3.

City metabolism – Resource flow management

3.1 Building municipal flow infrastructures

(3.1-3.2 by Lars Rydén)

For the traditional farmhouse in the countryside flow managment was straightforward and handling of resources and waste - recycling - easy. The food came from the farm, the waste went back to the soil, and most physical needs from buildings to clothes were provided for at the farm. Cities, by comparison, are found at the other extreme. In cities we very seldom see either the beginning or the end of the material flows we are part of. Villages are somewhere between these two extremes.

A basic principle in sustainable resource management is that shorter cycles are better. Short cycles are energy-wise cheaper, risk less pollution and require minimal investments in "infrastructure", (infrastructure refers to all kinds of physical arrangements needed for the flow management, from horse carts for wood to sophisticated electricity grids). Shorter cycles are also closer to the biologial situation.

Also in cities each household originally took care of its own sewage and toilet waste, heated the house and provided light with for example kerosene lamps. But as cities grew, this became increasingly disadvantageous. At the end of the nineteenth century, as part of industrialization, several kinds of infrastucture were introduced in European cities. Removal of sewage and solid waste was required for sanitary reasons. Toilet waste and heaps of solid waste attracted flies, rats and other disease-carrying animals and spread odours.

The first energy supply networks were gas piplines from gasworks built at the end of last century. Gas was used for heating, for cooking, and for lighting in the streets. Not long thereafter, electric grids were introduced. Electric power was first used only for lighting, it provided 'the white light'. Later were added many other purposes both domestic and industrial. Electricity was originally generated in electricity works using diesel or gas, but soon it arrived in cities and households over electricity grids from remote power stations. Finally, the telephone network added to an increasingly complicated infrastructure.

A new phase of development started much later, after the 1950s. Then district heating was made available through hot water distribution. The many individual boilers or furnaces in thousands of households were less efficient and, if burning coal, resulted in air pollution and smog, especially in winter.

In the 1980s district cooling has become available in some larger cities, while information distribution has been supplied with cable TV networks and Internet lines.

A community, just as an ecosystem or an organism, depends on exchanges with the surrounding world. Inputs of material, energy, food, water and information are converted and returned as outputs or waste emitted to air, water, and soil.

In ecosystems the various flows are interlinked and waste from one organism is a resource for another. All materials flows are part of cycles. In a sustainable regime the same principle should apply to the functions of a community.

This is easier when the cycles are shorter as on individual settlements on the countryside. Flow management in large cities, especially those on water-fronts, on the contrary represent a challenge for sustainable development.

3.2 Connections between parts of the infrastructure

In most cases it is the municipality which owns the services and structures needed for a city. The municipality builds and owns water works, sewage treatment plants, electricity or gas works and district heating plants. The city also collects fees for the services or finances some of it from taxes.

There are many connections between the different networks. The fresh water supply runs continuously into the sewage system as the water is used. Food and material provision and waste removal may be connected to the energy systems through incineration of waste and the use of heat for district heating and electricity production in power plants.

The sharing of space in the underground system of the city for many systems is important for limiting the cost of the building of infrastructure. It is interesting to note that the costs for several of the infrastructures discussed are similar. It probably depends on the fact that the major cost for all of them is the construction of underground tunnels.

Table 3.1 The components of municipal infrastructure

System	*Infrastructure*	*From*	*To*
Water			
Water	Pipes	Water works	Households/Industry
Sewage	Pipes	Households/ Industry	Treatment plants
Solid			
Provisions	Roads	Suppliers	Households/Industry
Solid waste	Roads	Households/ Industry	Land fill/incineration
Energy			
Electricity	Cables	Power station	Households/Industry
Gas	Pipes	Gas works	Households/Industry
Hot water	Tubes	District heating plant	Households/Industry
Cooling water	Tubes	District cooling plant	Households/Industry
Information			
Telephone	Cables (radio masts)	Telephone station	Households/Industry
TV	Cables (antennae)	Telephone station	Households/Industry
Internet	Cables	Telephone station	Households/Industry

Even if infrastructures are very similar in all cities, there are alternatives. It may be simply illustrated by the most ancient infrastructure, that of water supply from a well or pump, to which each household had to go to get the water. In developing countries this is still typical and also serves important social functions. A more technical example is that of telephone connections that may be established through either cables or radio transmission.

