construction/renovation project planning.

IDP involves creating a design team with a wider range of technical experts, local stakeholders, and partners than is normal. It engages more of these participants at very early stages of the project, and uses their expertise to influence seminal design



decisions. The entire design team may participate in a target-setting workshop at the beginning of a project. Energy modelling and value analysis may be conducted in parallel with concept design work. 'Whole-system engineering' may be used to provide broad thinking about technical options. A facilitator may be hired to ensure successful team meetings with large numbers of participants.

Because more decision-making is made in the early stages of design, more time is needed up front in the design process. However, the additional time taken up front is usually recovered during the construction documents phase, due to early decision-making and better co-ordination between disciplines. IDP will provide satisfied clients more effective and controlled public input, and infrastructure plans that are optimized for higher performance.

PUBLIC-PRIVATE PARTNERSHIPS

With a separation between private and public ownership of buildings, and with fragmented management of utility systems, it is getting increasingly difficult to finance multi-media and multi-company utility capital projects. For example, shared utility collectors are rare even in locations where local building and land use conditions are favourable, such as revitalized downtown areas.

A key role for the municipality is to partner with businesses to help create more integrated and smaller scale infrastructure systems. While the municipalities' role in such partnerships may remain small, their involvement adds a large measure of confidence to the investors and to the marketplace. Lowering the perceived risk among stakeholders makes it easier to finance such projects at affordable rates. For this reason municipal participation, in the form of public private partnerships (PPPs), can be an essential enabling strategy.

MICRO-UTILITIES

Neighbourhood scale integration raises substantial difficulties in terms of ownership, liability and maintenance of infrastructure systems. Often this is the greatest obstacle to embracing Green infrastructure. One solution is to facilitate the creation of small, community-based utilities that are capable of managing all aspects of shared infrastructure for the cluster. Every connection (i.e. everyone connected to a sewage system) is then automatically a stakeholder with revenue incentives to use the system responsibly. Success of resource recovery approaches may require some guarantee of buyers for the products. Stakeholders have a built-in incentive to consume the products (trees, water, bedding plants, flowers, tropical plants, compost, materials, etc.) from their "own" utility thereby supporting its revenues and their dividends.

URBAN ECOLOGY PLANNING

Ecological city planning involves land use planners and engineers in co-ordinating the flow of resources with the needs of consumers, and the localized industrial strategy. Like a natural ecology, an urban-industrial ecology should be designed to create no waste. Instead, resources (or nutrients) cycle through different processes (or organisms). If the local industry uses lots of water, urban planners must look for other industries that can locate nearby, and re-use the same water. If the local agriculture creates lots of fibre waste, urban planners look for industries that can use the fibre for other uses, or as a source of energy. If local office buildings need to be cooled in winter, planners must consider locating smaller buildings nearby so the waste heat can be pumped to where it is beneficial. It is these types of perspectives that must influence land use patterns and facilitate use of on-site renewable resources and local waste products.

Urban and industrial ecology planning requires cities to partner with their pillar industries, and with local educational institutions and specialist consulting teams. The goal is to explore new scenarios for urban energy and material flows. The research involves examining the interface between land use and infrastructure, on the one hand, and the marketplace, industrial processes, local resources, and skills on the other. This is obviously not an easy task, but the environmental benefits of waste utilization and the improved system efficiencies are likely to exceed any other city initiative.

RISK MANAGEMENT

Civil engineering is a discipline that is by nature risk- averse. However, a number of strategies may be used to help manage change and facilitate the acceptance of unfamiliar Green infrastructure technologies. The first strategy is to reduce the perceived risk by means of three tools:

1. **Pilot tests.** Significant changes are best introduced in stages, so that results can be carefully evaluated before widespread adoption. Pilot projects are often the most effective learning tools, and are particularly well suited to Green infrastructure. A pilot can happen at a small scale quickly and can take advantage of the redundancy provided by larger existing systems.
2. **Contingency plans:** The plans must clearly outline the approach to resolving failures, and may actually layer Green infrastructure on top of traditional infrastructure for his purpose.
3. **Precedents:** Past experience with similar technology should be well documented, and used to verify the innovative technology or process that has been proven to work well in another location. The only major variable should be the local conditions.