Today streams, especially waste streams, are often combined. This might have serious disadvantages, which were not appreciated when the systems were built. High-quality drinking water is used when it might not be needed; for example for industrial purposes. Different sewage streams, grey water from washing and black water from toilets, are normally combined and so is waste water from industries and households. This has serious negative consequences for the opportunity to 'close the cycles' by using nutrients in the waste. The sustainable management of flows might in some cases require the rebuilding of the infrastructures themselves; for example by separating different flows.

3.3 Urban water management

(3.3 - 3.4 by Bengt Hultman)

There are many examples of ancient sophisticated systems for water supply and sewerage, such as the building of aqueducts and the Roman *cloaca*. The collection of storm water and drainage dates from ancient times. The building of present infrastructure for water and waste water handling started about a century ago in western Europe. General functions of these systems are:

The systems in urban areas have been built up gradually. The central water supply was developed from the urgent need to decrease the water-borne diseases which were a major cause of death a century ago. The solution to health problems was to find an uncontaminated water source and to transport the water after treatment to the urban area. Another important role of the water supply was for fire-fighting.

The supply of water into urban areas also led to the need to transport sewage away from the area. The simplest way was to build sewers and to discharge the sewage directly into the recipient. It was gradually recognized that this procedure led to significant environmental pollution problems. A well-known early example is the discharge of sewage into the river Thames in London which caused noxious odours rising from the river and periodically disrupted

Applying the principles of sustainability to flow management

1. Material flows should be cyclical, that is, substances should not accumulate in the systems. For example, recycling of solid waste, or return of sludge to farmland.
2. Cycles should whenever possible be coupled so that waste from one is a resource for another. For example, incineration of solid waste for district heating; combustion of organic waste to produce biogas for municipal transport.
3. Resources should be used efficiently. For example, insulation of houses to reduce energy needs; return of nitrogen from sludge or in urine to farmland.
4. Avoiding toxic and non-biodegradable substances. For example, source separation of waste to remove heavy metals from organic waste; non-mixing of industrial and household sewage.
5. Responsibility of the local/household level: Resource efficiency at the local level through, for example, proper household water management, and insulation of houses; energy production at the household level through, for example, heat pumps and solar panels.

the work of Parliament and the Law Courts. 1858 was known as the 'Year of the Great Stink'. Environmental concerns gradually led to the introduction of mechanical, biological and chemical treatment of waste water.

Urban water and waste water should be seen as part of a sustainable city. This means interactions with other sectors in society will have an increasing importance. Examples are the use of the heat in waste water for district heating (use of heat pumps), use of the sludge as a resource, use of waste water for irrigation, etc. The important role of increased public awareness and participation is also gradually being recognized.

3.4 Water cycles

Urban water cycles should be linked in a sustainable way to the natural water cycle. In the natural water cycle, water evaporates from the surface of the earth to the atmosphere where it forms clouds and returns to the land surface as precipitation. On land, the water passes through ground water, smaller streams, larger rivers to lakes and finally to the sea (Hultman, 1993).

Urban storm water is rainwater and melt water which runs off streets, roofs and other surfaces. The infrastructure hinders a natural infiltration of the water and may pollute the water. Much emphasis must be laid on source control for reduction of the pollutant contents, local handling of storm water and the use of storm water as a resource. Some possible uses are open dams and creeks, running water and water mirrors. Hygienic aspects are therefore important to consider.

The quantity of water which is available for use in any particular period is equal to the difference between total precipitation and the amount lost through evaporation ('effective runoff'), plus any water held in surface or underground storage ('stock of fresh water'). From a sustainable point of view, water demand should only be met by effective runoff. This should in principle be applied for a certain runoff area. Water conflicts between countries often arise when dependence exists on water 'imports' from rivers; that is, effective runoff is not sufficient for the water supply in the country.

Many options are available for the handling of storm water, water and waste water in urban areas. A way to describe the different systems is to follow the material flow from source control, transport, treatment of waters, effluent discharge and use, sludge treatment, and sludge disposal and use. The different options may then be evaluated by different criteria based on health and quality of life, environment, resources and services to users, and public confidence. Certain special evaluation methods exist such as environmental impact assessment (EIA) and life cycle assessment (LCA).

Different options for analyzing storm water, water and waste water handling may also be based on different system levels ranging from water handling inside buildings to regional aspects (see Table 3.2).

The important role of increased public awareness may be illustrated by the possibilities that exist even in individual flats and households. Thus more care to ensure that taps do not drip, and toilets do not use too much water, the possible reuse of one type of water, for example, from showers, for another, for example, toilets, is forming small-scale loops.

System levels may also reinforce each other. One possible combination of system levels is, for example, local handling of waste water in a septic tank combined with central handling of the sludge. Site-specific factors such as population density, percentage of impervious surfaces, climate, topography and soil properties are important factors for determining the relative role of the system levels for the optimal handling of urban waters.

At present there is considerable disagreement both among experts and between experts and politicians with regard to the future development of urban water systems. Much attention is today given to the use of improved source control and extended use of

Guiding principles and goals for sustainable urban water management

Urban water handling is a multi-disciplinary area in which the following goals should be met (MISTRA, 1996):

Health and quality of life: Water-borne diseases should be prevented and the urban water systems should provide high water quality also in the future. Urban water management should promote urban quality of life; for example by the provision of attractive green areas and high-quality water for recreation.

Environment: Water quality in surface waters and ground waters should be maintained or, if necessary, restored to meet long-term goals and the ground water level should not be lowered due to water supply needs. Efficient source control and detoxification should be used.

Resources: Waste water should be regarded as a multipurpose resource where methods should be developed for efficient energy use and resources recovery. Sludge and other residues should not be accumulated in deposits.

Services to users and public confidence: Future water, waste water and storm water systems should provide services in a cost-effective way. Criteria for sustainability should be developed, public participation and awareness should be encouraged and efficient collaboration should be developed between users, owners and other actors in the management of urban water systems.

Table 3.2 System levels in urban water and waste water handling (MISTRA, 1996).

System level	*Examples*
I. Consumer and surrounding building	Households in flats, single houses, etc., institutional buildings (schools, hospitals, etc.), commercial buildings (shops, restaurants, offices, etc.), and industrial buildings (factories, power stations, etc.)
II. Local handling systems	Septic tanks, infiltration beds, wetlands, mini treatment plants, compost toilets, etc.
III. Central handling systems	System consisting of water treatment works, water networks, sewer networks and sewage treatment works; storm water pipe networks, etc.
IV. Interactions with urban and rural surroundings	Water supply and interactions with ground water level; waste water discharge and interactions with the recipient; sludge disposal on agricultural land, etc.

ecotechnological methods. Therefore, it is important to reassess present systems on the basis of different criteria including the concept of sustainability.

In the development of sustainable urban water and waste water handling systems, several approaches are important. Future water and waste water handling systems will probably be more flexible than present systems. The systems may be developed into more resource- and energy-efficient systems and with the possibility of recovering nutrients and producing energy. New techniques range from urine-separation toilets, nature-based treatment methods, and advanced methods such as membrane technology. A combination of improved existing systems with better source control and the successive development and critical assessment of new emerging technologies should be a first step.