Another strategy is to find better ways of sharing risks. Sometimes the greatest risk is borne by the developers and professional designers, or by the city engineers and planners that approve and permit the new projects. These people may be risking their careers and reputations because they are not sticking to accepted "professional standards of good practice". Since innovation and experimentation is necessary and ultimately beneficial to the entire community, their personal risk needs to be underwritten by the community. A revolving performance bond is one example of how this risk can be shared. Essentially, a fund is created to "guarantee" performance of projects that appear to reflect the best application of Green infrastructure principles.

POLICIES THAT REWARD PERFORMANCE

Policy reform is a crucial prerequisite for Green infrastructure. This is sometimes referred to as an 'Alignment Strategy'. Basically, a process is created that ensures each policy document, from top to bottom, is revised to reflect new commitments towards sustainability. The changes are first outlined, and then implemented over several years, in accordance with the pre-existing schedules for policy review and revision. Some policy tools that are especially useful when aligning municipal and utility documents are marginal pricing, regulations requiring Green technology, and the use of broad-based weighting systems for evaluation of project proposals. Some excellent literature can be found on this subject[2]. J. Atcheson, of the USDOE, has established 10 principles[3] for designing environmental regulations in the 21st century, (see below).

Policies for Encouraging Lean and Mean Management

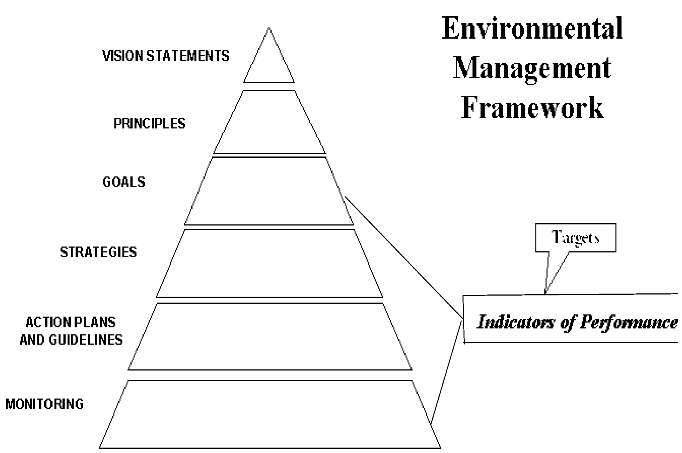
1. **Focus on facilities, communities and ecosystems.**
2. **Emphasize multi-media, multi-stressor solutions.**
3. **Base standards on required performance, not design.**
4. **Emphasize continuous improvement, not fixed compliance.**
5. **Expand the use of measurement and feedback.**
6. **Increase community involvement in setting goals and evaluating progress.**
7. **Provide different levels of regulation for different levels of performance.**
8. **Use fiscal tools and market incentives whenever possible.**
9. **Regulate at the lowest jurisdiction possible; assign responsibilities to the jurisdiction best able to carry them out.**
10. **Coordinate policy changes so they are concurrent and coherent.**

[2] A good reference on policy implementation is: Young, M.D. (1992) **Sustainable Investment and Resource Use, Equity, Environmental Integrity and Economic Efficiency**, Man and the Biosphere Series.

[3] Adapted from: Atcheson, J. *Management Systems: Getting Lean, Getting Green in the USA*, in **Environmental Management Systems and Cleaner Production**, R. Hillary, 1997, John Riley & Sons

AN ENVIRONMENTAL MANAGEMENT FRAMEWORK

A comprehensive Environmental Management Framework is another vital tool for steering an effective public process and brokering Green infrastructure solutions. Frameworks create a mental map for setting and justifying specific environmental recommendations. They become the underlying structure through which cities can transcend motherhood statements and provide tangible, measurable targets for designing and assessing the performance of a community. Frameworks have recently achieved considerable success in helping diverse groups reach consensus and create bold visions[4,5] A typical framework can be represented as a pyramid that has, at its top, a definition of sustainable urban development, the fundamental principles of eco-city planning, and the creation of a unique 'vision' for the community. From this pinnacle, the framework divides into a spreading tree of elements, at increasing levels of specificity, until at the bottom it addresses the monitoring of performance for new systems. Each level in a typical framework is described below.



Principles are broad motherhood type statements that are intended to set the direction for all activities and to define the priorities. Stewardship of the natural environment is an example of a principle.

Goals elaborate upon the fundamental principles and define the ultimate condition desired. Each principle can have a number of goals associated with it. Sometimes called objectives, goals can indicate the direction of change that is desired. Maintain and enhance the ecological function of the site is an example of a goal.