3.5 Solid waste management

(3.5-3.8 by Per E.O. Berg)

Solid waste collection is one of many material flows in urban areas. Those material flows are connected to the urban infrastructure, where roads and pipes are used as media for the transportation of goods and wastes. Quantitatively it is an important flow, with typically more than a tonne per year per person. About two-thirds of this is industrial waste and a third comes from households, offices, shops and the like.

Household waste is about the same in the entire Baltic region. The differences depend mainly on differences in packaging consumption. Industrial waste, however, differs from place to place, depending on the local industry and the local industrial history.

Some kinds of solid waste require special attention, such as hazardous waste, radioactive waste and other types of special wastes. The recent Soviet military withdrawal left behind enormous amounts of waste such as unusable equipment and buildings as well as forgotten landfill sites and dumps.

Waste classification systems refer to either attribute or source, most commonly source, which we shall use here. There is thus household (domestic) waste, industrial waste, commercial waste, etc. The attribute system refers to some intention with the waste - composting, recycling, energy recovery or more prosaic; sanitary landfilling with an acceptable leachate treatment.

Most waste composition studies are done at a treatment place or at a landfill. At such sites it is difficult to classify waste and it is even more difficult to compare waste composition studies from different countries. What we see in those studies are the consequences of the total waste management system, a mix of industrial and domestic waste affected by recycling and other activities. Some examples are given in Table 3.3.

The total amount of waste is difficult to estimate as tonnes. At most dumps and landfills the volume is recorded - if any records are taken. In Sweden, Germany and Denmark recording is more common with weighbridges at the waste treatment plants and landfills. To estimate the waste generation per annum and capita we can use the situation in Borås in 1986 (Table 3.4). Today, ten years later, after implementation of a recycling and waste minimization programme, the amounts of waste are cut to less than 50 per cent of the figures for 1986. The amount of recycled material is increasing, but less than the decrease of waste!

3.6 Waste management strategies

The need for good *urban hygiene* is the basic motive for solid waste management as well as for waste water collection and sewerage. There is traditionally a number of diseases that are spread by solid waste and waste water in urban areas with no proper sanitation. In industrial areas, chemical and radioactive hazards are added to the microbiological ones. This absolute need for sanitation is fulfilled by waste collection systems, which mainly are managed by public organizations such as municipalities. They can also be private and contracted out by the local authorities.

The *collection* systems are technically basically the same everywhere in the region, but the management is developed in different ways. The hygiene strategy of waste management is a 'getting-rid-of-waste' strategy, and

Table 3.3 Solid Waste Composition Studies: Liepaja Landfill, Järvamaa County, Warsaw and Borås
(Percentage of different categories)

Component		*Liepaja*	*Järvamaa County*		*Warsaw*	*Borås*
		Spring	*Fall*			*Domestic*
Industrial						
Compostables		65	76		53	5
Food	6			23-31		
Bones		2				
Paper, Cartons	20	11	10	13-22	23	21
Textiles	8			3-6	1	1
Plastics	10	4	1	5-12	6	11
Wood	30	3	2			15
Leather		10				
Misc. burnable		2	5		10	18
Glass	5*	7		6-12	4	2
Metals	8	2		3-5	2	7
Misc. 'inert'		6	6		2	17
Particles< 1 cm				8-25		
Others	1			8-20		
Total	100	100	100		100	97

* includes ceramics

Table 3.4 Solid waste and recyclables in Borås 1986
(kg/capita & annum)

Categories	*Waste*	*Recyclables*
Household waste	220	23
Commercial waste	105	
Bulky	90	
Industrial and service sector	280	170
Construction waste and rubble	50-200	
Ashes	150	
Sludges	125	
Total	1,220-1,170	193

the waste stream normally ends up in a landfill, which too often is a dump rather that a sanitary landfill.

Landfilling is a part of the hygienic strategy, but the treatment methods are of secondary hygiene interest. When the primary problem - urban hygiene - is solved, it is possible to face the local hygiene and environmental problems around the dumps; ground and surface water contamination and littering. Other problems are connected with burning on open dumps, with rats, flies and birds or with gas and odours.

Incineration was once seen as the ultimate method for getting rid of waste, but instead there were important environmental problems connected with the flue gas. Today, the aspect of destruction and 'getting rid of' is focused on organic hazardous waste which, treated in an incinerator or at very high temperatures and long retention time, can be completely destroyed. Adequate thermal treatment of hazardous waste is a well-respected method for solving a part of the hazardous waste problem.

When the energy in the waste is used in the incineration plants to produce electricity or for district heating, the incineration plants convert the 'getting-rid-of' technology to beneficial technology. The possibility of producing energy is often the motive today for incineration. Therefore we often talk about 'waste-to-energy-plants' instead of just 'incineration plants'.

Waste collection, landfilling and incineration is the basic level of solid waste management. *Recycling* is the secondary level and thereby the second strategy.

3.7 Recycling

The need for recycling is obvious when consumption runs away uncontrolled. In the fast-rate consumption, affluent, society there will eventually be a lack of a raw material, and one way to serve the society with its needs is to recover the material from the waste stream. Societies with a slower rate of consumption can also be motivated to a recycling strategy. There can be high prices of raw materials or lack of money for international trading. The extra bonus of this strategy is the decreasing amount of waste going to the landfills. Therefore a number of western European countries have adopted the recycling strategy - more in order to save volumes in the landfills than to save raw materials for more equal consumption in the entire world for future generations.

Biological treatment of organic waste in order to produce compost as a fertilizer or a soil enhancement product is, from a strategic point of view, recycling technology. Biological treatment methods are an old and well-known technology but, without conscious waste flow management, it is impossible to produce any marketable products.

The recycling strategy means that we are trying to see the residues from society as something that could be of some value

A WASTE INCINERATION PLANT

Collection of waste

The waste is first collected in a bunker big enough to hold 4-5 days' worth of garbage. The garbage is moved, by a crane, into a pit, which is often connected to a scale. This enables a continuous measurement of the amount of garbage that is added. The waste is moved into an incinerator from the pit.

Incinerator

The incinerator comprises a slanting surface, a *grate*. built with poles rolling or moving back and forth. The grate moves the garbage forward through the incinerator and mixes the material.

The *primary air,* is now added in excess and often, at least partly, preheated to improve the energy balance in the first part of the incinerator.

The ashes and slag from the incinerator fall down into a *trough* that is filled with water. From there, they are transported with a belt to a container or bunker, and after that to a special *landfill*.

Furnace

The flue gases from the incinerator are guided up to a secondary incineration chamber where more air, secondary air, is added. The gas stays here at about 1000°C for a number of seconds before it continues to the furnace. In the furnace the heat energy from the gases is transmitted to hot water or water vapour.

Flue gas cleaning

The flue gases are cleaned in a special *flue gas cleaning device*. Since the demands on the effectiveness nowadays are very high, the cleaning devices can often be the same size as the rest of the waste incineration plant. There are several different types of cleaning system that can be used.

- Most of the fly ashes and dust are separated in the electronic filter.
- An economizer cools the gas to 140°C and is an extra heat exchanger in the ordinary furnace system.
- The cooler sprays water into the gases so the temperature drops to 60°C.
- A washing reactor consists of a bedding that recirculates water. Acid gases in the flue gases, HCl, HF and SO_2, are dissolved in the water. Dust and particles that contain heavy metals also get caught in the water and metallic mercury condenses. Even dioxins and other compounds get caught in the water.
- The water is guided to a water-cleaning device. Lime (calcium oxide) is added to get a higher pH value. A precipitating agent binds mercury and sulphide compounds. Finally, a flocking agent allows the sludge to be removed in a lamella thicker. The sludge is mixed with the fly ashes from the electronic filter. It has been shown that the components can safely be deposited after making this mixture.