Key Strategies identify the basic approaches that can be implemented in order to achieve a goal or a set of goals. A goal can be linked to a number of different key strategies. Generally strategies should be selected that are known to address more than one goal, as this demonstrates a comprehensive approach and the achievement of synergies. Preserve natural drainage patterns on all sites is an example of a key strategy.

Specific Actions provide a range of activities that can be implemented in order to fulfil the key strategies. By virtue of the clear link of key strategies with goals and principles, it is also clear how the specific actions address the higher layers of the framework. Reduce the impermeability of sites is an example of a specific action.

Guidelines and Specifications provide much more detailed information on how to implement specific actions. For example, guidelines on reducing site impermeability can be prepared.

Monitoring Systems close the loop of the process through tracking and measuring changes in performance on an on-going basis. This information can be used to demonstrate whether strategic direction is appropriate or whether further changes are required. Monitoring and communication of results are linked to improved environmental performance.

Frameworks work best when combined with performance indicators and targets. Performance indicators quantify the impact of specific actions, and therefore help to determine if the specific actions are being successful in their intent. Targets are a kind of policy tool that set ideal levels of performance. Two kinds of indicators are useful:

Design indicators are performance values that can be measured or estimated at the design stage, and that can be used to set targets for challenging designers and coordinating and apportioning their effort. Percentage of site area covered in effectively impermeable surfaces is an example of a design indicator. An example of a desirable target would be 10% effectively impermeable area.

Monitoring indicators are performance values that can be used to measure how well a particular project is actually performing. They can assist in learning and in setting procedures for managing systems and allocating costs. Percentage change in quality and quantity of water running off the site is an example of a monitoring indicator. An example of a desirable target might be no net change.

[4] Sheltair Group, **Environmentally Sustainable Development Guidelines for Southeast False Creek, A Policy Development Tool Kit**, 1988, for City of Vancouver

[5] **Whistler Environmental Strategy**, Resort Municipality of Whistler, September, 1999

Tools For Making It Happen

WATERSHED MANAGEMENT

Jurisdictional boundaries for urban planning typically exclude substantial portions of the city's watershed. This can increase uncertainty and risk of failure. Policies need to be based upon reliable predictions of water availability and quality – issues that can only be considered in the context of the watershed.

In an effort to improve planning, a number of states and nations now insist upon watershed planning as a parallel exercise to urban planning[6]. A watershed plan analyzes all of the water flows in and out of the watershed (creating a water balance) and attempts to allocate the limited resources equitably. The plan should also match the quality of water to the end use, and create watershed-wide policies to minimize risks of flood, disease, and drought. The absence of watershed planning is especially problematic for the many cities trying to conserve scarce water resources. Without an effective watershed plan, the city is unable to optimize investments and address wasteful practices by industries and farms.

GREEN BUILDING AND DEVELOPMENT GUIDELINES

Barriers to implementation of Green infrastructure by developers, and by the design community, include lack of knowledge, lack of time, fear, and perceived cost. These barriers must be overcome by supporting new standards of practice. Such support can be provided through fee subsidies, and through guidelines that include standard details and specifications.

The emphasis must be on providing designers with practical knowledge of solutions, at exactly the time and place when such knowledge is helpful. If solutions will take lots more time to research than standard technology, there is a built-in disincentive to change. For each innovation, designers need to know:

- who are the suppliers of integrated, tested construction solutions?
- what are the engineering standards?
- what are the most economical methods?
- what are the maintenance requirements? and
- where can he or she view successful installations?

Very few cities have specific regulations and guidelines that address the overall environmental performance of buildings, despite the major impact of building design on urban infrastructure and the quality of the environment. Without a set of guidelines, it is probably impossible to achieve significant movement towards sustainability at the scale of the building and site. Guidelines can be applied directly to all public sector projects. They can also be enforced in the private sector as building by-laws. More commonly, guidelines for the private sector become part of an incentives package, wherein special benefits are conferred to developers who comply. It is also possible to implement a revenue-neutral fund, that collects money from developers that fail to implement the guidelines, and distributes funds to others who go beyond the minimum recommended performance levels.

Guidelines can cover a broad range of topics and can address either the development planning process, or the building design process. A recent publication[7] for the City of Santa Monica contained 94 separate guidelines for green buildings, and included everything from the site and form of buildings, to energy control systems. Each guideline contains schematics, references, technical guidance and a rating system. A portion of the Santa Monica guidelines have been mandated by law.