Gas treatment – condensation

- The water-saturated gas goes through a condensing reactor where the temperature drops to about 40°C. The gas temperature is then raised to 150°C to prevent direct condensation of the gases when they are let out of the chimney. The acid gases are neutralized by blowing in powdered limestone into the gas stream, followed by dust separation with a textile filter catch, in which even mercury is condensed and separated.

Figure 3.1 The district heating net in Uppsala. The total length of pipelines, is 400 km. Coverage is 95%, 1600 GWh is yearly delivered to the city (1992 figure). A little more than 100 GWh comes from waste incineration.

instead of something we have to get rid of. This leads us to the conclusion that the needed materials should be uncontaminated - they shall not be mixed into the waste!

Recycling must thus be based on source separation. For household waste this has to be done by the households. A number of large-scale domestic waste separation plants have been built, but none of them has been successful. The process of waste separation is too complex to be done automatically. However, there are a number of industrial residues and wastes that can be successfully separated in large-scale plants.

Non-recycled waste will be either treated or deposited. The purpose of the treatment is to convert the waste into a substance that can be inserted into a bio-geo-chemical cycle or deposited in a landfill. All kinds of treatment involve some kind of conversion. The term 'destruction' is often used, but one should avoid this term. It can in a way be used when referring to the decomposition of toxic organic substances; for example through incineration into oxides or other substances that are later discharged into water, air or earth. Acids, for example, let out in gases and smoke from industries, cars, etc. may be converted into salts through neutralization.

Sanitary landfilling is based on the idea of isolation of the material dumped in the landfill. Therefore the landfill has to be isolated from the ground water, which today is done with different kinds of sealing. In addition, one would like to see a plant that is not too ugly and which does not smell too badly.

The recycling strategy will after time develop into a waste minimization strategy. Handling waste in the household will result in a dramatic reduction of waste volumes. Society and its subsystems will be organized in a way so that as little waste as possible will be produced. This is the big challenge for the future. This is the big task for engineers and planners for the future.

38 Energy and waste

Total energy consumption in Sweden is roughly 450 TWh, with 150 TWh being used for heating houses, apartments, offices, service facilities, etc. Energy management is thus a very important part of city flow management. Most of this amount is produced through the burning of fossil fuels or as electricity from hydro or nuclear power. More sustainable strategies focus on energy saving and closing other flows in municipalities.

Incineration is the most important treatment method of household waste. Approximately 55 per cent of the waste in Sweden is incinerated. This process enables an energy extraction of nearly 2.8 TWh. The energy is mainly used for district heating. Household waste is a good fuel due to its large proportion of paper and plastic with a high energy level. Nevertheless, the maximum level of energy production is some 5 TWh or 3 per cent of present requirements. In the best waste power stations about 40 per cent of the energy content can be converted into electricity.

At least 50 per cent of the domestic waste is food waste and other wet biodegradable waste products. By taking also paper, cardboard and other waste of biological origin into account, 70-80 per cent of the domestic waste is biodegradable. Degrading or stabilizing organic material by biological treatment is a natural process that has been used by man since time immemorial.

There are two different kinds of process: aerobic degradation that takes place when oxygen is present, and anaerobic degradation that takes place when oxygen is not present. Bacteria, mould, fungi and other saprophytic organisms are active in these processes. They feed on garden waste, manure, latrine and other organic waste products and convert them into more stable products. In the aerobic processes, about two-thirds of the carbon serves as an energy source and is oxidized by micoorganisms to form carbon dioxide. The remaining third is converted to cell biomass along with, for example, nitrogen. However, in the anaerobic processes, the carbon is mainly converted to biogas which consists of methane, CH_4, and carbon dioxide CO_2.

Biogas may constitute an important source of energy for heating, fuels for buses, burning, etc.

The household level of energy management is the most important in energy saving strategies. Insulation of houses becomes more important as energy costs increase. Combined with local energy production by, for example, solar heating panels and heat pumps based on geothermal energy, one might even arrive at a zero net energy requirement at the household level. This would of course change municipal energy flow management drastically.

3.9 Transport – traffic relates to forms of habitation

(by Harri Andersson)

Human habitats transform raw material into finished products. They convert food, fuels, forest products, minerals, water, human energy and even waste into buildings, manufactured goods, and financial and political power (all the components of civilization). A very central part of this flow is transport.

The Technical Research Centre of Finland has developed a model for estimating energy and emission consequences of urban structure (EMICUS -model, see Rauhala 1994). EMICUS estimates the total energy and emission caused by an urban structure. The most interesting part of the model concerns transportation. The transportation model estimates the annual number of trips generated by the building groups as well as the corresponding mileage, fuel consumption of vehicles and transportation costs. The transportation model is an ordinary four-step model: firstly the trip generation in five trip classes is estimated, secondly the modal split in each trip class is estimated according to the trip lengths, thirdly the person mileage in different transportation modes is calculated according to the trips generation and trip lengths in each trip category, and fourthly the vehicle mileage is determined according to the person mileage and mean vehicle loads in each transportation mode.

One serious problem of transportation is that in an industrial world demand for more road space has tended to be matched with ever increasing road construction: the more roads are built the more they will fill up with cars and more new roads are needed —> 'urban circulation noose'. Transportation and land-use trends interact to produce an increasingly mobile society. The concept of an 'unbound society' leads to large costs in infrastructure and transport, waste of time, land and housing, loss of community, vitality and public safety. Inevitably, in the near future there will be a need to reduce the physical separation of activities on local and regional scales towards a 'neo-traditional development', that is, increased density. There is also a need to integrate land-use and transport planning according to the crucial role of transport: "urban choices will be fundamentally determined by transport choices" (cf. Girardet 1992: 146-148).

3.10 Future water, waste and energy systems

(by Per G. Berg)

From a strict economic point of view, the right time to equip our urban cultures with a more sustainable infrastructure is when the old system's technical lifespan is coming to its end. In many western European countries, like UK and Germany, waste management is changing right now, mostly forced by acute economic and environmental problems with the old systems. In many eastern European countries also the problems are no less urgent but the economy limits the possibilities for action. In Sweden, the ongoing renewal of waste systems is mostly done by replacement pipe by pipe, street by street. This unfortunately is both expensive and blocks renewal.

What are the future options?

Present sewage treatment methods (mechanical, chemical and biological) will continue to be important but adaptations are needed. The most important are reduction of the content of heavy metals as already mentioned. This will allow the reuse of phosphorus precipitates, as much as possible of the nitrogen, and the sludge.

The option of anaerobic digestion of waste water is also developing. This process produces a hygienic organic fertilizer product and biogas as by-products. In many Swedish cities, such biogas is already being utlized by town buses as fuel. An interesting new option is aerobic digestion of waste water, which produces a residue with excellent nutrient properties. In both cases the carbon to nitrogen ratio is critical and the addition of carbon-rich household - or possibly agricultural - waste may be important.