Experience with implementation of guidelines suggests that they work most effectively when they are objective-based, and linked to a framework of goals and targets. Guidelines also work better if they include performance-

[6] One example is: **Guide to Watershed Planning and Management,** Economic and Engineering Services Inc., for the Association of Washington Cities, et al, 1999

[7] Sheltair Group, City of Santa Monica Green Buildings Design and Construction Guidelines, 1999

based evaluation procedures wherever possible, since this allows developers to adopt innovative approaches as long as they still achieve the same intent. Finally, guidelines can benefit from existing technical programs and rating systems developed by other authorities. By referencing such 'third party' standards, it becomes possible to simplify the guidelines, and adds support to larger initiatives that may provide on-going technical support. For example, a number of cities have implemented higher energy standards for buildings by simply specifying that developers achieve a level of performance 30% or 50% better than the national energy codes for buildings.

Guidelines can sometimes incorporate or translate environmental performance targets that have been established for the city as a whole. Firstly, the monitoring targets are translated into design targets for the building sector, so they can be easily understood and applied by designers and developers. Secondly, the design targets are supported by guidelines that amplify and explain the targets. For example, a monitoring target related to habitat creation might be: *Achieve 35 species in the annual bird count for the neighbourhood*. This monitoring target can be translated into design targets for landscape architects: e.g. *30% of the open space on the site will have habitat quality*. A guideline would then explain what is meant by habitat quality, how it is measured, and the best practices and references that can be used by designers. In such ways it becomes possible to operationalize the city's environmental targets during the design and construction stages.

INCREASED USE OF ENERGY AND MATERIAL FLOW MODELS

The next threshold in planning technology is the creation of a bottom-up urban forecasting model that can use a community database to predict, in real time, the actual costs, resource consumption, and emissions associated with development plans. Essentially such a model will need to simulate the interaction between buildings and other elements of the city (infrastructure, people, ecologies) and aggregate the net impacts on resource use, costs and emissions. Impacts must be expressed using standard indicators of performance. The model must account for the dynamic relationships between sectors, between resources, and between supply and demand systems.

Unfortunately, the current state of the art does not provide planners or designers with access to such a multi-resource, multi-sector model. Instead what has been occurring is a slow evolution towards such a model, as a wide variety of more specific applications are used for design and planning purposes. Combining the results from, say, a transportation model and a demographic model, is the difficult part, since the boundaries of the models and the units can be so different. Another major methodological problem is that infrastructure adjacent to buildings is not just serving these buildings but, due to its network character, other locations and buildings as well.

Until better models exist, the challenge for urban planners and developers is to accurately estimate and apportion the costs and benefits associated with Green infrastructure options.

RULES OF THUMB FOR SELECTING OPTIMUM SCALE AND LOCATION

In the absence of sophisticated modelling and forecasting tools it is especially difficult for planners to identify the best location and scale for providing Green infrastructure. When viewed in isolation, the optimum scales for power supply, heat supply, solid waste treatment and sewage treatment may be different from each other. However, as we move towards an integrated circulation system of energy, material and water, we must find the optimum scale of the integrated system. Adding to the complexity is the likelihood that each scale offers difficult trade-offs between economics, environmental impacts, thermodynamic efficiency and community acceptability. At a very local scale, innovative design solutions can sometimes achieve a good compromise among the competing objectives. But as the spatial scale expands, it becomes much harder to achieve design solutions, and more reliance must be placed upon process solutions. In other words, larger scale integration of infrastructure becomes less ‘physical’ and more institutional and dynamic. Instead of selecting renewable energy technologies for all buildings, for example, the best solution may be to facilitate trading greenhouse gas reduction credits between new and older developments.

For all these reasons, the design process may fail unless designers recognize that issues are frequently too complicated to be resolved by any single project design team.

One method for avoiding complexity is to use ‘rules of thumb’ to simplify the decisions until better tools are available. A rule of thumb for transportation planners, for example, might be: *average residents will forsake the car, and walk instead, if the distance to shops, transit, and services is no greater than 400 metres*. This rule makes it easier to design pedestrian-friendly infrastructure, without sophisticated modelling.

Two broad rules of thumb that can be applied to all Green infrastructure projects include:

Adaptable communities need diverse technologies. Thus what seems best at the local scale may not be best if applied everywhere else.

Green infrastructure is evolutionary. In the short term the systems may not be sustainable. However, they must create a situation or opportunity that will facilitate changes to longer-term sustainability.

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