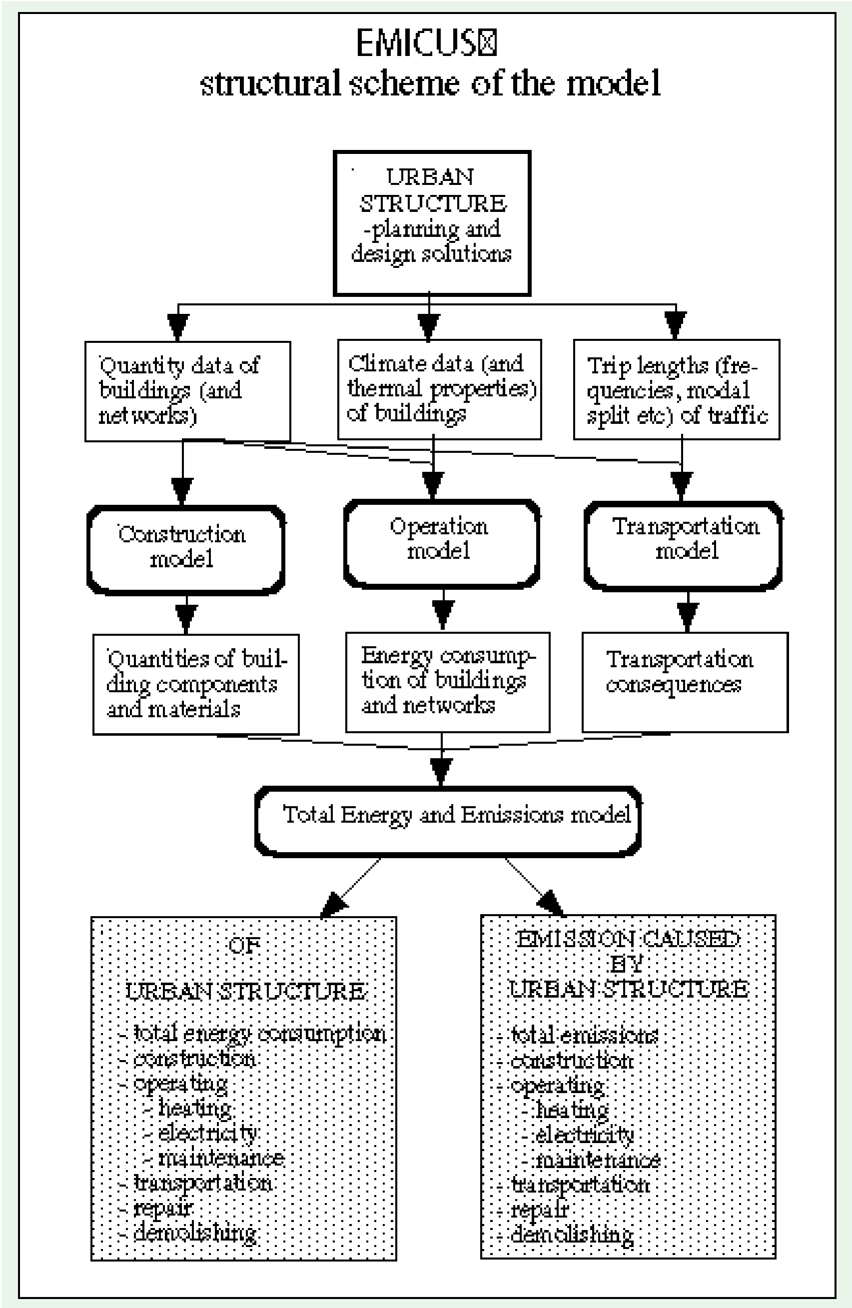

Figure 3.2 The EMICUS model of urban planning

Solid waste strategy relies on the waste being sorted into clean fractions, compostable, paper, glass, plastic, etc., that may be recycled. Collected organic waste may be treated in central automated reactors to produce mildly contaminated nutritious products for the production of forage and food. Treatment at local level in local compost bins has a particularly great chance of producing appropriately clean compost. Organic household waste may then be mixed with the sludge or waste waster for digestion.

All the mentioned strategies require that waste streams are separated to a much larger extent than now. Industrial waste water with heavy metals should not be mixed with household sewage. Solid waste heavy metal content is mostly due to light bulbs, fluorescent tubes, electronic scrap, etc. in the waste, and these must be taken out in source separation. Separation of toilet waste streams to recover urine, with a high nitrogen content, separately is a strategy now implemented in some places.

A long-term approach is the separation of waste streams and thereby the pipe systems themselves for flexible adaptations for future development. This is especially important in buildings because exchanging tubings inside buildings is much more expensive than outside. Flexibility is thus a main strategy for preparing human habitats for a different, more sustainable future that will allow for development of local strategies and integrated solutions.